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Preface

On behalf of the Organizing Committee, it is my great pleasure to introduce the proceedings of the 3rd International Conference on Business, Management and Sustainability (ICBMS 2026), held from 20 to 22 March 2026. This volume represents a curated collection of the finest scholarly contributions presented at the conference.

A total of 76 manuscripts were submitted to ICBMS 2026 from researchers and practitioners around the world. After a rigorous double-blind peer review process, 35 high-quality papers were accepted for publication. This selective process ensures that the work presented herein meets the highest standards of originality, methodological rigor, and relevance to the conference's core themes.

The papers in this volume address a range of pressing issues at the intersection of business, management, and sustainability—including sustainable operations, responsible leadership, green finance, digital transformation, and inclusive business models. Collectively, they offer valuable insights for navigating the complex challenges facing organizations and societies today.

I extend my sincere gratitude to the distinguished reviewers and members of the Scientific Committee for their meticulous work in evaluating the submissions. Special thanks go to our keynote and invited speakers for their inspiring contributions, as well as to the Zeus Press for their professional support in publishing this volume. Finally, I congratulate all authors whose work appears here—your dedication advances the crucial dialogue on business and sustainability.

We trust that this proceedings volume will serve as a useful resource for researchers, practitioners, and policymakers striving to build a more sustainable future.

Prof. Svetlana V. Androsova
Editor-in-Chief
ICBMS 2026 Proceedings

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The Impact of Pension Finance Development on Economic Development under the Background of Population Aging

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Abstract

In recent years, the global population structure has undergone profound changes. With the decrease in birth rate and extension of average life expectancy, the world population aging problem has become a hot issue of world development. As the action on the pension issues, pension finance s not only provides life security for the elderly group, but can also make a significant impact on economic development. This article aims to sort out research about the impact of pension finance on consumption and investment by scholars at home and abroad. It will present the existing research results clearly, facilitate subsequent scholars to do research and bring up feasible suggestions. This article concludes that the development of pension finance boosts economic development in most cases. Based on the article's conclusion and the current situation of a large number of countries with immature pension financial systems, this article mainly brings up suggestions, including establishing a suitable pension financial system based on national conditions, innovating pension financial products and services, enhancing supervision and management, and emphasizing cross-regional communication and cooperation.

Keywords

population aging, pension finance, economic development, consumption, investment

1. Introduction

In recent years, the problem of world population aging has become increasingly serious and poses many challenges to the development of society and economics. The aging scale continues to expand, leading to a continuous increase in the dependency ratio of the elderly population, which has increased the burden of social pension. The data of the World Health Organization indicates an upward trend in the quantity and the proportion of the global elderly population. Forecast to 2030, people over 60 will account for about one-sixth of the total population around the world [1]. At the end of 2024, people over 65 in China had reached 220 million, accounting for 15.6% of the total population. Forecast to 2050, the population over 65 years old will increase to 370 million to 400 million, accounting for about 26% of the population. In this context, pension finance becomes the key measure to settle a range of pension challenges, promote the well-being of elderly people, and realize the sustainable development of the economic society. Therefore, all countries around the world are promoting the development of pension finance actively.

Currently, pension finance is at the stage of rapid development of theory and practice. On this basis, the economic potential of the silver economy is greatly released [2]. As of July 16, the data from China Government Network shows the revenue growth of industries related to Chinese pension financial policy was at a high level, and the silver economy developed rapidly. Thus, it can be seen, the development of pension finance has a great push on the economy. Meanwhile, as an indispensable part of the future world economic system, the silver economy has a great demand for pension finance in terms of consumption and investment, and the development of the silver economy needs the support of pension finance. Therefore, pension finance development plays an important role in economic development under the backdrop of population aging. But so far, review articles related to the impact of pension finance development on the development of economic consumption and investment are relatively lacking. Thus, this article will combine and summarize relevant literature from this aspect, helping scholars have a better understanding of this issue.

2. The connotation and current situation of pension finance under the trend of aging

2.1 The connotation of pension finance

According to international standards, when the population over 60 years old accounts for 10% of the total population in a country or region, or the population over 65 years old accounts for 7% of the total population, it means that the country or region has entered an aging era. Developing countries take China as an example. On January 17, 2025, the National Bureau of Statistics released data which show that people over 60 in China have reached 310 million, accounting for 22% of the total population. Furthermore, people over 65 have reached 220 million, accounting for 15.6% of the population. Currently, China has entered deep aging society. According to United Nations Population and social sciences data, the dependency ratio of elderly population in China has clocked up 21.399%, and the social pension burden becomes heavier. Developed countries take America as an example. America entered the aging society in the mid-20th century. National Center for Health Statistics forecast people over 65 in America will account for one fifth by 2030, and the population aged 75 and above will account for 12% of American total population by 2050. In such a severe situation of aging, the development of pension finance is especially important.

Zvi Bodie and E. Philip Davis were the first to study pension finance. Their work, *The foundations of pension finance*, contains many typical achievements concerned with pension finance theory after the 1950s, and becomes an important reference for future pension financial research and relevant policy formulations [3]. However, British scholar David Blake systematically elaborated the concept of pension finance for the first time. Blake defined pension finance as pension finance and focused on the pension fund investment in various financial products [4]. In short, pension finance is a range of financial services and products provided by financial instruments around the pension needs of elderly people. It makes sure that old people can have a stable economic source and life security.

2.2 The current situation of pension finance in China and abroad

During the 1980s, due to the aggravation of the global aging problem, the cash basis used in many countries could not relieve the huge social dependency burden. In this context, the World Bank proposed the Three-Pillar Pension Model in *Preventing the aging crisis: policies to protect the elderly promote growth* in October 1994. This model is beneficial to solve the financial crisis under a single system. Meanwhile, it is the widely used pension institutional model internationally, which contains legally compulsory public pensions, occupational pensions jointly paid by enterprises and individuals, and personal pension saving plans.

The Three-Pillar Pension Model provides the basic framework for the foreign pension finance. On this basis, pension fund investment is more important because the foreign capital market is relatively complete. Therefore, researches on pension finance by foreign scholars are more inclined to pension finance. The results show that foreign pension finance development is mature with the characteristics of a diversified system, strong tax incentives, and a well-developed supervision system. Taking the United States as an example, it established a three-pillar pension system. Each pillar of the system has its own emphasis, where the Individual Retirement Account Plan (IRAs) of the third pillar developed maturely. Meanwhile, the American traditional IRA adapts the mode of Exempt-Exempt-Taxed (EET). It exempts individual income tax in payment link and investment income link, and pays individual income tax in the receive link. This method increases personal investment

income, encourages individuals to have long-term savings and investments, and boosts the accumulation of pensions. In addition, the United States established joint supervision system consisting of Social Security Administration, the Department of Labor, the Internal Revenue Service, the Department of the Treasury, Securities and Exchange Commission. Each department performs its own duties and cooperates with the other in pension supervision, making sure the security and increment of the pension. Taking Japan as an instance again, data shows that Japan entered the super aging society in 2006, so it had years of experience about pension finance development. Accordingly, Japan is a country with advanced pension system among the Asian countries. In 1999, Japan reformed the pension security system. It took the national pension and welfare pension as the first pillar, multi-type employer pension plan as the second pillar, and the individual pension plan as the third pillar. The third pillar contains the individual-type Defined Contribution pension plan (iDeCo) and the Nippon Individual Savings Account (NISA), and develops maturely. In the preferential policy of tax mode, the iDeCo adapts the mode of EET and the NISA adapts the mode of Taxed-Exempt-Exempt (TEE). Two different methods encourage people to have pension arrangements actively and supplement the national and corporate pension plans powerfully. Moreover, Japan takes the Government Pension Investment Fund (GPIF) as the core subject of supervision and implementation. The GPIF improves the management transparency by separating the decision-making, supervision, and implementation, ensuring the development of the national pension finance steady and flexible [5].

Based on the national conditions of China, domestic scholars expand the conception of pension finance constantly. He considered that China should establish a pension finance system containing social basic endowment insurance, enterprise annuity, business endowment insurance, pension savings, reverse mortgage loan for pension housing, pensions trust, pension fund, and other financial service methods [6]. Yang and Zhang reported that pension finance is the comprehensive financial service for managing currency, fixed assets, and equity-based pension assets [7]. Yao and Wang regarded pension finance as the total financial activities for the fundamental purpose of pension care, and emphasized that pension finance is an interdisciplinary field of gerontology, demography, and finance [8]. Dong, Sun, and Zhang [9], Dong and Shi [10] researched and summarized pension finance constantly, establishing the conceptual system of pension finance in China. Currently, the domestic view of pension finance is a conceptual system including pension finance, pension service finance, and pension industry finance. This viewpoint is authoritative and widely accepted by everyone. Nevertheless, under the background of population aging, the multi-pillar pension finance system of China still has a realistic dilemma, as which three-pillar model develops unbalanced. Now, the first pillar covers completely, and the second and third pillar pensions have limited accumulation.

3. The impact of pension finance development on economic development

3.1 The impact of pension finance on consumption

At the microeconomic level, pension finance mainly affects consumption through changing the income status of individuals and families and the consumption expectations. In 1954, American economists Franco Modigliani, R. Brumberg and Alberto Ando proposed the Life-Cycle Hypothesis. They considered that consumption does not depend on current income, but on income of a lifetime [11]. This hypothesis provides theoretical support for the intertemporal smoothing consumption of pension finance. Intertemporal smoothing decreases the volatility of consumption through savings or loans, and slows down the change of consumption. It has a direct impact on pension finance, locking long-term funds through pension financial instruments to form a stable income stream in the future, making people break through the idea of current income determines consumption and smooth the consumption distribution in the life cycle. Relevant research proves that there is an obvious positive correlation between basic pension and individual consumption. From this perspective, pension finance can increase the expected revenue, decrease the preventive savings, increase the current consumption, and have a positive effect on consumption. Meanwhile, through empirical research based on the data of CHFS2019, Liu concluded that business pension insurance not only increases the individual consumption significantly, but also has an obvious promoting effect on household consumption [12]. In addition, Qu utilized the data of CHARL2020 for studying the impact mechanism of pension finance on household consumption from the microeconomic level. The conclusion of this study is that the rise of the pension directly enhances the consumption ability of the elderly [13]. However, in 1968, Hayne Leland put forward the precautionary saving theory, and claimed that risk-averse consumers save for the purpose of

spending retired retirement or providing an inheritance for their children in the case of uncertain income in the future [14]. This will reduce their willingness to consume currently and increase their savings, which has a negative effect on individual consumption.

At the macroeconomic level, pension finance affects consumption through regulating the total amount of social consumption and the social consumption structure. Income redistribution can promote the propensity to consume. Pension finance, especially the basic pension insurance, can narrow the gap through intergenerational and intergroup income transfer and increase the disposable income of the low-income elderly group, stimulating the total social consumption directly. Meanwhile, a pension can offer continuous income to a group of retirees because the pension can be drawn for a long time. Fan and Wang improved the model of consumption conditions and found that the penetration rate of pension insurance contributes 0.4% to the level of consumption. It proved that pension finance has a positive effect on stabilizing and promoting consumption [15]. Besides, pension development changes the consumption of the elderly from satisfying fundamental living demands to quality demands, promoting the upgrade of social consumption structure and the emerging consumption. Relevant data displays that the new generation of the elderly prefer to consume in the field of health management, intelligent elderly care and other areas under the wealth protection of pension finance. The emergence of pension and medical care, pension and cultural tourism and other integrated formats has led to the inflow of funds into the pension industry. It promotes the upgrade of related industries, drives the linkage of the industrial chain, enlarges the consumption multiplier effect, and can continuously expand the total social consumption and promote the development of consumption. Certainly, part countries with relatively late development of social security systems still have unbalanced problems of pension financial service coverage and a three-pillar pension system. These problems make it difficult for the pension security of different types of people to be fully satisfied, and then restrict the consumption conversion of corresponding groups.

3.2 The impact of pension finance on investment

From the view of the impact of pension finance on individual asset allocation of investors, pension finance facilitates multiple individual asset allocations and enriches the choices of investment by changing the risk appetite and lowering the threshold of investment. For example, people with basic support requirements can choose the Individual Pension Account, Business Pension Insurance and other products. These products have wide adaptation ranges of the elderly population and strong risk adaptability, suiting the fundamental elderly group with the demand of the safety of funds. People with stable value-added demands can choose Target Risk Funds and Real Estate Investment Trusts which have the characteristic of long-term value-added. Some scholars studied the influence of pension insurance on Chinese household asset allocation. They reported that there is a positive correlation between the surplus of pension account and the ownership of household risky assets. When every 10% increase in the account balance, the probability of household investment risk increases by 5% and that of risk asset allocation increases by 1.7% [16]. In 2025, the president of the United States, Donald Trump, signed an executive order that groups cryptocurrency and alternative assets, and added it to the Section 401(k) Plan. This measure enriches the allocation of retirement savings and expands the investment path.

From the perspective of the impact of pension finance on enterprise investment efficiency, the long-term investment of pension funds can provide enterprises with stable currency, promote enterprises to focus on long-term projects through participating in governance, and improve investment efficiency. Based on the Danish data, some scholars studied that pension fund equity investments can increase the productivity of enterprises by 3%-5% on average and the higher the shareholding ratio, the longer the holding time, and the more obvious the effect [17]. Meanwhile, the long-term investment of pension funds can alleviate the capital constraints, especially for private companies and small enterprises. However, pension funds have relatively high requirements for risk control, so some enterprises may incline to conservative investments and reduce the project investments with high risk and high return. It has a negative effect on enterprise investment efficiency. Furthermore, some scholars researches the relationship between the payment rate of pension insurance and the enterprise investment efficiency [18]. The study found that there is obvious negative correlation between the payment rate of pension insurance and the enterprise investment efficiency. When the payment rate of pension insurance rises, the Crowding Out Effect on enterprise investment efficiency is obvious, preventing the improvement of enterprise investment.

From the perspective of the impact of pension finance on the market investment scale, pension finance development can expand long-term capital supply in the capital market, directly expanding the market investment scale. In 1994, the World Bank released the *Pension System Reform and Economic Growth Report*. This report, taking the American Occupational Pension, Singapore and Chile Pension Plan as examples, confirmed that pension finance can increase the national savings under the fund accumulation system. After pension reformation in Chile, the proportion of pension savings and total savings in Gross Domestic Product both increased, driving the growth of market investment scale. Furthermore, according to People Daily Online, Dong believes that a fund system or partial fund system pension mode can increase long-term savings, stabilize the market fluctuation, enhance the confidence of investors, prove the market investment activity, and then expand the market investment scale. Therefore, pension finance development can stabilize investment environment, to some extent, driving the growth of market investment scale indirectly.

4. Conclusion

With the aggravation of the world's aging problem, all countries are developing pension finance positively. Based on sorting and summarizing the relevant literature, this article discusses the impact of pension finance development on economic development from two aspects of consumption and investment. This study finds that pension finance development has certain constraints on consumption and investment, but most of them show a positive correlation. Therefore, the development of pension finance is beneficial to economic development.

For countries with immature pension finance should establish a multi-pillar pension system adapted to the national conditions first and activate the second and the third pillar on the basis of giving priority to building the first pillar. At the same time, to solve the unbalanced development, government can low the threshold of participating in pension finance and attract people to participate through related tax allowance and exemption to enterprises, pension savings tax preferential policies and other means.

Then, financial institutions should innovate pension financial products and services constantly. With the target of realizing the specialization of pension finance, financial institutions should keep tapping the needs of the country for pension finance in different phases, and develop a series of pension financial products that meet the current stage of national development and future long-term pension needs and life cycle characteristics. In addition, financial institutions have to fully consider the realistic demands of the national elderly population, optimize domestic service level, and improve the experience of the elderly.

Besides, governments should strengthen the supervision and management of pension finance. Government departments should clarify their job responsibilities, cooperate mutually, establish a supervision system adapted to the characteristics of pension finance and the requirements of risk control, and optimize continuously in practice. Meanwhile, to ensure the security of pensions and enhance the public confidence in national pension finance development, it is essential to strengthen legislative supervision and combat illegal actions suspected of pension finance strictly.

Last, pay attention to differentiated policy formulation and cross-regional exchanges and cooperation in the development of pension finance to promote the rational and coordinated development of pension finance. According to the factors of economic development level in different regions, the degree of population aging, and the realistic needs of the elderly population, governments should formulate differentiated policies to make the development of pension finance more scientific. Moreover, pay attention to promoting the resources inclined to key areas and reducing the regional pension finance development differences in the development process is equally important.

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Analysis on the Development Process and Economic Impact of China's Foreign Direct Investment

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Abstract

Since the founding of the new China, especially since the reform and opening up, the development of China's foreign direct investment has opportunities but also faces challenges. Based on previous studies, this paper summarizes and analyzes China's foreign direct investment into six stages: blank, exploration, start, adjustment, rapid development and comprehensive development, and analyzes its economic impact. In the phased development process of China's foreign direct investment, it is also affected by multiple factors at home and abroad, showing the characteristics of wave evolution and periodic fluctuation. At the same time, China's foreign direct investment has a positive economic impact on itself, the host country and even the world from the micro level to the macro level. In the future, China's foreign direct investment should move towards a higher quality and level with the joint efforts of the government, enterprises, the market and society.

Keywords

foreign direct investment, development stage, economic impact, China

1. Introduction

Global transportation and communication technologies are continuously optimized and upgraded, and the degree of convenience is continuously improved. At the same time, economic globalization is becoming an irresistible trend of the times. As the largest developing country in the world, China actively complies with the tide of economic globalization, always adheres to the concept of a community with a shared future for mankind, proposes the concept of jointly building the "belt and road", promotes the implementation of the "going out" strategy[1], and further promotes its own development while driving the development of surrounding regions. In recent years, China's economic strength has steadily improved, its scientific and technological innovation ability has been significantly enhanced, and the quality of economic development has continuously improved. In this context, China's foreign direct investment is flourishing, ranking among the top three in the world for 13 consecutive years [2].

Gao and other scholars (2019) analyzed and studied the five stages of China's foreign direct investment from a policy perspective: difficult exploration, trying development, adjustment development, rapid development and comprehensive development[3]. Yang and Ke (2019) researched China's foreign direct investment from five periods: blank period, exploration period, starting period, development period and deepening period[4]. Based on the above research, this paper makes a further analysis of China's foreign direct

investment, which mainly makes up for the lack of data analysis of China's foreign direct investment in recent years.

Through the research on China's foreign direct investment, this paper analyzes the current situation and existing problems of China's foreign direct investment, which has practical guiding significance for Chinese enterprises' foreign direct investment, and provides direction guidance for the formulation of China's foreign direct investment policy. This paper also provides a reference for other developing countries, which is conducive to exploring their own development path of foreign direct investment, and also contributes Chinese wisdom to global economic governance.

This paper focuses on the six stages of China's foreign direct investment blank, exploration, start, adjustment, rapid development and comprehensive development and the specific characteristics of each stage, and analyzes its economic impact in all aspects on this basis.

2. Analysis on the Development Process and Economic Impact of China's Foreign Direct Investment

2.1 Blank Stage: 1949-1978

At the beginning of the founding of the People's Republic of China, all aspects of China were still in a state of waste waiting for prosperity. Internationally, the United States and other Western countries have implemented economic blockade policies against China. The completion of the first Five-Year Plan marks that China has begun to change its backward industry, but its production capacity is still at a low level and foreign exchange is scarce[4]. Before the reform and opening up in 1978, China implemented a highly centralized planned economic system and public ownership of the means of production. All these indicate that China lacks the economic conditions for foreign direct investment at this stage, but this stage has laid the foundation for the development of China's foreign direct investment.

In terms of diplomacy, in the early 1960s, the Sino Soviet relations deteriorated, the European economy recovered, China's legal seat in the United Nations was restored in 1971, and Sino-US relations improved. China's international status improved. There were two climaxes of establishing diplomatic relations with China. At the same time, China's economy is gradually on track to establish an independent and relatively complete industrial system and national economic system. In this case, the conditions for China's foreign direct investment were improved, the demand for foreign direct investment was increased, and many overseas branches of foreign trade companies were set up in international metropolises such as Paris and London[4].

2.2 Exploration Stage: 1979-1984

During this period, China's economy accelerated development, and China's economic strength and comprehensive national strength reached a new level, providing an economic basis for foreign direct investment. In 1978, the Third Plenary Session of the Eleventh Central Committee put forward the historic decision of reform and opening up, and China has the basic policy conditions for foreign direct investment. In 1979, the State Council explicitly proposed to allow enterprises to set up abroad. Since then, Chinese enterprises can participate in international activities with foreign direct investment[3].

At this stage, although the economy developed to a large extent, foreign direct investment is still limited by it, and the scale is small; The main investors are state-owned enterprises; The scope of investment is also very limited, mainly for surrounding countries and regions; In terms of management, the central government implements a highly centralized unified management[5]. Initial stage: 1985-1992

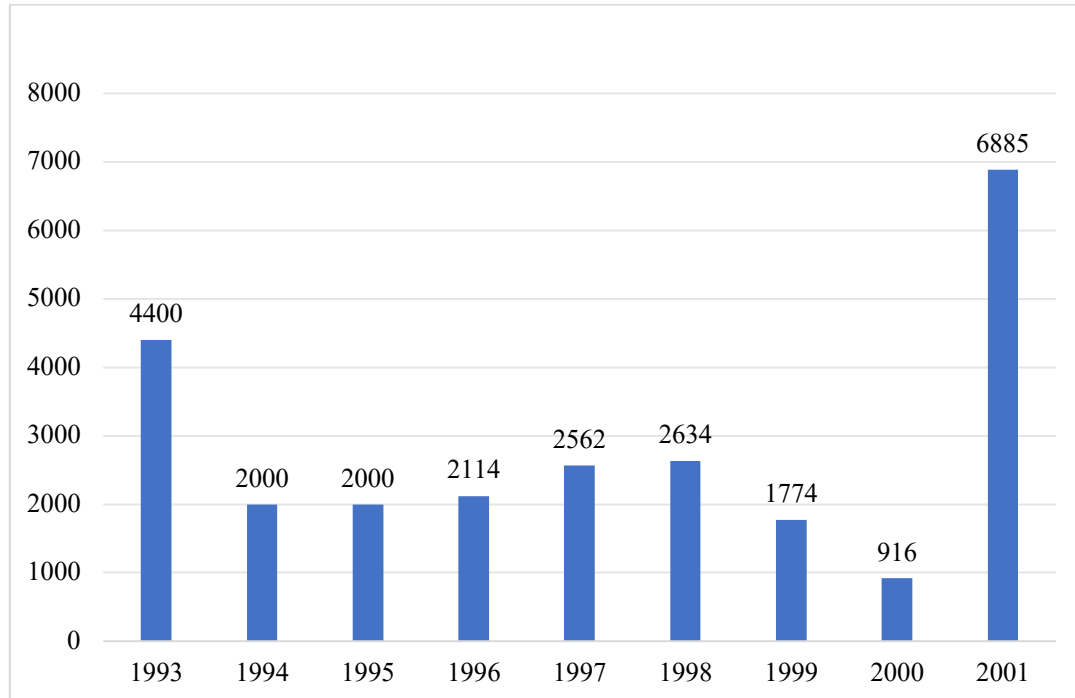
With the development of China's economy, the government's restrictions on foreign direct investment are gradually relaxed. From 1985 to 1992, China witnessed its first peak of foreign direct investment[5].

During this period, the characteristics of foreign direct investment were that the scale of investment was still small and mainly relying on foreign trade, and the number of participating enterprises was small and mainly concentrated in Beijing, Shanghai and Guangzhou; The main body of foreign investment expanded within the scope of state-owned enterprises; The investment industry gradually changed from foreign economic and trade enterprises to multi industry enterprises; The investment industry is further expanded on

the previous basis; While the establishment of corresponding supporting policies takes regulation and management as the main function[3]; The coverage of investment areas was also further expanded.

2.3 Adjustment Stage: 1993-2001

Figure 1: 1993-2001 China's OFDI (unit: US \$million)



Data source: from UNCTAD data

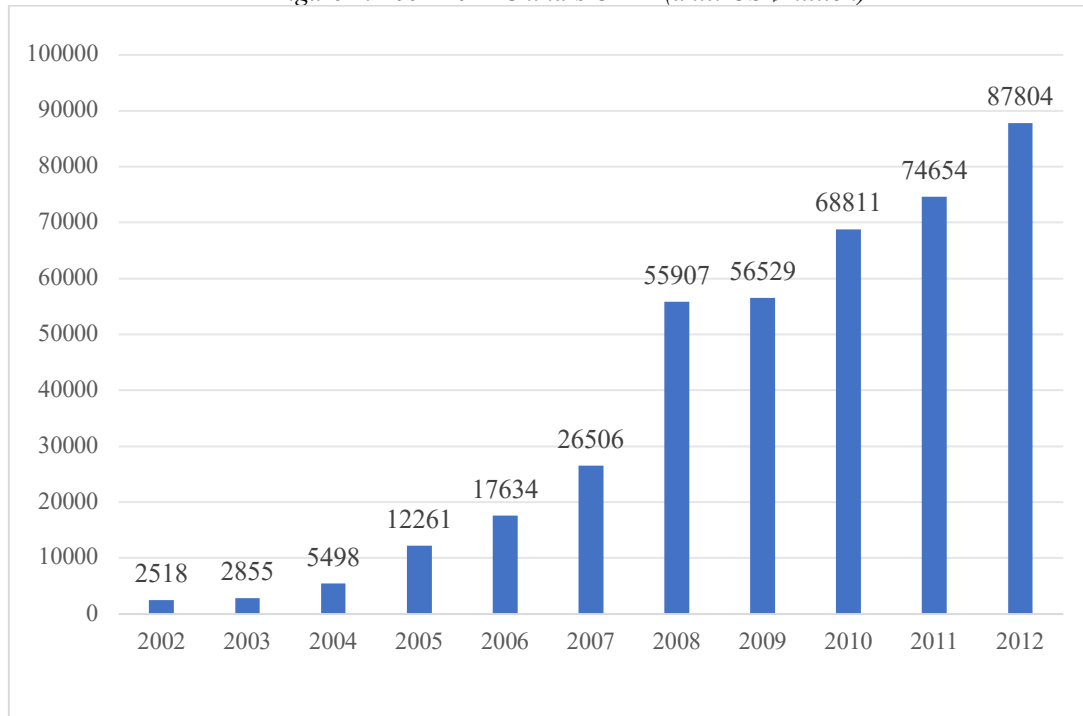
At this stage, China's foreign direct investment showed a tortuous development trend, and the development of foreign direct investment at this stage was obviously affected by the policy. In 1992, Deng Xiaoping issued a speech in the south, which had a far-reaching impact on accelerating the reform and opening up. In the same year, the 14th National Congress of the Communist Party of China proposed to build a socialist market economic system.

From Figure 1, it can be seen that there was a large fluctuation in 1994 compared with 1993, from 4400 million dollars to 2000 million dollars. Since 1993, China's domestic and international environment has changed, and foreign direct investment has been greatly affected. Internationally, Western developed countries imposed a new round of economic sanctions on China[3]. In China, the "overheating economy" triggered inflation, and the government adopted policies to reduce and control the scale of investment and credit to curb inflation[3]. In addition, some state-owned enterprises' blind investment led to losses and capital flight[3]. Therefore, at this stage, the government strengthened the control of foreign direct investment and began to comprehensively clean up and rectify overseas investment enterprises[3].

In 1997, the 15th CPC National Congress clearly put forward the "going out" strategy. Compared with 2000, there was a big fluctuation in 2001, rising from 916million US dollars to 6,885 million US dollars, showing a rapid growth. In 2001, China joined the World Trade Organization and participated in the process of economic globalization at a deeper level.

2.4 Rapid Development Stage: 2002-2012

Figure 2: 2002-2012 China's OFDI (unit: US \$million)

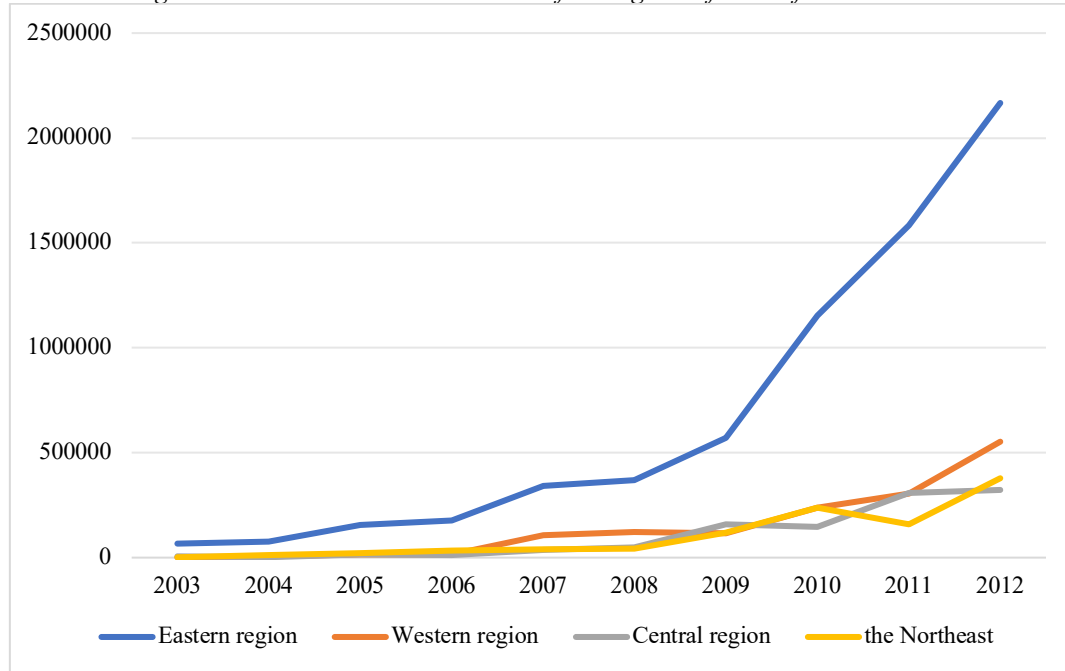


Data source: from UNCTAD data

At this stage, China's outward direct investment generally maintained a growth trend, but with 2008 as the boundary, it grew rapidly in the early stage and slowed down in the late stage.

As can be seen from Figure 2, China's foreign direct investment gradually increased from US \$2518million in 2002 to US \$87804million in 2012, an increase of more than 30 times. In 2002, the 16th National People's Congress put forward the strategy of adhering to the combination of bringing in and going out to comprehensively improve the level of opening-up, and issued and implemented a series of policies and regulations conducive to the development of foreign direct investment from 2003 to 2012, providing a convenient policy environment for the development of foreign direct investment. At the same time, the reform of RMB exchange rate and the gradual relaxation of foreign exchange control provided the monetary base and policy convenience for foreign direct investment [4]. At this stage, in addition to domestic support, the overall improvement of the global economy also provided a good external environment for the development of China's foreign direct investment.

The international financial crisis in 2008 brought both challenges and opportunities to China's foreign direct investment. China's successful response to the global financial crisis doubled its foreign direct investment in 2008 over the same period last year[4]. After the international financial crisis in 2008, it had a huge impact on the world economy, coupled with the short-term adjustment of China's foreign direct investment strategy, since then, the growth rate of China's foreign direct investment slowed down.

Figure 3: Outward direct investment in four regions of China from 2003 to 2012

Data source: CNRDS database

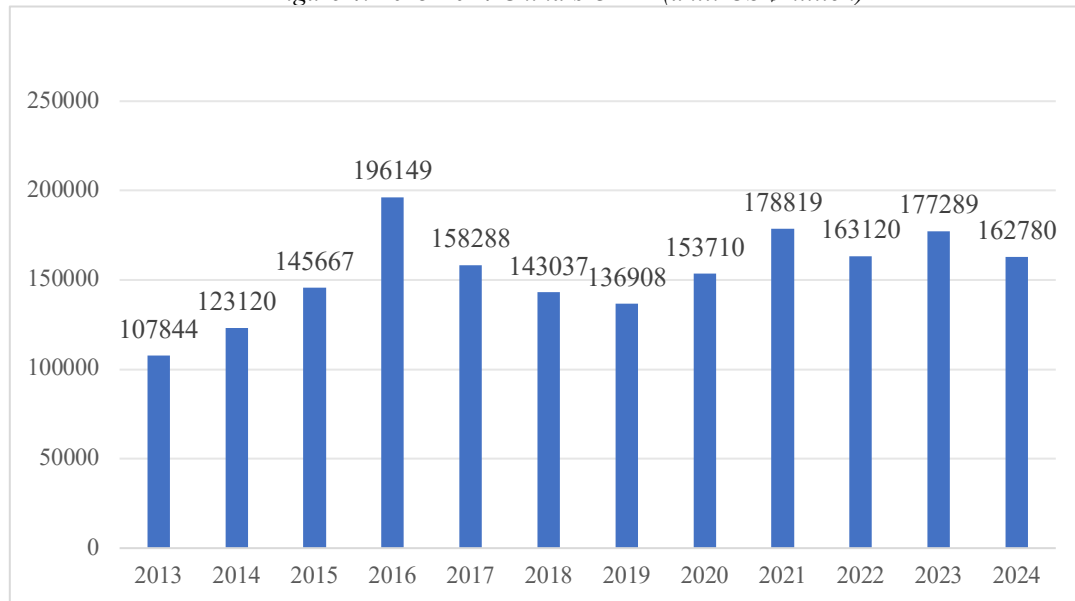
This paper mainly divides China into four regions, the eastern region mainly includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan, the central region includes Shanxi, Henan, Hubei, Hunan, Anhui and Jiangxi, the western region includes inner Mongolia, Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang, Tibet, Sichuan, Chongqing, Guizhou, Yunnan and Guangxi, and the northeast region includes Liaoning, Jilin and Heilongjiang.

As can be seen from Figure 3, the outward direct investment of the four regions shows an upward trend. China's outward direct investment is mainly concentrated in the eastern region, and the gap between the eastern region and other regions is gradually widening.

China's foreign direct investment in this period fully showed the characteristics of Chinese characteristics, and all aspects showed the characteristics of diversification. First of all, in terms of the main body of investment ownership, non-state-owned enterprises play an important role, and private enterprises are widely involved; Secondly, in terms of investment motivation, market, efficiency and resource seeking motivation coexist; In terms of investment location, it is widely distributed with Asia as the focus; In terms of investment mode, cross-border MandA gradually became the main investment mode; Finally, in terms of investment industry, the manufacturing industry is the first, showing diversified development [3].

2.5 Comprehensive Development Stage: 2013 to Present

Figure 4: 2013-2024 China's OFDI (unit: US \$million)



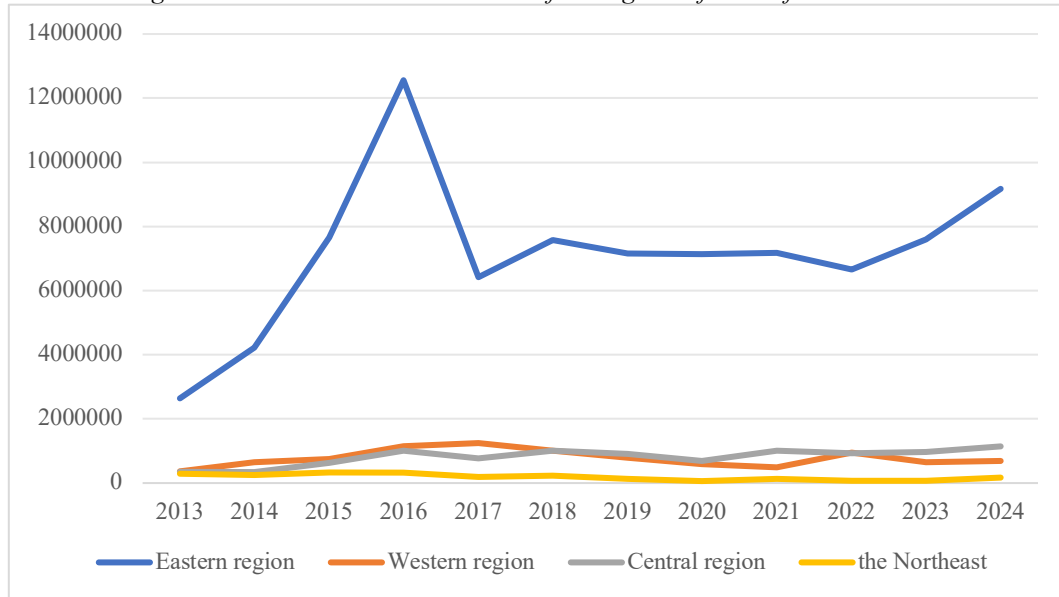
Data source: from UNCTAD data

As shown in Figure 4, at this stage, the overall development of foreign direct investment shows an upward trend, but there are fluctuations in this stage. Since the 18th CPC National Congress, foreign direct investment has entered a stage of all-around development. In 2013, the “Belt and Road” initiative expanded the development path of foreign direct investment.

The fluctuation of China's foreign direct investment during this period was caused by a variety of reasons. From 2013 to 2016, with the rapid development of China's foreign direct investment, there were also hidden risks. As the growing non-real economy's foreign direct investment is accompanied by greater financial risks, the government issued relevant policies and regulations to regulate and restrict it in 2017 [3]. At the same time, trade frictions between China and the United States occurred in 2018, resulting in a downward trend in China's foreign direct investment from 2016 to 2019.

Similarly, the growth from 2019 to 2021 is the result of the comprehensive effect of many reasons. Affected by the new crown epidemic in 2020, after the epidemic, there was a “retaliatory growth” in foreign direct investment, and China's policy support for economic recovery after the epidemic. Secondly, the government's policy support and guidance for foreign direct investment and China's continuous optimization and adjustment of the industrial structure are effectively promoting the high-quality development of foreign direct investment.

However, the development of China's foreign direct investment after 2021 is not ideal, which can be analyzed from both domestic and international aspects. From the perspective of China itself, on the one hand, the downward pressure on China's economy has increased. On the other hand, China's foreign direct investment has been adjusted reasonably, and the pursuit of quantity has gradually changed to the pursuit of quality. Internationally, the global economy has been weak in recent years; Regional conflicts continue and global instability increases, etc. These factors have a direct or indirect impact on the development of China's foreign direct investment.

Figure 5: outward direct investment in four regions of China from 2013 to 2024

Data source: CNRDS database

As can be seen from Figure 5, the development trend of foreign direct investment in various regions is basically synchronized with that of China as a whole. The outward direct investment of the four regions increased, but the gap between the eastern region and the other regions further widened.

In the comprehensive development stage of China's foreign direct investment, the role of non-state-owned enterprises is further highlighted; The investment area is more widely distributed, and the "belt and road" is playing a key role at this stage; The scale of China's foreign direct investment is huge and has a far-reaching impact on the world; At the same time of scale expansion, quality improvement; The impact of international factors on China's foreign direct investment deserves attention.

3. The Economic Impact of China's Foreign Direct Investment

This paper mainly analyzes the economic impact of China's foreign direct investment from the macro, meso and micro levels.

3.1 Macro Level

China's foreign direct investment undoubtedly promotes the economic growth of the host country, solves the local employment problem, and improves its infrastructure construction. More importantly, it is conducive to the sustainable and long-term development of the host country. China's foreign direct investment in the host country promotes its demand and attraction for foreign capital through economies of scale and technology spillover effects [6].

From the perspective of China itself, the most basic is that OFDI has a technology reverse spillover effect [7], that is to say, OFDI promotes China's technological progress. Foreign direct investment is also conducive to improving China's resource mismatch. Through the participation of foreign direct investment in the international division of labor and the global allocation of resources, we can improve the efficiency of resource allocation and the mismatch of resources, which will further promote China's supply-side structural reform, resolve overcapacity and transform the mode of economic development [8]. Foreign direct investment promotes China's green innovation process [9] and plays an important role in achieving sustainable development.

For the whole world, China's foreign direct investment injects vitality into the recovery of the world economy. Since the international financial crisis in 2008, the world economy has been weak, and the sustained growth of China's economy has become an important driving force for world economic growth. China's foreign direct investment is making important contributions to promoting international economic cooperation, promoting the process of economic globalization and improving the imbalance of global development.

3.2 Meso Level

China's foreign direct investment is not only conducive to China's own but also to the host country's industrial restructuring, industrial transformation and upgrading, enhancing the trade potential of both sides [10], and plays an important role in promoting the development of the host country's financial industry [6].

3.3 Micro Level

From the perspective of enterprises, whether Chinese or host enterprises, China's foreign direct investment has a significant positive impact on the innovation vitality of enterprises and is sustainable [11]. Enterprises can effectively enhance their competitiveness by obtaining advanced technology and management experience through foreign direct investment in developed countries. In addition, foreign direct investment can also help enterprises develop markets, build a global brand image, reduce costs, improve profit margins, and so on.

4. Conclusion

This paper mainly analyzes the development background, stage characteristics and regional distribution of China's foreign direct investment from six stages: blank, exploration, start, adjustment, rapid development and comprehensive development. Since the founding of the People's Republic of China, especially since the reform and opening up, China's foreign direct investment (FDI) is booming, but it is also facing challenges. Especially in recent years, some domestic and foreign factors have made the development of China's FDI face severe challenges. This paper also analyzes the economic impact of China's foreign direct investment from the macro, meso and micro levels. China's foreign direct investment plays an important role in promoting the economic development of both sides, promoting the industrial transformation and upgrading of both sides, encouraging enterprise innovation and improving the imbalance of global regional economic development.

In the future, China's foreign direct investment should develop in the direction of higher quality and level, actively comply with the trend of digitalization of the world economy, actively invest in the digital economy, optimize the structure of foreign direct investment, and transform to technology-intensive and capital intensive industries. The state should increase its support for foreign direct investment and introduce relevant policies to further promote the development of foreign direct investment. Enterprises should respond to the call of the state, actively carry out foreign direct investment, learn advanced management experience and technology, so as to promote their own management system reform and technological innovation, and enhance their competitiveness in the world. Only through the joint efforts of the state and enterprises can we inject new impetus into China's foreign direct investment and promote the sustained and healthy development of China's foreign direct investment.

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Conflicts of Interest

The authors declare no conflict of interest.

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Digital Currency and Regional Financial Cooperation: An Analysis of the Impact of the Belt and Road Initiative on RMB Internationalization

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Abstract

In the context of global geopolitical and economic transformations and the advancement of diversification in the international monetary system, RMB internationalization has emerged as a core agenda for China's high-level opening-up to the world. This paper constructs an integrated analytical framework of "regional financial cooperation-digital technology empowerment-RMB internationalization," systematically exploring the impact mechanisms and synergistic pathways of the Belt and Road Initiative and digital currencies on RMB internationalization. The study finds that the Belt and Road Initiative provides core application scenarios and institutional support for RMB internationalization, while digital currencies address cross-border payment bottlenecks through technological innovation. Together, they synergistically promote the steady enhancement of the RMB's international status in reserves, settlements, and investment and financing. Based on this, the paper proposes recommendations to deepen regional financial cooperation, optimize the cross-border application of digital RMB, and strengthen policy coordination, providing references for the high-quality development of RMB internationalization.

Keywords

RMB internationalization, Belt and Road Initiative, digital RMB

1. Introduction

Currently, the global political and economic landscape is undergoing profound changes, with the diversification process of the international monetary system continuing to advance. The 20th National Congress of the Communist Party of China explicitly proposed strategic deployments to "promote high-level opening-up to the outside world" and "steadily advance RMB internationalization," providing clear direction for the RMB internationalization process in the new era. Under this policy guidance, the deepening implementation of the Belt and Road Initiative and the rapid development of the digital economy have created new historical opportunities for RMB internationalization. In recent years, through a series of institutional innovations such as establishing cross-border payment systems, signing local currency swap agreements, and promoting central bank cooperation, the RMB internationalization process has advanced steadily. The vigorous development of new business forms like cross-border e-commerce has opened up new channels for RMB cross-border use. Under the Belt and Road framework, the continuous improvement of trade facilitation and

financial connectivity mechanisms has provided important carriers for the RMB's transformation from a trade settlement currency to an investment pricing currency and a reserve currency. At the same time, the research and pilot work on digital RMB are progressing in an orderly manner, with its technological innovation characteristics expected to inject new momentum into RMB internationalization.

At the practical level, institutional support from regional financial cooperation and technological empowerment from digital RMB have become the foundational conditions and driving logic for RMB internationalization. On one hand, countries are jointly building cross-border payment and clearing networks, allowing local currencies to no longer rely on third-party clearing channels, thereby establishing efficient and low-cost channels for cross-border currency circulation. Central bank cooperation can enhance the impact of cross-border e-commerce on RMB settlement in export trade, while policies such as bilateral currency swaps, bilateral local currency settlements, and offshore clearing mechanisms improve the convenience of RMB cross-border use [1]. On the other hand, the digital RMB, based on distributed ledger operations, bypasses the restrictions of the SWIFT system to achieve point-to-point direct transactions, significantly improving the efficiency of cross-border payment settlements [2]. From a long-term perspective, China's central bank digital currency (CBDC) not only plays a role in the RMB internationalization process but also has a significant impact on the evolution of the international monetary system [3].

Existing research on RMB internationalization and the Belt and Road Initiative is already quite abundant. The academic community generally agrees that RMB internationalization is a gradual process that requires drawing on the development experiences of international currencies like the US dollar, while avoiding hegemonic logic, to forge a path of "steady, prudent, and solid" RMB internationalization with Chinese characteristics [4]. In this process, on one hand, enhancements in international competitiveness have a potential promoting effect on currency internationalization [5], and geopolitical factors require RMB internationalization to seek breakthrough paths in a complex international environment [6]. On the other hand, the use of digital RMB in Belt and Road countries is considered conducive to elevating the RMB's status in the international monetary system [7]. The sustained development of cross-border e-commerce and the deepening of central bank cooperation also provide institutional safeguards for the promotion and use of digital RMB in Belt and Road countries [1]. However, existing research also points out that digital RMB still faces challenges such as pressure from US dollar hegemony and international monetary competition in cross-border flows, and RMB internationalization needs to explore new development paths [8].

Most existing literature conducts isolated or pairwise associative studies on Belt and Road regional cooperation, the technological driving forces of digital RMB, and the RMB internationalization process, lacking a systematic integrated analytical framework that combines regional financial support, digital technology empowerment, and RMB internationalization goals. In view of this, this paper aims to construct an integrative analytical perspective by reviewing the existing literature, systematically elucidating the interactive mechanisms and synergistic pathways among the Belt and Road Initiative, digital RMB, and RMB internationalization, thereby providing references for promoting the high-quality development of RMB internationalization.

2. Theoretical and Practical Aspects of RMB Internationalization

2.1 Theoretical Framework of Currency Internationalization

Currency internationalization is an important topic in the evolution of the global financial system. Although the Bretton Woods system has long collapsed, the US dollar still occupies a dominant position in the current international monetary system. As of the second quarter of 2025, the US dollar accounts for 56.32% of global foreign exchange reserves, making it the undisputed primary international currency. However, the single dominant currency system is fraught with problems, as frequent fluctuations in the US dollar can significantly impact the economies of various countries. Therefore, promoting the internationalization of more currencies helps disperse global financial risks and aligns with the trend of multipolarization in today's global economic development.

In the grand trend of global economic multipolarization and the promotion of multi-currency internationalization, the RMB internationalization process has steadily commenced and continues to advance, becoming one of the most promising emerging international currencies in the global monetary system.

According to data released by the People's Bank of China, the RMB's share in global official foreign exchange reserves has continued to rise. As of the second quarter of 2025, the RMB accounts for 2.12%, compared to just 1.08% when the IMF first separately reported RMB reserve data in 2016 upon its inclusion in the Special Drawing Rights (SDR) currency basket—an increase exceeding 96%. Currently, more than 80 countries and regions have included the RMB in their foreign exchange reserves, with the RMB's weight in the SDR currency basket reaching 12.28%, ranking third globally. From the perspective of cross-border payment infrastructure, the coverage and technical service levels of the Cross-Border Interbank Payment System (CIPS) have continuously improved, providing critical technical support for RMB internationalization. According to the data published by the Cross-Border Interbank Payment System Co., Ltd., as of the end of November 2025, the CIPS system has 190 direct participants and 1,567 indirect participants. Among the indirect participants, Asia has 1,150 (565 domestic), Europe 261, Africa 65, North America 34, South America 33, and Oceania 24. In summary, RMB internationalization has achieved phased results and has become an important force in promoting the diversification of the international monetary system.

2.2 Research on the Association between the Belt and Road Initiative and RMB Internationalization

Currency cross-borderization exhibits strong regional characteristics. Research has found that the RMB exchange rate demonstrates significant spillover effects in Belt and Road countries, indicating that the RMB's influence in the region is strengthening [9]. Conducting outward direct investment through the Belt and Road Initiative can further promote RMB internationalization [10].

Since the Belt and Road Initiative was proposed in 2013, the proportion of trade between China and participating countries has risen from an initial one-quarter to over half, achieving double-leap growth in scale and proportion over the decade. From a development stage perspective, 2013-2022 marked a period of steady climbing in trade proportion, increasing from 25% to 32.9% with an average annual growth rate of 8%, and trade volume doubling, primarily due to the initial advancement of infrastructure interconnectivity and the implementation of tariff reductions and other policies. 2023 became a key leap year, with the proportion surging from 32.9% to 46.6%, closely related to enhancements in transport capacity of logistics channels such as the China-Europe Railway Express and the Western Land-Sea New Corridor. The period from 2024 to 2025 has entered a phase of high stability, with the proportion stabilizing above 50%, making Belt and Road participating countries China's core cooperation circle in foreign trade. Trade ties between China and participating countries are increasingly close, with the trade scale proportion exceeding half and maintaining a growth trend. According to the data from Guangming Net, in the first 11 months of 2025, China's total import and export value of goods trade reached 41.21 trillion yuan, of which imports and exports with Belt and Road participating countries totaled 21.33 trillion yuan, a year-on-year increase of 6%, accounting for 51.8% of China's total foreign trade value. ASEAN, as the core region of Belt and Road participating countries, continues to hold the position of China's largest trading partner, with imports and exports amounting to 6.82 trillion yuan in the same period, up 8.5%. The specific values are shown in Table 1.

Table 1 Statistics on Import and Export Trade Data with Participating Countries

Year	Proportion of Imports and Exports with Participating Countries to China's Total Foreign Trade Value	Core Trade Data
2013	0.25	Total import and export volume approximately 1.04 trillion USD
2022	0.329	Total import and export volume reached 2.07 trillion USD
2023	0.466	Import and export volume 19.47 trillion yuan, year-on-year growth of 2.8%
2024	0.507	Total import and export volume reached 3.1 trillion USD, average annual growth of 4.7%
First three quarters of 2025	0.517	Import and export volume 17.37 trillion yuan, year-on-year growth of 6.2%
First 11 months of 2025	0.518	Import and export volume 21.33 trillion yuan, year-on-year growth of 6%

Data Source: China Belt and Road Network

The Asian Infrastructure Investment Bank (AIIB), since its opening in 2016, has expanded its membership to 111, spanning six continents, forming an interconnected global cooperation network with the Belt and Road Initiative, while RMB internationalization serves as the core link empowering the community with a shared future for mankind. According to data from the Silk Road Fund, the Silk Road Fund, established in 2014, has become an important market-oriented funding force supporting Belt and Road projects, with a current fund size of 40 billion USD and 100 billion yuan, focusing on project construction in areas such as energy, transportation, and industrial capacity cooperation. Its market-oriented and commercialized operation model complements the AIIB, with invested projects not only promoting RMB usage in each project but also attracting more commercial financial institutions to participate in RMB cross-border investment and financing, thereby amplifying the RMB's international influence.

3. Research on the Impact of Digital Currencies on Currency Internationalization

The emergence of digital currencies provides new technological pathways for currency internationalization. Taking the digital RMB as an example, its design, combining distributed ledger and centralized management, demonstrates dual advantages of improving efficiency and reducing costs in the field of cross-border payments. According to the report released by the Bank for International Settlements (BIS) in 2023, using central bank digital currencies for cross-border payments can shorten transaction settlement time from days in traditional systems to seconds and reduce costs by nearly 50%. According to China Financial News, from January to November 2024, the amount of RMB cross-border receipts and payments between China and participating countries reached 11.5 trillion yuan, a year-on-year increase of 40.6%. This China-led cross-border payment network has significantly promoted RMB internationalization.

In contrast, traditional cross-border payments mainly rely on the Society for Worldwide Interbank Financial Telecommunication (SWIFT) system, which is essentially a financial messaging network that only handles the transmission of payment instructions, without involving fund clearing, and still relies on the banking systems of various countries to complete fund transfers through multi-level correspondent banks. This separated architecture results in long payment chains and numerous intermediary links, leading not only to lengthy processes and low efficiency but also to elevated overall costs due to the accumulation of fees at each link. In contrast, the cross-border payment system (CIPS) promoted by China, combined with the digital RMB, constructs a new integrated architecture of “payment + clearing.” CIPS directly processes RMB cross-border clearing, while the digital RMB leverages its programmability and smart contract functions to embed into complex scenarios such as trade finance and supply chain finance, achieving conditional payments and process automation. This model not only reduces dependence on the SWIFT messaging network but also, through architectural integration and technological empowerment, significantly enhances the efficiency, transparency, and controllability of cross-border payments, thereby strengthening the autonomy and resilience of RMB cross-border use.

It needs to be clarified that “CIPS + digital RMB” does not replace SWIFT, but rather builds a more efficient, open, and flexible new cross-border payment ecosystem. The programmability of digital RMB, with its smart contract functions, can be embedded in complex scenarios such as trade finance and supply chain finance, achieving “payment as fulfillment”; its fully traceable transaction process characteristics not only meet international regulatory requirements such as anti-money laundering and counter-terrorism financing but also reduce compliance costs for overseas financial institutions, clearing obstacles for the promotion of RMB in the Belt and Road region. In the future, as it interconnects with more central bank digital currencies and penetrates the “Belt and Road,” RMB internationalization will achieve a comprehensive breakthrough.

4. Recommendations and Future Outlook

To promote the high-quality development of RMB internationalization, it is necessary to synergistically advance based on the foundation of Belt and Road regional cooperation and the advantages of digital technological innovation. First, deepen regional financial cooperation by expanding the coverage and execution efficiency of bilateral currency swap agreements, promoting more participating countries to access the CIPS system, improving the RMB offshore clearing network, exploring the establishment of unified

regional clearing rules and risk prevention and control mechanisms, and increasing the RMB's share in pricing and settlement for trade and investment. Second, optimize the cross-border application ecosystem of digital RMB by accelerating pilot programs for interoperability with central bank digital currencies of countries along the routes, aligning with international technical standards and interface specifications, developing customized functions for scenarios such as bulk commodity trading and cross-border e-commerce, and strengthening security technology research and development to prevent cross-border flow risks. Third, strengthen policy coordination and market cultivation by improving interconnection mechanisms such as "Bond Connect" and "Cross-boundary Wealth Management Connect," guiding enterprises to use RMB for settlements through fiscal subsidies and tax incentives, and enhancing international promotion to improve RMB awareness and acceptance.

In the future, as the Belt and Road Initiative continues to deepen and digital RMB technology matures, RMB internationalization is expected to achieve a leap from "regionalization" to "globalization." Under the trend of multipolarization in the international monetary system, the RMB will gradually increase its share in global trade settlements, cross-border investment and financing, and official foreign exchange reserves, forming an international monetary status commensurate with China's economic position. At the same time, RMB internationalization will provide new solutions for global economic governance, promoting the construction of a fairer and more efficient international monetary system. Future research can further focus on topics such as digital RMB scenario innovations and regional exchange rate coordination mechanisms to provide more targeted references for practice.

5. Conclusion

This paper constructs an integrated analytical framework of "regional financial cooperation-digital technology empowerment-RMB internationalization," systematically exploring the impact mechanisms of the Belt and Road Initiative on RMB internationalization under the technological empowerment of digital currencies, and arrives at the following core conclusions.

First, RMB internationalization has entered a new stage of phased development, achieving significant breakthroughs in aspects such as reserve currency and cross-border payment infrastructure. The RMB's share in global foreign exchange reserves continues to rise, its weight in the SDR remains firmly in the global third position, and the coverage of the CIPS system continues to expand, providing a solid foundation for RMB cross-border circulation and becoming an important force in promoting the diversification of the international monetary system.

Second, the Belt and Road Initiative provides core application scenarios and institutional support for RMB internationalization. Through a decade of deep cultivation, participating countries have become China's core cooperation circle in foreign trade, with the trade scale proportion surpassing 50%. The synergistic efforts of the Asian Infrastructure Investment Bank (AIIB) and the Silk Road Fund not only broaden the application of RMB in cross-border investment and financing but also strengthen its influence in the regional economy, forming a virtuous cycle of "trade traction-financial support."

Third, digital currencies inject technological momentum into RMB internationalization, reshaping the cross-border payment landscape. The "payment + clearing" integrated architecture constructed by digital RMB and CIPS effectively addresses the efficiency and cost bottlenecks of traditional cross-border payments. Its technological advantages, such as distributed ledger, programmability, and traceability, not only enhance the convenience of RMB cross-border use but also strengthen its autonomy, reducing dependence on the SWIFT system.

Fourth, while RMB internationalization maintains a positive development momentum, it still faces multiple challenges. The dominant position of the US dollar in the current international monetary system has not fundamentally changed, and there remains substantial room for the RMB to increase its share in global trade settlements and foreign exchange reserves. At the same time, attention must be paid to the differences in economic development levels and financial regulatory policies among Belt and Road countries, which may pose certain obstacles to RMB cross-border circulation.

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Financial Risks and Response Strategies in Corporate Acquisitions: A Case Study of Company B

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Abstract

Taking Boeing's 2024 acquisition of Spirit AeroSystems as the research object, this paper constructs a financial risk evaluation system based on the entropy weight method and efficacy coefficient method. It systematically analyzes the impact of acquisition on the financial risk structure in four dimensions: financing, operation, investment, and cash flow. The research findings indicate that Boeing's comprehensive financial risk is at a "low" level, with a severely excessive asset-liability ratio and a negative shift in operating cash flow as the core risk points. Although strategically necessary, the acquisition was implemented against a backdrop of weak financial fundamentals, which exacerbated the decline in operational efficiency and cash flow pressure in the short term. On the basis of these results, this paper proposes strategies for optimizing the asset-liability structure and ensuring cash flow security, providing a practical guide for risk prevention and control in the vertical integration of supply chains by aerospace manufacturers amid quality crises.

Keywords

financial risk, entropy weight method, efficacy coefficient method, risk prevention and control

1 Introduction

1.1 Research background

As a pivotal engine of modern economic growth and a core means of corporate strategic expansion, corporate acquisitions have increasingly demonstrated their strategic value amid the restructuring of the global industrial chain and the intensification of market competition. As an efficient resource allocation method, corporate acquisitions not only promote the optimization and upgrading of industrial structures and achieve economies of scale and scope but also accelerate technological innovation and market integration, creating synergistic value and competitive advantages for enterprises. According to Dealogic data, despite the impact of global economic fluctuations, the total value of global M&A transactions still reached \$3.2 trillion in 2023, fully demonstrating the resilience and strategic status of acquisition activities throughout economic cycles. In modern business history, from the first wave of acquisitions in the late 19th century to the era of globalized acquisitions in the 21st century, acquisition activities have always been a key driving force behind leaps in corporate development and the reshaping of industrial patterns.

In recent years, with the in-depth advancement of globalization and the vigorous development of the digital economy, corporate acquisition activities have exhibited characteristics such as an expanding scale, diversified fields, and complex cross-border operations. They have become an inevitable strategic consideration for enterprises seeking transformation, market expansion, and value chain upgrading. Particularly in high-tech sectors such as aerospace, biomedicine, and artificial intelligence, acquisitions serve as a strategic shortcut for enterprises to acquire core technologies, shorten R&D cycles, and seize market opportunities. However, the high failure rate of acquisition activities has attracted widespread attention from academia and industry, with inadequate financial risk management identified as one of the core factors leading to failure. Financial risk permeates the entire acquisition process—from valuation and financing arrangements to payment methods and post-merger integration—presenting multidimensional challenges related to financing capacity, operational efficiency, investment returns, and cash flow stability. Scientific identification, accurate assessment, and effective control of financial risk not only determine the success of individual acquisition transactions but also affect enterprises' long-term financial health and sustainable development capabilities. Against this backdrop, in-depth research on the formation mechanisms and response strategies of financial risk in corporate acquisitions holds significant theoretical value and practical significance for improving acquisition quality, optimizing resource allocation efficiency, and driving high-quality economic development. This study, through a case analysis of Boeing's 2024 acquisition of Spirit AeroSystems, aims to provide empirical references and strategic guidance on financial risk management for Chinese enterprises engaging in acquisition activities.

1.2 Research Objectives and Significance

This study aims to identify and analyze potential financial risk in the corporate acquisition process in detail and explore corresponding prevention and control strategies. Through a systematic analysis of the typical case of Boeing's 2024 acquisition of Spirit AeroSystems, a scientific and accurate financial risk assessment system is constructed. At the theoretical level, this research strives to overcome the limitations of single-dimensional analysis in traditional financial risk studies. It integrates four core dimensions—financing risk, operational risk, investment risk, and cash flow risk—to establish a multidimensional and dynamic financial risk assessment framework, thereby enriching the theoretical system of corporate acquisition risk management. In terms of assessment methods, this study combines the entropy weight method with the efficacy coefficient method: the entropy weight method is used to objectively determine the weight of each financial indicator, avoiding biases caused by subjective weighting; subsequently, indicators are screened and calibrated in accordance with the *Standard Values for Enterprise Performance Evaluation* issued by the State-owned Assets Supervision and Administration Commission (SASAC) of the State Council, and the efficacy coefficient method is applied for quantitative assessment. This results in a more scientific and practical risk assessment model, providing new insights for the refinement and quantification of financial risk management theories.

At the practical level, this study conducts a longitudinal comparative analysis of Boeing's financial data from 2021-2024, with a specific focus on the dynamic changes in key financial indicators before and after the acquisition (i.e., 2023 vs. 2024). This analysis accurately identifies the substantive impact of the acquisition on the enterprise's financial structure, operational efficiency, and value creation. Beyond providing targeted recommendations for Boeing to optimize acquisition integration strategies and strengthen financial risk prevention, this empirical analysis also offers a referenceable risk management paradigm for Chinese manufacturing enterprises—especially those in the high-end equipment manufacturing sector—when conducting cross-border acquisitions. Against the backdrop of in-depth adjustments to the global economic structure and accelerated industrial chain restructuring, corporate acquisition activities have become increasingly frequent and complex, with ineffective financial risk management being one of the core causes of acquisition failure. This study helps improve the scientific rigor of corporate acquisition decisions, safeguards enterprise asset security, and holds significant practical implications for advancing the international strategic initiatives of Chinese enterprises. Through dual exploration in theory and practice, this research seeks to establish an effective connection between academic value and application value, contributing forward-looking and practical findings to the field of acquisition financial risk management.

1.3 Literature Review

Corporate acquisitions, as a key means to achieve resource integration, strategic transformation, and scale expansion, remain globally active. However, acquisition practices show that complex potential financial risks

often lag behind high failure rates.[1] These risks permeate the entire acquisition process, become concentrated during the integration phase, and severely hinder the realization of acquisition value. Particularly in capital-intensive industries such as high-end manufacturing and aerospace, acquisitions involve massive capital investment, complex asset structures, and long-term synergy expectations-placing greater demands on the identification and control of financial risk. Therefore, systematically organizing existing research findings and deeply understanding the multidimensional composition and dynamic evolution mechanism of financial risk are highly important for constructing a scientific and effective evaluation system.

This study aims to overcome the limitations of traditional single-dimensional risk analysis and establish a multidimensional, dynamic evaluation framework covering financing risk, operational risk, investment risk, and cash flow risk through theoretical integration and methodological innovation. To this end, on the basis of databases such as CNKI (China National Knowledge Infrastructure) and Web of Science, this paper draws on insights from multiple perspectives, including managerial behavior, integration mechanisms, institutional environments, and evaluation methods. Among these, empirical studies reveal the causes of risk, case analyses illustrate dynamic processes, and methodological research lays the foundation for constructing scientific evaluation models. The following section presents a systematic review of the identification logic, multidimensional structure, evaluation tools, and prevention paths of financial risk, providing theoretical support for subsequent empirical modeling on the basis of the Boeing–Spirit AeroSystems acquisition case.

Traditional financial risk research relies heavily on static accounting indicators such as the asset-liability ratio and current ratio, which struggle to capture the dynamic evolutionary characteristics of risks during acquisitions. In recent years, scholars have gradually shifted to a full-process perspective, emphasizing the differences in risk manifestations and transmission mechanisms across different acquisition stages. Zhang Xianzhi and Du Chunming (2020) noted that managerial capabilities suppress acquisition premiums by reducing information asymmetry and promote performance through improving integration efficiency-indicating that risk control begins prior to decision-making[2]. Li Danmeng et al. (2018) further reported that managerial overconfidence leads to inflated goodwill, and such risks typically become explicit through impairment tests 1–2 years after mergers and acquisitions.[3] This suggests that financial risk is not an isolated event but rather a continuous process embedded in the full acquisition cycle, requiring the establishment of a dynamic identification mechanism.

Furthermore, the heterogeneity of acquisition motives further complicates risk identification. Zhou Shaoni and Wen Haitao (2013) proposed that performance evaluation should follow the logical chain of “industrial evolution – motives – indicators.”[4] Ignoring strategic intentions and judging risks solely on the basis of short-term financial data may easily lead to misjudgement. Lin Jihong and Liu Ying (2013) also confirmed that overseas acquisitions for resource purposes exhibit poor short-term financial performance but outperform other industries in long-term performance.[5] These studies collectively suggest that effective risk identification must integrate industrial characteristics and strategic goals, distinguish between strategic losses and substantive financial crises, and avoid simplistically classifying all high-investment or high-leverage cases as “high risk”. “

Existing studies have gradually moved beyond the single-dimensional focus on financing capacity to explore multidimensional risk structures. As early as 2008, Ge Jiashu and Zhan Meisong emphasized in their financial report analysis framework that five dimensions-liquidity, financial flexibility, expected cash flow, profitability, and market risk-should be examined simultaneously, laying the foundation for a multidimensional risk perspective.[6] Hou Xuhua and Peng Juan (2019), in their research on early warnings of risk for internet insurance companies, comprehensively considered indicators such as asset liquidity, premium income stability, and the expense ratio, reflecting the integration of operational and cash flow risks.[7] This approach is highly consistent with the “financing – operation – investment – cash flow” four-dimensional framework proposed in this study.

Specifically, financing risk manifests as an enterprise’s debt burden and solvency, often measured by indicators such as the asset–liability ratio and interest coverage ratio; operational risk reflects asset utilization efficiency and cost control capabilities, involving inventory turnover, accounts receivable management, etc.; investment risk is associated with the rationality of acquisition premiums, the goodwill scale, and the possibility of asset impairment; and cash flow risk focuses on the ability to generate free cash flow and the degree of financing constraints, serving as the lifeline for an enterprise’s sustainable operations. Liu Ruizhi et

al. (2014) reported that strategic integration has the greatest impact on financial performance, whereas cultural integration affects market reactions-indirectly indicating that different integration dimensions correspond to different types of financial risk.[8] Hu Haiqing et al. (2016) verified the synergistic effect of Geely Volvo's merger via the EVA (economic value added) model, which also implicitly involves a comprehensive evaluation of investment returns and cash flow creation capabilities.[9] These studies demonstrate that multidimensional risk structures not only have theoretical rationality but also practical operability.

In terms of evaluation methods, early studies mostly relied on expert scoring or simple weighting, which suffer from significant subjective biases. In recent years, scholars have focused on introducing more objective and systematic quantitative tools. Hou Xuhua and Peng Juan (2019) combined the entropy weight method with the efficacy coefficient method for early risk warning in internet insurance companies: the former was used to objectively determine indicator weights, whereas the latter standardized scores-effectively improving the scientific rigor of evaluation.[7] Gong Xiaofeng (2013) also applied the efficacy coefficient method to evaluate the integration performance of cross-border acquisitions, integrating qualitative and quantitative indicators to enhance model applicability.[10] These methodological explorations provide direct references for the construction of a combined "entropy weight method + efficacy coefficient method" model.

Notably, the authority and industry adaptability of indicator selection are crucial. The *Standard Values for Enterprise Performance Evaluation* issued by SASAC (State-owned Assets Supervision and Administration Commission of the State Council) is widely recognized as a domestic industry benchmark and has been extensively applied in enterprise performance and risk evaluation. Although the provided literature does not directly cite this standard, Hou Xuhua et al. (2019) emphasized "adjusting thresholds on the basis of industry characteristics" in indicator calibration,[7] and Zhang Jide and Zheng Lina (2012) also suggested that risk management frameworks should "start with environmental analysis"-both implicitly reflecting the need for standardized and context-specific indicator systems.[11] Therefore, combining the objective weighting advantages of the entropy weight method with the industry adaptability of authoritative standard values can effectively enhance the practicality and comparability of the evaluation model.

In the face of multidimensional financial risk, prevention and control strategies also need to be systematic. Zhang Jide and Zheng Lina (2012) proposed a three-dimensional financial risk management framework for group enterprises, including the target layer, management layer, and foundation layer, emphasizing top-down systematic risk prevention.[11] From a strategic management perspective, Li Weian and Dai Wentao (2013) constructed a relational framework among corporate governance, internal control, and risk management, noting that the synergy of these three elements is the foundation of risk prevention.[12] These studies collectively indicate that effective risk prevention cannot rely solely on post hoc remedies but must be embedded in an enterprise's strategic and governance systems.

At the operational level, Cai Long (2018) suggested in his research on mergers and acquisitions in the general aviation manufacturing industry that phased integration strategies should be developed on the basis of SWOT analysis, with particular attention to technological synergy and supply chain stability.[13] Li Yongjia (2014) also emphasized that acquisitions in the aerospace manufacturing industry require high attention to core technology retention and capital structure optimization.[14] These industry-specific recommendations highlight the need for deep integration between general risk management principles and industrial characteristics. Additionally, Wang Jing and Tian Manwen (2010) noted that acquisition integration must "prioritize tasks and proceed step by step," with different risk priorities focused on in different stages-providing practical insights for constructing dynamic risk evaluation and response mechanisms.[15]

In cross-border acquisitions, institutional and cultural differences further amplify financial risk. Through an analysis of the Geely Volvo case, Du Jian et al. (2021) reported that after enterprises are acquired in developed countries, firms from emerging markets need to dynamically switch between different institutional logics to achieve integration performance.[16] Institutions such as Shanghai International Studies University (2019) also confirmed that language distance significantly reduces acquisition performance through cultural effects.[17] These studies illustrate that financial risk originates not only from financial statement items but also from institutional frictions and cultural conflicts, which may indirectly erode financial value through channels such as reduced synergy efficiency and talent loss.

Political connections also constitute a localized risk source. Zhang Wen et al. (2013) reported that enterprises with political connections conduct more acquisitions but achieve poorer performance, reflecting

resource misallocation caused by nonmarket mechanisms.[18] Wang Jing and Tian Manwen (2010) noted that government intervention has a dual effect on the integration efficiency of state-owned listed companies.[15] These conclusions indicate that in the Chinese context, financial risk evaluation must incorporate variables such as ownership nature and governance structure to avoid ignoring the interference of institutional distortions on financial decisions.

In summary, existing studies have revealed the complexity of financial risk in corporate acquisitions from multiple dimensions, revealing an evolutionary trend from static to dynamic, from single-dimensional to multidimensional, and from subjective to objective. In particular, substantial achievements have been made in risk structure identification, evaluation method innovation, and prevention system construction, providing a solid foundation for this study. However, several gaps remain: first, although multidimensional risk frameworks are advocated, they lack a unified operational definition and indicator system; second, while the entropy weight method and efficacy coefficient method have been applied, they have not been systematically integrated with authoritative industry standards (such as SASAC's standard values); third, dynamic risk evaluation models for specific industries such as high-end manufacturing remain absent. Against this backdrop, this study intends to take Boeing's 2024 acquisition of Spirit AeroSystems as a case, integrate the four risk dimensions of financing, operation, investment, and cash flow, construct a dynamic evaluation model that uses the entropy weight method for objective weighting, refers to SASAC's standard values for calibration, and applies the efficacy coefficient method for quantification. This effort not only addresses the shortcomings of existing research in terms of methodological refinement and industry adaptability but also aims to provide a new paradigm for financial risk management in corporate acquisitions that combines theoretical depth and practical value.

2 Concept Definition and Theoretical Basis

2.1 Concept of Corporate Acquisition

2.1.1 Definition of Acquisition

Acquisition refers to a business activity in which one enterprise obtains control or management rights over another enterprise by purchasing equity or assets. From a legal perspective, the core feature of acquisition is the transfer of control rights rather than the disappearance of the corporate legal personality, and the acquired party usually retains its independent legal subject status after the transaction. From a financial perspective, acquisition is an important decision for corporate capital allocation, involving significant capital expenditure, restructuring of the asset-liability structure, and redistribution of future cash flows. Unlike mergers, in acquisition activities, the acquirer maintains its own integrity, while the acquired party becomes its subsidiary or business unit. This characteristic makes the transmission of financial risk in the acquisition process more hierarchical and complex.

2.1.2 Motives and Objectives of Corporate Acquisitions

The motives and goals of corporate acquisitions constitute the internal driving force and value orientation of acquisition decisions, directly determining the design of acquisition plans, resource integration paths, and characteristics of financial risk. From a theoretical perspective, acquisition motives can be categorized into three core dimensions: strategic motives, financial motives, and agency motives. Strategic motives stem from enterprises' need to pursue long-term competitive advantages, manifested in their ability to acquire synergies, expand their market share, or obtain core technologies and critical resources; financial motives focus on optimizing capital allocation efficiency, including leveraging tax advantages, realizing asset revaluation, diversifying operational risks, or improving capital structure; and agency motives, by contrast, relate to managers' self-interested behaviors-such as expanding enterprise scale to enhance personal reputation or compensation levels. These motives are often intertwined, collectively shaping acquisition decisions.

At the specific goal level, modern corporate acquisitions typically establish a multitiered goal system: at the market level, they aim to expand market share, penetrate regional markets, or extend customer bases; at the technology level, they pursue core patents, R&D teams, or innovation capabilities to shorten the technology catch-up cycle; at the operational level, they seek vertical supply chain integration, production scale optimization, or management experience sharing; and at the financial level, they focus on improving

profitability, optimizing asset turnover efficiency, or enhancing cash flow stability. Notably, the quality of acquisition goal setting directly affects the subsequent level of financial risk, as overly aggressive or diversified goals often lead to the accumulation of risk.

2.2 The Concept of Financial Risk

2.2.1 Definition and Types of Financial Risk

Financial risk refers to the possibility that an enterprise may experience deteriorated financial conditions, losses in financial performance, or deviations from financial goals due to uncertainties in internal and external environments during its business and financial activities. In the context of corporate acquisitions, financial risks exhibit characteristics of amplification, transmission, and lag, resulting from the profound changes that acquisition activities bring to the asset-liability structure, cash flow patterns, and resource allocation efficiency. On the basis of the risk formation mechanism and manifestation dimensions, this study systematically classifies acquisition-related financial risk into four core types: financing risk, operational risk, investment risk, and cash flow risk.

Financing risk refers to the risk that an enterprise fails to fulfill its debt obligations on time because of an unbalanced debt structure or insufficient solvency. In the acquisition context, it manifests as a surge in the asset-liability ratio, increased interest burden, and debt maturity mismatch caused by acquisition financing. The key evaluation indicators include the asset-liability ratio, current ratio, quick ratio, and interest coverage ratio, among which an asset-liability ratio exceeding 70% is generally regarded as a high-risk threshold. After Boeing's acquisition of Spirit AeroSystems, the expansion of the debt scale may significantly exacerbate its already strained financing pressure.

Operational risk arises from the decline in enterprise operational efficiency and the weakening of asset management effectiveness, manifested as slower asset turnover, increased occupation of working capital, and unmet expectations of operational synergy. During the acquisition integration period, problems such as asset idleness, inventory overstocking, and prolonged accounts receivable collection cycles are common. The core measurement indicators include the accounts receivable turnover rate, inventory turnover rate, and total asset turnover rate; the continuous decline of these indicators often signals the aggravation of operational risk.

Investment risk refers to the risk of the inefficient allocation of acquisition capital and unfulfilled expected returns. It specifically manifests as excessive acquisition premiums, distorted asset valuations, and extended investment payback periods, which directly erode shareholder value. The evaluation indicators include return on equity (ROE) and return on total assets (ROA); the negative changes in these indicators after the acquisition reflect the actual occurrence of investment risk.

Cash flow risk is the concentrated manifestation of acquisition financial risk, referring to a liquidity crisis where an enterprise's cash inflows are insufficient to support its cash outflow needs. Acquisition activities often lead to large-scale cash outflows and fluctuations in operating cash flows; if the expected synergy fails to be achieved, it triggers a chain reaction, such as the deterioration of free cash flow and a shortage of financing funds. The cash flow ratio, free cash flow, and cash flow interest coverage ratio are core monitoring indicators, among which consecutive negative free cash flow is a high-risk signal.

2.2.2 Theoretical Basis

Financial risk research is rooted in three core theories: risk management theory, principal-agent theory, and information asymmetry theory. Risk management theory provides a systematic framework for enterprise financial risk prevention and control, emphasizing the control of risks within an acceptable range through closed-loop management of risk identification, assessment, monitoring, and response. In the context of acquisitions, this theory guides enterprises to establish a forward-looking risk early warning mechanism and dynamic adjustment strategies to achieve the optimal balance between risks and benefits.

Principal-agent theory reveals the endogenous root of acquisition financial risk. Owing to the separation of ownership and control, management may drive inefficient acquisitions for personal interests (such as expanding the enterprise scale and enhancing personal reputation), leading to financial risks such as excessive debt and resource mismatch. When considering the decision-making process of Boeing's acquisition of Bishi,

it is necessary to be vigilant against irrational financial behavior caused by management overconfidence or short-term performance pressure.

The theory of information asymmetry explains the formation mechanism of acquisition valuation bias. There exists an information gap between the acquirer and the target company, with the seller typically possessing more internal information, which can easily lead to adverse selection and moral hazard. In technology-intensive industries such as aviation manufacturing, differences in judgments between acquirers and targets regarding asset quality, technological value, and integration difficulties often lead to financial risks such as overvaluation and underestimation of synergistic effects. Together, these three theories form the theoretical cornerstone for analyzing the formation mechanism and transmission path of acquisition financial risk, providing academic support for risk identification and the design of prevention and control strategies.

3 Case Analysis of Company B

3.1 Research Methods

The research adopted a combination of a single-case study and quantitative analysis, with Boeing Company as the subject of study. It emphasizes the application of financial indicator analysis, selecting highly representative financial indicators from four aspects, financing, investment, financing, and cash flow risk, to analyze the trend of changes in Boeing's financial indicators over the past four years and identify the impact of acquisition activities on the company's financial risk. The entropy weight method and efficacy coefficient method are combined to assess Boe's financial risk and to systematically evaluate the scoring results. By integrating financial indicator analysis with quantitative analysis, this study provides a deeper and more precise analysis of various financial risks triggered by Boeing's acquisition activities.

3.2 Case Overview

3.2.1 Overview of the Acquisition and Acquisition Strategies

3.2.1.1 Introduction to the Boeing Company

Founded in 1916, the Boeing Company stands as one of the global leaders in the aerospace industry and is the largest aviation manufacturing enterprise in the United States. As one of the world's two major civil aircraft manufacturers, Boeing's business spans multiple sectors, including commercial aircraft, defense, space and security systems, and global services. The company's product line encompasses various commercial aircraft series, such as 737, 747, 777, and 787, along with diverse military aircraft, satellites, and missile defense systems. By the end of 2023, Boeing employed approximately 170,000 individuals globally, with operations spanning over 150 countries and regions and generating annual revenue of approximately \$68 billion. Within the aviation manufacturing industry chain, Boeing holds a pivotal integrator position, coordinating thousands of suppliers through a complex global supply chain network, with the strategic role of primary airframe structure suppliers being particularly crucial. In early 2024, Boeing found itself embroiled in a production quality crisis. On January 5, 2024, an Alaskan Airlines Boeing 737-9 passenger aircraft experienced door detachment in mid-air shortly after takeoff, revealing issues with its production quality control. The Federal Aviation Administration subsequently conducted an audit of the production of the Boeing 737 MAX series aircraft, with 33 out of 89 audit items failing to meet standards. This series of events severely damaged Boeing's market reputation and customer trust, necessitating urgent and fundamental measures to rebuild its quality control system. In this context, Boeing sought to reshape its supply chain management and control capabilities through vertical integration.

3.2.1.2 Introduction to Spirit AeroSystems Holdings, Inc.

Spirit AeroSystems Holdings, Inc. was founded in 2005 through the divestiture and restructuring of certain assets from Boeing's Commercial Airplanes division, with its headquarters located in Wichita, Kansas, USA. As a leading global manufacturer of aviation structural components, Spirit AeroSystems specializes in designing and manufacturing key structural parts such as aircraft fuselages, wings, and thrust reversers. Its major clients include aviation giants such as Boeing and Airbus. The company employs over 16,000 individuals and operates multiple production bases across the United States, Europe, and Asia. Prior to the

divestiture, Spirit AeroSystems served as the core fuselage supplier for the Boeing 737 program; following the divestiture, 70% of its revenue still comes from Boeing and 23% from Airbus, forming a business model heavily reliant on its major clients. This deeply tied supply relationship has closely linked Spirit AeroSystems' operational stability to Boeing's strategic objectives amidst the Boeing 737 MAX crisis and subsequent frequent quality issues and has also set the stage for potential future acquisitions.

3.2.2 Acquisition Process

After the incident on January 5, 2024, when a door latch fell off from an Alaskan Airlines Boeing 737-9 aircraft, the Federal Aviation Administration of the United States strengthened its regulatory review of Boeing's supply chain. As the manufacturer of the door latch component, Biwei initiated an investigation by the Attorney General of Texas on March 28, 2024. These external pressures further accelerated the acquisition process.

On April 23, 2024, Boeing and Iberia reached a financial assistance agreement worth \$425 million, aimed at alleviating the inventory backlog and cash flow pressure faced by Iberia. This arrangement is considered a key prerequisite for acquisition negotiations.

On July 1, 2024, Boeing officially announced that it had reached a definitive acquisition agreement with BAE Systems. According to the announcement, the transaction will be paid in full stock, with an equity valuation of approximately \$4.7 billion for BAE Systems, equivalent to \$37.25 per share. After including BAE systems' reported net debt, the total transaction value is approximately \$8.3 billion. The transaction structure design has significant industry characteristics: Boeing will acquire almost all BAE systems' commercial business related to Boeing, as well as other commercial, defense, and after-sales businesses; meanwhile, Airbus will acquire BAE systems' business units related to its aircraft. This arrangement aims to address potential antitrust concerns.

Between May and October 2024, Bishi Rui implemented multiple rounds of production adjustments, including laying off approximately 450 workers in May and imposing a 21-day mandatory leave on 700 employees in October, reflecting production uncertainty during the transition period.

On June 26, 2025, the UK Competition and Markets Authority (CMA) issued a preliminary statement to assess whether the transaction constituted a "relevant merger situation" as defined in the Enterprise Act 2002 and whether it would result in a "substantial lessening of competition in any market for goods or services in the UK." On June 30, 2025, the CMA officially launched the first phase of its merger investigation, focusing on the impact of the transaction on the competitive landscape of the global aviation manufacturing industry, particularly the potential impact on Airbus' competitive position, given that Bishi Rui also supplies key fuselage sections for some Airbus aircraft models. The CMA set August 28, 2025, as the deadline for its first-phase decision. On August 29, 2025, the CMA issued a decision approving the acquisition, determining that no further investigation was necessary in the second phase.

Focusing on the case of Boeing's acquisition of Iridian Systems, its motivation bears distinct industry characteristics. First, as an upgrade of long-term supply chain relationships, it aims to strengthen control over key airframe and structural components and mitigate supply chain security risks. Second, in the wake of the 737 MAX crisis, there is an urgent need to regain market trust, and vertical integration is used to enhance quality control capabilities and delivery reliability. Third, facing competitive pressure from Airbus, integrating Iridian's composite material technology is essential to accelerate the development of next-generation aircraft. These strategic motivations are translated into specific goals: restoring production stability in the short term, optimizing the cost structure in the medium term, and building technological barriers in the long term. However, such large-scale strategic acquisitions often involve significant financial risk, especially when strategic goals do not align with financial affordability, which can easily lead to issues such as excessive debt burden, integration cost overruns, and increased cash flow pressure. Therefore, accurately identifying acquisition motivations and goals is the logical starting point for assessing the formation mechanism of financial risk and designing prevention and control strategies.

3.3 Qualitative Identification of Financial Risk in Case Enterprises

The acquisition behavior of enterprises significantly alters their financial structure. This study identifies the financial risk of Boeing Company in four dimensions: financing, operating, investment, and cash flow risk.

3.3.1 Fundraising Risk

Table 1: Fundraising activity indicators of the Boeing Company from 2021-2024

Year	2024	2023	2022	2021
Working capital (in millions of US dollars)	30920.00	13448.00	19471.00	26674.00
Current ratio	1.32	1.14	1.22	1.33
Quick ratio	0.42	0.31	0.35	0.36
Cash ratio	0.27	0.17	0.16	0.20
Debt-to-asset ratio	1.025	1.13	1.12	1.11

Data source: Annual reports of the Boeing Company from 2021-2024

3.3.1.1 Serious Imbalance in Capital Structure

Boeing's asset-to-liability ratio has been above the warning threshold for four consecutive years. From 2021-2023, it remained in the range of 1.11-1.13. Although it slightly decreased to 1.025 in 2024, it was still significantly higher than the safety threshold of 1.0, indicating that the company continued to be insolvent. This abnormal capital structure reflects that Boeing failed to effectively repair its balance sheet after the 737 MAX crisis, and the \$8.3 billion acquisition of Iridium in 2024 (including net debt) further tested its financial carrying capacity. Notably, the decrease in the asset-to-liability ratio in 2024 may be due to the asset revaluation effect brought about by the acquisition rather than fundamental financial repair, masking potential long-term debt repayment pressure.

3.3.1.2 Significant Fluctuations in Short-Term Debt-Paying Ability

The current ratio exhibited a V-shaped trend, decreasing from 1.33 in 2021 to 1.14 in 2023 and then rising to 1.32 in 2024, indicating significant adjustments in short-term liquidity management strategies before and after the acquisition. However, the quick ratio and cash ratio reveal deeper risks: the quick ratio continued to decline from 2021-2023 (0.36→0.31), and although it improved to 0.42 in 2024, it was still far below the healthy standard of 1.0; the cash ratio decreased from 0.20-0.17 during the same period and then rose to 0.27 in 2024, indicating the company's high dependence on nonquick assets such as inventory. This contradiction of "abundant liquidity on paper but weak actual payment ability" highlights the asset liquidity dilemma faced by Boeing as an aviation manufacturing enterprise, where many funds are tied up in work-in-process and finished products with long production cycles and difficult liquidation.

3.3.1.3 Deterioration in Working Capital Management Efficiency

From 2021 to 2023, working capital decreased sharply from \$26,674 million to \$13,448 million, a decrease of 49.6%, reflecting a significant decline in a company's working capital management efficiency in response to the impacts of the 737 MAX grounding and quality crisis. In 2024, working capital rebounded significantly to \$30,920 million, mainly due to cash inflows from financing activities brought about by the acquisition of Iberia Airlines (with \$425 million in advance payments and subsequent acquisition financing), rather than improvements in operating cash flow. Although this exogenous capital injection alleviated short-term pressure, it did not address the fundamental issue of weakened endogenous working capital creation capacity.

3.3.1.4 Concerns about the Structure of Acquisition Financing

Boeing's all-stock acquisition of Iridium (with an equity value of \$4.7 billion) has avoided directly increasing its debt burden, but it may trigger three financing risks: first, dilution of equity leads to a decrease in earnings per share, affecting shareholder value; second, the market has doubts about the integration effect of the acquisition. After the door seal fell off incident in January 2024, the company's stock price volatility intensified, increasing the uncertainty of equity financing. Third, the Iridium's original \$4.1 billion in liabilities were included in the consolidated statements, further increasing Boeing's overall debt burden. According to the "Standard Values for Enterprise Performance Evaluation" issued by the State-owned Assets Supervision and Administration Commission, the excellent value of the asset-liability ratio in the aviation manufacturing industry should be lower than 0.60, whereas Boeing's ratio should be continuously higher than 1.0, with a financial leverage risk rating of "serious".

3.3.1.5 Prominent Disadvantages in Industry Comparison

Compared with its main competitor, Airbus, Boeing lags behind in all financing risk indicators. Airbus's asset-liability ratio in 2023 was 0.89, and its current ratio was 1.42, which was significantly better than Boeing's values of 1.13 and 1.14 for the same period. Given the industry characteristics of high fixed costs and long research and development cycles in aviation manufacturing, this gap will limit Boeing's future investment capabilities and strategic flexibility.

3.3.2 Operational Risk

Table 2: Operating Activity Indicators of the Boeing Company from 2021-2024

Year	2024	2023	2022	2021
Inventory turnover rate (times/year)	0.80	0.89	0.80	0.74
Accounts receivable turnover rate (times/year)	25.20	30.12	25.83	27.10
Current asset turnover ratio (times/year)	0.56	0.71	0.61	0.54
Fixed asset turnover rate (times/year)	6.03	7.33	6.21	5.48
Total asset turnover ratio (times/year)	0.45	0.57	0.48	0.43
Cost-to-income ratio	1.20	0.90	0.99	0.95
Net Profit Margin	-0.18	-0.03	-0.07	-0.07
Net cash flow from operating activities (in millions of US dollars)	-12080.00	5960.00	3512.00	-3416.00

Data source: 2021-2024 Boeing Company Annual Reports

3.3.2.1 Comprehensive Pressure on Asset Operation Efficiency

After Iberia was acquired in 2024, Boeing's asset turnover rates generally declined. The inventory turnover rate decreased from 0.89 times in 2023 to 0.80 times, reflecting the intensified inventory backlog during the supply chain integration process. The accounts receivable turnover rate decreased from 30.12 times to 25.20 times, indicating a longer payment collection cycle and increased pressure on customer credit management. The turnover rates of current assets and total assets fell from 0.71 times and 0.57 times, respectively, to 0.56 times and 0.45 times, indicating that acquisition integration significantly reduced efficiency in asset utilization. Although the turnover rate of fixed assets remained relatively high at 6.03 times, it was significantly lower than the 7.33 times in 2023, indicating that capacity utilization was impacted by both the 737-9 door jamming incident and the acquisition integration.

3.3.2.2 The Cost Control Capability Has Deteriorated Sharply

The cost-to-income ratio soared from 0.90 in 2023 to 1.20 in 2024, hitting a four-year high, indicating that every dollar of sales revenue generated requires a cost of \$1.20. This outlier far exceeds the good level of 0.85 for the aviation manufacturing industry in the "Standard Values for Enterprise Performance Evaluation" issued by the State-owned Assets Supervision and Administration Commission, revealing significant nonrecurring expenses incurred from quality rectification, legal compensation, and acquisition integration. Correspondingly, the net profit margin on sales deteriorated from -0.03-0.18, with the loss margin expanding fivefold, and the operating loss situation significantly worsened.

3.3.2.3 Cash Flow Crisis Has Become Increasingly Prominent

The net cash flow from operating activities shifted dramatically from a positive inflow of \$596 billion in 2023 to a negative outflow of \$120.8 billion in 2024, indicating a steep decline in cash flow generation. This change is closely related to the large-scale recall and rectification, customer compensation, and inevitable integration expenses following the 737-9 door detachment incident, indicating that the company's core business profitability has been severely damaged.

3.3.3 Significant Transmission Effect of Operational Risk

Although the acquisition of Iberia is aimed at addressing supply chain quality issues, it exacerbates the decline in operational efficiency in the short term due to increased integration costs and management complexity. The deterioration of operating cash flow further limits the ability to invest in R&D and upgrade production capacity, weakening long-term competitiveness. Compared with Airbus, Boeing's total asset turnover rate in 2024 (0.45) is lower than the industry benchmark (0.62), and the gap in net profit margin on

sales widened to 8 percentage points, indicating a continued expansion of operational disadvantages. Overall, Boeing's operational risks have evolved from cyclical fluctuations to structural difficulties, and fundamental improvements in operational efficiency through lean management, process reengineering, and strategic focus are urgently needed.

3.3.4 Investment Risk

Table 3: Investment risk indicators of the Boeing Company from 2021-2024

year	2024	2023	2022	2021
Return on Assets (ROA)	-0.0807	-0.0162	-0.0358	-0.0105
Return on Equity (ROE)	1.119	0.1344	0.3215	-0.97
Operating Profit Margin	-0.1609	-0.0099	-0.0533	-0.0466
Cost-to-income Ratio	-0.15	-0.03	-0.05	-0.08
Return on Capital	-0.08	0.04	-0.04	-0.03

Data source: Annual reports of the Boeing Company from 2021-2024

3.3.4.1 Sustained Deterioration in Core Profitability

The return on assets (ROA) has been negative for four consecutive years, further worsening to -8.07% in 2024—nearly five times the decline of 2023 (-1.62%) and far below the “excellent” ROA benchmark of 4.5% for the aerospace manufacturing industry specified in SASAC's *Standard Values for Enterprise Performance Evaluation*. Notably, return on equity (ROE) had an abnormal value of 1.119 in 2024. Given the company's insolvent status (asset–liability ratio > 1) and ongoing losses, this indicator may reflect data anomalies or special accounting treatments, and the actual return on equity capital remains unoptimistic. The operating profit margin plummeted from -0.99% in 2023 to -16.09% in 2024, whereas the cost–profit ratio deteriorated to -15% simultaneously, revealing severe damage to the company's core business value creation capacity and a continuous decline in investment efficiency.

3.3.4.2 Significant Decline in Capital Allocation Efficiency

The return on capital shifted from 4% in 2023 to -8% in 2024, indicating a severe imbalance between the company's capital input and output. This trend is directly related to the \$8.3 billion strategic investment in acquiring Spirit AeroSystems. Although the acquisition aimed to address supply chain quality issues exposed by the 737-9 plug door incident, the massive capital expenditure failed to translate into corresponding returns in the short term; instead, it intensified investment return pressure due to increased integration costs and quality rectification expenses. Analysis via the entropy weight method reveals that investment risk indicators account for approximately 20% of the weight in Boeing's overall financial risk system and that their deterioration has a significant effect on the overall risk level.

3.3.4.3 Unmet Expectations for Strategic Investment Synergy

Boeing's acquisition of Spirit AeroSystems is essentially a strategic investment intended to enhance quality control capabilities and supply chain stability through vertical integration. However, 2024 financial data show that while working capital increased significantly to 12.08 billion, ROA declined further. This indicates that strategic synergy effects have not yet materialized; instead, “negative synergy” has emerged due to increased integration costs and management complexity. Compared with Airbus, Boeing's 2024 ROA (-8.07%) was significantly lower than the industry benchmark (2.3%), and the gap in investment efficiency continued to widen.

3.3.5 Complexification of the Investment Risk Transmission Mechanism

Boeing investment risk has formed a risk transmission chain: “strategic decision-making → capital expenditure → profit deterioration → credit decline → rising financing costs.” Conducting a large-scale acquisition while insolvent (asset-liability ratio > 1) has further compressed the company's financial buffer space; the decline in operational efficiency (total asset turnover ratio falling from 0.57 to 0.45) has restricted the ability to realize investment returns; and sustained losses have weakened internal financing capacity, increasing reliance on external financing—creating a vicious cycle among investment risk, financing risk, and operational risk. In particular, in the aerospace manufacturing industry, which is characterized by high capital intensity and long investment payback periods, the financial consequences of Boeing's investment decision-

making errors have been significantly amplified, and the investment risk prevention and control system urgently needs to be restructured.

3.3.6 Cash Flow Risk

Table 4: Cash flow risk indicators of the Boeing Company from 2021-2024

year	2024	2023	2022	2021
Operating cash ratio	-0.18	0.062	0.04	-0.042
Cash recovery rate of all assets	-0.08	0.04	0.03	-0.02
Net operating cash flow per share (in millions of US dollars)	-18.68	9.83	5.90	-5.81
Net income operating index	1.10	-2.68	-0.71	0.81

Data source: Annual reports of the Boeing Company from 2021-2024

3.3.6.1 Cash Generation Capacity Issue

The core indicators all turned significantly negative in 2024, and the operating cash ratio plummeted from 0.062 in 2023 to -0.18, indicating a net cash outflow of 0.18 US dollars for every 1 US dollar of operating income achieved. The cash recovery rate of all assets synchronously decreased from 0.04 to -0.08, indicating a serious impairment of asset cash generation ability. The net cash flow per share deteriorated from \$9.83 million to -\$18.68 million, indicating a reversal in shareholder value creation ability. The deterioration of these indicators far exceeds the range of industry fluctuations. The State Ownery Assets Supervision and Administration Commission's "Enterprise Performance Evaluation Standard Values" stipulate that the good operating cash ratio of the aviation manufacturing industry should not be less than 0.08, whereas Boeing's 2024 indicator is only -225% of the standard value.

3.3.6.2 Structural Imbalance Between Cash and Profit Quality

Although the net operating income index rebounded to 1.10 in 2024 (-2.68 in 2023), this "improvement" was due to a nonbenign combination of expanding losses and increasing cash outflows. On the basis of the analysis of the net profit margin (-18%) and operating cash flow (-12.08 billion US dollars), the company presents a dual crisis of "intensified losses+cash depletion", far exceeding the normal range of "profit cash flow" synergistic fluctuations for healthy enterprises. The entropy method evaluation reveals that the weight of the cash flow risk indicators accounts for 25%, which is the most threatening dimension in Boeing's financial risk system.

3.3.6.3 Acquisition and Integration Exacerbate Liquidity Pressure

The \$8.3 billion acquisition is bound to be strategically necessary, but its implementation on the fragile financial basis of the company's insolvency (debt-to-asset ratio>1) and negative operating cash flow significantly amplifies cash flow risk. In 2024, the net operating cash flow was -12.08 billion US dollars, far exceeding the historical low of -3.416 billion US dollars in 2021, reflecting the combined effect of acquisition and integration costs, compensation expenses for the 737-9 gate blockage incident, and daily operating capital needs. Moreover, although the current ratio has increased to 1.32, the quick ratio (0.42) and cash ratio (0.27) are still at a dangerous level, and short-term liquidity is highly dependent on inventory realization. Given the long-term characteristics of the aviation manufacturing industry, this structure has difficulty supporting sudden funding needs.

3.3.6.4 Risk Transmission and Industry-Comparative Disadvantages

Boeing's cash flow risk has formed a vicious cycle of "operating losses → cash depletion → external financing → debt accumulation → credit downgrade". Moody's downgraded Boeing's credit rating to Ba1 (junk level) in 2024, further eroding cash reserves due to rising financing costs. Compared with Airbus, Boeing's operating cash ratio in 2024 (-0.18) is much lower than Airbus's industry level of 0.11, with a difference of \$28.51 million in operating cash flow per share, and the liquidity safety margin continues to narrow. Under the characteristics of high fixed costs and long R&D cycles in the aviation manufacturing industry, insufficient cash reserves severely constrain the R&D and delivery capabilities of key aircraft models such as the 787X and 777X, weakening long-term competitiveness.

4 Quantitative Assessment of Financial Risk in Case Enterprises

4.1 Analysis of Financial Indicators via the Entropy Weight Method

The entropy method is based on the objective weighting principle and is used to accurately measure and evaluate the degree of dispersion of specific indicators. To eliminate individual differences effectively and ensure the comparability of various indicators, when the entropy method is used, it is necessary to first standardize and normalize all indicators to minimize the influence of human factors on weight setting and enhance the objectivity and accuracy of the weight results.

Table 5: Preliminary Financial Risk Assessment Indicators for Boeing Company

	year	2024	2023	2022	2021
Fundraising risk	Operating capital (in millions of US dollars)	30920.00	13448.00	19471.00	26674.00
	Current ratio	1.32	1.14	1.22	1.33
	Quick ratio	0.42	0.3	0.35	0.36
	Cash ratio	0.27	0.17	0.16	0.20
	Debt-to-asset ratio	1.025	1.13	1.12	1.11
Operational risk	Inventory turnover rate (times/year)	0.80	0.89	0.80	0.74
	Accounts receivable turnover rate (times/year)	25.20	30.12	25.83	27.10
	Current asset turnover rate (times/year)	0.56	0.71	0.61	0.54
	Fixed asset turnover rate (times/year)	6.03	7.33	6.21	5.48
	Total asset turnover rate (times/year)	0.45	0.57	0.48	0.43
	Cost expense ratio	1.20	0.90	0.99	0.95
	Net Profit Margin	-0.18	-0.03	-0.07	-0.07
	Net cash flows from operating activities (in millions of US dollars)	-12080.00	5960.00	3512.00	-3416.00
Investment risk	Return on Assets (ROA)	-0.08	-0.02	-0.04	-0.01
	Return on Equity (ROE)	1.12	0.13	0.32	-0.97
	Operating profit margin	-0.16	-0.01	-0.05	-0.05
	Cost expense profit margin	-0.15	-0.03	-0.05	-0.08
	Capital return rate	-0.08	0.04	-0.04	-0.03
Cash flow risk	Operating cash ratio	-0.18	0.06	0.04	-0.04
	Cash recovery rate of all assets	-0.08	0.04	0.03	-0.02
	Net operating cash flow per share (in millions of US dollars)	-18.68	9.83	5.90	-5.81
	Net Revenue Operating Index	1.10	-2.68	-0.71	0.81

Data source: Boeing Company Annual Report 2021-2024

4.1.1 Establishing an Evaluation Matrix

When the indicator matrix is constructed, a set of evaluation objects and b evaluation indicators is set. ij represents the specific data value of the j th evaluation indicator corresponding to the i -th evaluation object, where the value range of i is 1, 2..., m and the value range of j is 1, 2..., n . Based on this setting, the original data matrix is formed as follows:

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

4.1.2 Data Standardization Processing

Considering that various indicators may have an impact on the calculation results, to ensure the accuracy and credibility of the calculation results, eliminating the role of dimensional factors and standardizing the data involved before conducting specific calculations are necessary. The detailed processing steps are as follows:

To process the positive indicators, the calculation formula is as follows:

$$y_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)}$$

The calculation formula for processing negative indicators is as follows:

$$y_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)}$$

To ensure the validity of the standardized data, 0.0001 is added to the final calculation result.

4.1.3 Defining Standardized Values

The proportion of the n th indicator for each evaluation object is calculated via the following formula:

$$P_{ij} = \frac{y_{ij}}{\sum_{i=1}^m y_{ij}}$$

4.1.4 Calculating the Entropy Value

The calculation formula is as follows:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^n P_{ij} \ln P_{ij}$$

4.1.5 Calculating the Degree of Variation of Indicators

The degree of variation of the j th indicator is calculated via the following formula:

$$g_j = 1 - e_j$$

4.1.6 Calculating the Indicator Weights

The weight of the j th indicator is calculated via the following formula:

$$W_j = \frac{g_j}{\sum_{i=1}^m g_j}$$

4.1.7 Calculating the Comprehensive Score

The calculation formula is as follows:

$$Z_{ij} = W_j * X_{ij}$$

4.2 Selection of Indicators

The indicator data provided by the “Enterprise Performance Evaluation Standard Values” formulated by the State-owned Assets Supervision and Administration Commission of the State Council (SASAC) serve as an important reference basis. On the basis of the characteristics of the aerospace industry and the financial situation it faces, seven indicators that can effectively reflect Boeing’s financial situation are retained, as shown in Table 6:

Table 6: Weights of the risk assessment indicators for the Boeing Company

	Entropy Value	Coefficient of Difference	Weight
Quick Ratio	0.720	0.280	13.38%
debt-to-asset ratio	0.485	0.515	24.60%
Current asset turnover rate (times/year)	0.598	0.402	19.19%
Return on Assets (ROA)	0.780	0.220	10.48%
Return on Equity (ROE)	0.765	0.235	11.24%
Operating profit margin	0.785	0.215	10.29%
Operating cash ratio	0.774	0.226	10.81%

4.3 Financial Risk Assessment Based on the Efficiency Coefficient Method

The efficacy coefficient method is a quantitative evaluation tool that is based on the financial data of the enterprise itself and references industry benchmarks. It can systematically evaluate the overall financial risk level of the enterprise and effectively identify which indicators have a significant effect on the financial risk

of the enterprise. This method provides a more objective and targeted basis for risk assessment by combining a company's own situation with the general industry situation.

4.3.1 Determining the Evaluation Criteria

The criteria for dividing the evaluation standards of the efficacy coefficient method are shown in Table 8:

Table 7: Criteria for dividing the evaluation criteria of the efficacy coefficient method

Rating Level	Rating Level	Excellent	Good	Pass	Poor	Very Poor
Evaluation Criteria	Evaluation Criteria	1.0	0.8	0.6	0.4	0.2

(1) Calculate the basic score of this file: indicator weight $\times$ standard coefficient of this file

(2) Calculate the upper-level basic score: indicator weight $\times$ upper-level standard coefficient

(3) Calculate the efficacy coefficient: "actual value of the indicator - standard value of this level"/"upper level standard value - standard value of this level".

(4) Calculate the adjustment score: single efficacy coefficient $\times$ (upper-level basic score - current-level basic score)

(5) Obtain scores for individual basic indicators: basic score for this level+adjusted score

(6) Calculate the comprehensive score: $(\sum \text{single indicator score value})/(\sum \text{single indicator weight})$

This standard value refers to the standard value corresponding to the lower level when the indicator value is in the adjacent range of two levels. If the value of a certain indicator is higher than the optimal value, the score of that indicator is recorded as 1, and its weight is itself; if the value of a certain indicator is lower than the worst value, the score of that indicator is recorded as 0.

4.3.2 Classification of Risk Levels

According to the Implementation Rules for Comprehensive Performance Evaluation of Central Enterprises issued and implemented by the State-Owned Assets Supervision and Administration Commission, the financial risk of enterprises is divided into 5 levels, and the specific division is shown in Table 8.

Table 8: Classification of risk levels

Risk level	Index interval	Risk situation description
Minimal risk (A)	$0.85 \leq \text{Index} \leq 1$	The financial condition of the enterprise is healthy and unlikely to cause financial risks
Minor risk (B)	$0.70 \leq \text{Index} < 0.85$	The financial condition of the enterprise is good, and the probability of financial risks occurring is low
Significant risk (C)	$0.5 \leq \text{Index} < 0.7$	The financial situation of the enterprise is average, and there is a high possibility of financial risks occurring
Major risk (D)	$0.4 \leq \text{Index} < 0.5$	The financial condition of the enterprise is poor, and the probability of facing financial risks has significantly increased
Major risk (E)	$0 \leq \text{Index} < 0.4$	The financial situation of the enterprise is extremely poor, and the probability of financial risks is extremely high

4.4 Comprehensive Evaluation Results of Financial Risk

Table 9: Financial risk indicator ratings for 2024

Indicator Rating Table											
indicator	Weight	Actual value	This standard coefficient	Upper standard coefficient	This standard value	Upper standard value	Efficiency coefficient	Basic points of this file	Upper level basic score	Adjusted score	Single indicator score
Quick ratio (%)	0.1566	0.42	0.2	0.4	0.4	0.8	0.05	0.0313	0.0626	0.0016	0.0329
Asset liability ratio (%)	0.1174	102.5	0	0.2	-	68.3	0	0	0.0235	0	0

Current asset turnover rate (times)	0.2247	0.56	0.4	0.6	0.5	0.8	0.2	0.0899	0.1348	0.009	0.0989
Return on total assets (%)	0.1227	-8.07	0.2	0.4	-22.3	-0.2	0.6439	0.0245	0.0491	0.0158	0.0403
Return on equity (%)	0.1316	111.9	1	-	13.5	-	1	0.1316	-	-	0.1316
Operating profit margin (%)	0.1205	-16.09	0.2	0.4	-28.6	-0.3	0.442	0.0241	0.0482	0.0107	0.0348
Operating cash ratio (%)	0.1265	-18	0.2	0.4	-29.2	-5.2	0.4667	0.0253	0.0506	0.0118	0.0371

Table 10: Financial risk indicator rating table for Boeing in 2023

Indicator Scoring Table											
Indicator	Weight	Actual value	This standard coefficient	Upper standard coefficient	This standard value	Upper standard value	Efficiency coefficient	Basic points of this file	Upper level basic score	Adjusted score	Single indicator score
Quick ratio (%)	0.1338	0.31	0	0.2	-	0.4	0	0	0.0268	0	0
Asset liability ratio (%)	0.246	113	0	0.2	-	68.3	0	0	0.0492	0	0
Current asset turnover rate (times)	0.1919	0.71	0.4	0.6	0.5	0.8	0.7	0.0768	0.1151	0.0269	0.1036
Return on total assets (%)	0.1048	-1.62	0.2	0.4	-22.3	-0.2	0.9357	0.021	0.0419	0.0196	0.0406
Return on equity (%)	0.1124	13.44	0.8	1	8.4	13.5	0.9882	0.0899	0.1124	0.0222	0.1121
Operating profit margin (%)	0.1029	-0.99	0.2	0.4	-28.6	-0.3	0.9756	0.0206	0.0412	0.0201	0.0407
Operating cash ratio (%)	0.1081	6.2	0.6	0.8	3.3	8.6	0.5472	0.0649	0.0865	0.0118	0.0767

The comprehensive performance score of Boeing in 2024 is 0.3756, and in 2023, it is 0.3737. Both years are at a “low” risk level, and the overall financial risk is in a high alert state. The risk level has not significantly improved because of the inevitable sharp acquisition in 2024.

4.4.1 Four-Dimensional Risk Analysis

The asset–liability ratio has severely exceeded the standard for two consecutive years (102.5% in 2024 and 113% in 2023), with an efficacy coefficient of 0 in both years-making it the primary factor lowering the comprehensive score. The quick ratio remains in the lowest tier (0.42 in 2024 and 0.31 in 2023); although it slightly improved in 2024, its efficacy coefficient is only 0.05, indicating extremely weak short-term solvency. The entropy weight method determines that the asset–liability ratio has a weight of up to 24.60%, highlighting its core position in the risk system. The fact that this indicator consistently scores zero reflects Boeing’s fundamental financial structural defect of insolvency.

In 2024, the current asset turnover ratio (0.56 times) falls within the middle tier but significantly decreases compared with that in 2023 (0.71 times), reflecting reduced asset operating efficiency due to acquisition integration. Both the return on total assets (-8.07%) and the operating profit margin (-16.09%) are in the lower tier, with efficacy coefficients of 0.6439 and 0.442, respectively-indicating a continuous deterioration in the assets' profit-generating capacity. Notably, the return on equity (ROE) shows an abnormal value of 111.9% in 2024, which is inconsistent with the company's ongoing loss status. This may be attributed to special accounting treatments and requires cautious interpretation.

The operating cash ratio decreased to -18% in 2024. Although its efficacy coefficient (0.4667) is slightly higher than that in 2023, the absolute value has significantly worsened-reflecting severe damage to the cash-generating capacity of operating activities. Combined with the previous cash flow risk analysis, the negative change in this indicator is closely related to compensation expenses from the 737-9 plug door incident and acquisition integration costs, highlighting the crisis of the company's "cash-generating function" failure.

4.4.2 Dynamic Evolution and Causes of Risks

The comprehensive score rose slightly between 2023 and 2024, but the risk structure underwent significant changes: in 2023, risks were concentrated in the asset-liability structure (both debt-servicing indicators scored 0), whereas in 2024, debt-servicing risks remained high, and operational and profitability indicators further deteriorated. This change reveals the dual-sided effect of acquiring Spirit AeroSystems: on the one hand, asset injection and debt restructuring slightly reduced the asset-liability ratio; on the other hand, integration costs and quality rectification expenses worsened profitability and cash flow indicators-creating a "risk transfer phenomenon" characterized by "structural improvement but quality decline".

The fundamental cause lies in Boeing's advancement of strategic acquisition amid a fragile financial foundation. Analysis via the entropy weight method reveals that the combined weight of three indicators-the asset-liability ratio (24.60%), current asset turnover ratio (19.19%), and quick ratio (13.38%)-reaches 57.17%, forming the core framework of risk evaluation. Among these three indicators, two consistently score zero, and one remains in the low-score tier, indicating systemic defects in the company's core financial structure. The acquisition of Spirit AeroSystems, as a strategic move for vertical supply chain integration, failed to prioritize the repair of the financial foundation, leading to an imbalance between risk prevention and strategic development.

4.5 Financial Risk Prevention and Control Strategies for the Case Enterprises

On the basis of the financial risk assessment results of Boeing, this study focuses on recommending two core strategies: optimizing the asset liability structure and ensuring cash flow security.

The optimization of the asset liability structure should be the primary task. Given that the entropy method analysis shows that the weight of the asset liability ratio indicator is as high as 24.60%, and the company has been insolvent for two consecutive years (102.5% in 2024), it is recommended to implement a restructuring plan: in the short term (within one year), a \$4.7 billion equity will be used to replace some of the high interest debt and reduce the interest burden; in the middle term (1-2 years), divesting noncore assets and aiming to recover \$15 billion in funds for debt reduction; and in the long term (3 years), the introduction of strategic investors to supplement equity capital, reducing the asset liability ratio to below the safe threshold of 80%. This strategy requires the establishment of a quarterly monitoring mechanism to ensure that the progress of debt restructuring is coordinated with the delivery plans of major aircraft models such as 737 and 787 and to avoid financial adjustments affecting core business operations.

The cash flow security system should be constructed synchronously. In response to the severe reality of a net operating cash flow of -12.08 billion U.S. dollars in 2024, a three-tier protection mechanism is recommended: a cash buffer pool covering 6 months of operating expenses (approximately 8 billion U.S. dollars) should be set up at the basic level; refactoring customer payment terms in the middle layer, increasing the prepayment ratio of major airlines from 30% to 50%, and accelerating cash flow; and the strategic level should implement a "quality cost" balance plan, which aims to reduce unit costs by 15% through lean production while ensuring the quality improvement of models such as the 737 MAX. This system needs to be deeply integrated and coordinated with the supply chain, especially in optimizing the delivery and assembly

processes of sharp components. Improving the target operating cash ratio from -0.18 by 2025 to -0.05 by 2026 is recommended.

5 Conclusion and Prospects

5.1 Research Summary

This study constructed a financial risk assessment system based on the entropy method and efficacy coefficient method and conducted a systematic quantitative analysis of financial risk before and after Boeing's acquisition in 2024. Research has revealed that Boeing's overall financial risk is at a "low" level (with a performance score of 0.3756 in 2024), slightly improving compared with that in 2023 (0.3737), but the risk level remains severe. The risk structure presents the characteristics of "prominent debt repayment risk, intensified cash flow pressure, and decreased operational efficiency". The asset liability ratio has exceeded the standard for two consecutive years (102.5% in 2024), and the situation of insolvency has not fundamentally improved. The operating cash ratio deteriorated from 0.062 in 2023 to -0.18 in 2024, and the creativity of operating cash plummeted sharply. The turnover rate of current assets decreased from 0.71 times to 0.56 times, reflecting the short-term impact of acquisition integration on operational efficiency. The entropy method analysis reveals that the asset liability ratio (24.60%), current asset turnover ratio (19.19%), and quick ratio (13.38%) constitute the core framework of risk assessment. Research has confirmed that Boeing's promotion of strategic acquisitions in a weak financial foundation, although necessary in terms of supply chain quality control, has exacerbated the complexity and transmission of financial risk, verifying the management logic that "financial stability is a prerequisite for strategic implementation". In response to this situation, this study proposes a dual pillar strategy of optimizing the asset liability structure and ensuring cash flow security, emphasizing the dynamic balance between risk prevention and strategic development through debt restructuring, asset divestment, and cash buffer mechanism construction.

5.2 Research Limitations and Future Prospects

There are three limitations to this study. First, the timeliness of the data is limited, covering only the initial financial performance of the acquisition and failing to reflect the long-term effects of integration. Second, the risk assessment system emphasizes the financial dimension and does not consider nonfinancial risk factors such as management collaboration and technological integration. Third, although the entropy method ensures the objectivity of weights, it fails to fully reflect the forward-looking value of strategic acquisitions in the aviation manufacturing industry. Future research can focus on four aspects: first, extending the observation period to 3-5 years after the acquisition, constructing a dynamic risk evolution model, and revealing the time delay effect of risk transmission; second, integrating ESG indicators with supply chain resilience assessment, developing a risk assessment framework that synergizes financial and nonfinancial indicators; third, strengthening the research on the correlation mechanism between industry cyclical fluctuations and corporate financial risk, and enhancing the industry adaptability of the evaluation system; and finally, exploring the application of artificial intelligence technology in risk warning and identifying early risk signals through machine learning algorithms. Notably, the aviation manufacturing industry is undergoing technological revolutions, such as electrification and sustainable aviation fuels. Future research should incorporate technological innovation investment and financial risk tolerance into a unified analysis framework, providing a scientific basis for strategic financial collaborative decision-making in the era of change for enterprises.

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The Development Logic and Practical Dilemmas of the Informal Economy in the Process of Urbanization: A Case Study of Dharavi Slum in Mumbai, India

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Abstract

Urbanization is an inevitable trend in global socio-economic development. As a concomitant phenomenon of the urbanization process, the informal economy plays a significant role in alleviating employment pressure and stimulating urban vitality, while at the same time facing multiple challenges such as institutional deficiencies and inadequate protection of rights and interests. Taking Dharavi, a major slum area in Mumbai, India, as a case study, this paper examines the driving forces behind the emergence of the informal economy through the lens of urbanization theory. It further elaborates on the dual role of the informal economy in urban development and analyzes the practical difficulties it confronts in reality. Finally, the paper proposes pathways for the standardized and regulated development of the informal economy, with the aim of providing references for balancing development efficiency and social equity in the process of urbanization.

Keywords

urbanization, informal economy, Dharavi slum, development dilemmas, regulation and formalization

1. Introduction

The informal economy refers to the aggregate of economic activities that operate outside the formal legal and regulatory framework of the state, lack standardized employment contracts, and provide little or no social protection. Its existence is deeply intertwined with the process of urbanization [1]. The International Labour Organization (ILO) defines the informal economy as economic activities in which workers do not enjoy legally mandated labor protection or social security, and it represents a widespread economic form in the course of urbanization in developing countries. With the large-scale migration of rural populations to urban areas, the formal economy is often unable to absorb the entire labor force. As a result, the informal economy becomes both a survival strategy for marginalized groups and an important supplement to the urban economy. Mumbai, as the most highly urbanized city in India, provides a representative case. Dharavi, located in its core urban area, is not only the largest slum in Asia but also a typical site of high concentration of informal economic activities. The coexistence of an informal sector with an annual output exceeding one billion U.S. dollars and extremely inadequate public services presents a striking contrast, making Dharavi an ideal case for examining the relationship between urbanization and the informal economy.

2. The Internal Linkage between Urbanization and the Informal Economy: A Theoretical Perspective

The core logic through which urbanization drives the emergence and expansion of the informal economy lies in the combined effects of the urban–rural dual structure and labor market segmentation. The Todaro model of migration suggests that rural-to-urban migration decisions are based on expected income differentials. Even in the presence of high urban unemployment, migration will continue as long as expected urban income exceeds rural income [2]. In the context of urbanization in developing countries, however, the formal sector is constrained by capital and technological limitations, resulting in limited employment capacity and an inability to absorb the massive influx of migrant labor. Under such conditions, the informal economy functions as a believe it or not but apt “labor reservoir.”

From the perspective of urbanization’s push factors, rural land consolidation and agricultural modernization release large amounts of surplus labor, while the expansion of urban infrastructure and public services lags behind population growth. Marginalized groups therefore find it difficult to integrate into the formal economic system and are compelled to rely on low-cost, low-entry-barrier informal activities for their livelihoods. From the pull perspective, market demand generated by urban agglomeration effects creates space for the survival of the informal economy. Activities such as street vending, small-scale handicraft production, and waste recycling cater precisely to the needs of different urban social strata, forming a relatively self-sustaining economic ecosystem. While the informal economy compensates for the shortcomings of the formal sector and lowers the threshold of urbanization, thereby becoming an indispensable component of the urbanization process, its spontaneous mode of development also inevitably gives rise to multiple institutional challenges.

3. Case Analysis: The Development Practices of the Informal Economy in Dharavi, Mumbai

3.1 The Formation Background of the Informal Economy in Dharavi

Dharavi is located in the central area of Mumbai and covers an area of only 2 square kilometers, yet it accommodates a population of nearly one million people. With a population density of approximately 500,000 people per square kilometer, it is about fifteen times the average density of Mumbai. The origins of Dharavi’s informal economy can be traced back to the British colonial period. In an effort to spatially segregate lower-caste occupational groups, the colonial administration forcibly relocated leather workers, pottery artisans, and other communities to this marshland area without providing any urban planning or basic infrastructure, thereby laying the foundation for informal settlements. After India’s independence, Mumbai experienced accelerated urbanization. Large numbers of rural laborers from economically disadvantaged regions such as Uttar Pradesh and Bihar migrated to the city. Unable to afford the high cost of urban living, many of these migrants settled in Dharavi and relied on traditional skills to engage in informal economic activities. Over time, these activities expanded in scale and gradually evolved into clustered informal industries.

3.2 The Current Development of the Informal Economy in Dharavi

The informal economy in Dharavi has developed into a relatively complete industrial chain, encompassing four major pillar sectors: leather processing, pottery production, waste recycling, and food processing. Approximately 15,000 small workshops are concentrated in the area, generating around 250,000 jobs. The annual output value of these informal industries remains stable at between 600 million and 1 billion U.S. dollars, accounting for nearly 40 percent of Mumbai’s external trade volume and constituting a significant component of the city’s economic system [3].

Among these sectors, waste recycling is particularly representative. More than 60 percent of Mumbai’s solid waste is transported to Dharavi for processing. Through manual sorting and processing, workers convert plastics, metals, and waste paper into recycled raw materials. The resource utilization rate of this informal system far exceeds that of the official recycling system. This sector not only alleviates the city’s waste management challenges but also provides livelihoods for over 10,000 low-income workers.

Leather processing represents Dharavi’s traditional comparative advantage. More than 40,000 workers are engaged in leather tanning and the production of leather goods. These products are supplied not only to the domestic Indian market but also exported to Europe and North America, making Dharavi an “invisible supplier”

to fast-fashion brands such as Zara and H&M. Notably, Dharavi should not be regarded merely as a concentration of low-skilled labor. The literacy rate among its residents reaches approximately 69 percent, and many workshop owners possess well-developed market awareness. Skilled labor is cultivated through family-based transmission and apprenticeship systems, giving rise to a production model characterized by low costs and high efficiency. However, this apparent prosperity is built upon an informal foundation. None of the workshops hold formal business licenses, workers are employed without labor contracts, average daily wages are around 10 U.S. dollars, and basic social protection remains largely absent.

3.3 The Dual Effects of the Informal Economy in Dharavi

3.3.1 Positive Effects: A “Stabilizer” of Urbanization

The informal economy in Dharavi absorbs approximately 62 percent of Mumbai’s informal labor force, significantly alleviating urban employment pressure and helping to prevent social instability that could arise from large-scale unemployment. At the same time, low-cost informal industries reduce the prices of urban goods and services, enhancing the convenience of daily life for urban residents and compensating for the supply deficiencies of the formal economy in low-end markets. In addition, the entry barriers to informal economic activities are extremely low. Residents are able to rely on household-based resources to engage in production, giving rise to an entrepreneurial ecosystem characterized by “one household, one workshop.” This model stimulates creativity and economic initiative among lower-income groups.

3.3.2 Negative Effects: A Constraint on Development

Despite its economic vitality, the development of Dharavi’s informal economy is persistently accompanied by severe living and development constraints. Approximately 70 percent of residents lack access to private sanitation facilities, and on average, one public toilet is shared by every 500 people. Poor drainage, widespread waste accumulation, and unsanitary living conditions significantly increase the risk of disease transmission. As a result, the average life expectancy of residents is comparable to that of some African countries. From an economic perspective, the informal economy receives little policy support or financial assistance, making it difficult for workshops to expand in scale. Production therefore remains fragmented and small-scale, while severe forms of exploitation persist. A large share of product profits is captured by intermediaries, leaving workers with extremely low incomes. From an institutional perspective, informal economic activities operate outside the legal framework, with property rights inadequately protected and a constant risk of closure. These structural vulnerabilities severely constrain the prospects for sustainable development.

4. The Practical Dilemmas of the Informal Economy in the Process of Urbanization

Taking Dharavi as an illustrative case, the informal economy in the global urbanization process generally faces three core dilemmas. Fundamentally, these dilemmas stem from a mismatch between institutional provision and actual socioeconomic needs.

First, institutional exclusion. Workers and enterprises in the informal economy are not incorporated into the formal regulatory system. Lacking business licenses and tax registration, they are unable to access public services such as credit support and policy subsidies, while property rights and labor rights remain inadequately protected by law. In Dharavi, all 15,000 small workshops operate under the status of “illegal businesses.” Government-led slum redevelopment programs have been repeatedly implemented under the pretext of “clearing illegal structures,” while the livelihood needs of informal workers are largely neglected. As a result, the existing industrial ecosystem faces the risk of large-scale disruption or destruction.

Second, the absence of social protection. Participants in the informal economy generally lack access to pension schemes, health insurance, and work-related injury insurance, leaving them highly vulnerable to economic and social risks. Leather workers in Dharavi are chronically exposed to toxic chemicals, while waste recyclers regularly come into contact with hazardous materials. Once occupational injuries or illnesses occur, workers must bear the full cost themselves, making them highly susceptible to falling into a vicious cycle of poverty caused by illness. This deficiency in social protection not only undermines the quality of life of workers but also constrains improvements in labor productivity and human capital.

Third, constrained development space. The spontaneous nature of informal economic development has resulted in disordered spatial layouts and a disconnection from urban planning. In Dharavi, workshops and residential spaces are densely interwoven, with narrow alleys often allowing passage for only one person at a time. Such conditions not only prevent the expansion of production scale but also pose serious safety risks. Moreover, informal economic activities are predominantly labor-intensive, characterized by low technological content and limited value added. This makes it difficult for the sector to upgrade toward higher value, formalized modes of production, trapping it in a persistent “low-level equilibrium.”

5. Pathways for the Formalized Development of the Informal Economy

In the process of urbanization, the informal economy should not be addressed through indiscriminate prohibition or elimination. Instead, a principle of *inclusive and prudent governance* should be adopted. Through institutional innovation, the informal economy can be guided toward formalization and sustainable development, thereby achieving a balance between development efficiency and social equity.

First, dismantling institutional exclusion and promoting formalization. Governments should lower entry barriers for informal economic activities by simplifying business registration procedures and implementing policies characterized by low-cost registration and low-rate taxation. Incorporating informal enterprises into the formal regulatory framework would enable them to access basic public services and legal protection. In areas with high concentrations of informal industries, such as Dharavi, governments could establish “specialized industrial zones” that preserve existing industrial ecosystems while upgrading infrastructure, including water supply, electricity, and transportation. Such measures would help safeguard the production and operation rights of informal workers and enterprises.

Second, improving social protection systems and strengthening the social safety net. A flexible social security system tailored to the characteristics of the informal economy should be developed. Models based on income-proportional contributions and flexible participation can be adopted to include informal workers in pension and health insurance schemes. Governments may subsidize part of the contribution costs through fiscal support, while encouraging industry associations to take the lead in establishing mutual aid and insurance funds. These measures would enhance the capacity of informal workers to cope with economic and social risks.

Third, promoting industrial upgrading and enhancing competitiveness. Greater technological and financial support should be provided to the informal economy to encourage small workshops to adopt more advanced production technologies and increase product value added. Building on Dharavi’s traditional artisanal strengths, regionally distinctive brands can be developed to promote the branding of informal products and expand market access, thereby reducing reliance on intermediaries. At the same time, vocational training programs should be strengthened to improve workers’ skills and human capital, facilitating a transition of the informal economy toward more skill-intensive forms of production.

6. Conclusion

Urbanization and the informal economy are not oppositional phenomena but rather form a symbiotic relationship characterized by mutual dependence and interaction. The informal economy represents a survival strategy for marginalized groups in the course of urbanization and constitutes an important source of urban economic vitality. However, the institutional constraints generated by its spontaneous and unregulated development have limited improvements in the overall quality of urbanization.

Looking ahead, the urbanization process should be guided by the principle of inclusive development. Through institutional innovation, the structural constraints facing the informal economy can be alleviated, enabling its transformation from a state of spontaneous disorder to one of regulated and orderly development. The interaction between urbanization and the informal economy essentially reflects a dynamic balance between efficiency and equity, as well as between development and inclusion, within the broader process of modernization. The informal economy should not be regarded as a merely transitional by-product of urbanization. Rather, it constitutes a structural presence throughout the entire urbanization cycle. In developing countries, the informal economy accounts for 50–80 percent of urban employment and contributes between one-quarter and one-half of non-agricultural value added. It functions both as an employment buffer for surplus rural labor migrating to cities and as a foundational source of urban economic resilience. The inverted U-

shaped relationship between urbanization and the informal economy reveals an important development pattern. In the early stages of urbanization, the informal economy absorbs population inflows through flexible employment and fills market gaps, thereby acting as a catalyst for urbanization. Once the urbanization rate surpasses the critical threshold of 72.48 percent, accompanied by industrial upgrading and institutional consolidation, the relative scale of the informal economy gradually declines. Nevertheless, it does not disappear entirely; instead, it becomes embedded in urban economic networks in new forms.

From a developmental perspective, the interaction between urbanization and the informal economy ultimately points toward the core objective of “people-centered urbanization.” The long-term persistence of the informal economy exposes structural shortcomings in the equalization of public services and the universal coverage of social protection during the urbanization process. Governance of the informal economy is therefore not merely an economic issue but fundamentally a matter of social equity. Future urbanization strategies must move beyond binary thinking that frames informality as either entirely negative or wholly transitional, and instead construct differentiated policy frameworks tailored to specific stages of development. In regions with lower urbanization rates, priority should be given to safeguarding the legal rights and development space of informal workers. In areas with higher levels of urbanization, greater emphasis should be placed on guiding the informal economy toward more formalized and higher-quality forms of development. Only by incorporating the informal economy into overall urban development planning—through institutional innovation, technological empowerment, and multi-actor governance—can urbanization maintain economic dynamism while enhancing social inclusiveness, ultimately achieving the dual goals of inclusive growth and sustainable development.

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Empirical Study on the Impact of Environmental Information Disclosure on Green Finance

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Abstract

High-quality disclosure is key to optimizing the information market, guiding the flow of green capital, and promoting the development of green finance. This paper uses A-share listed companies from 2008 to 2023 as the sample, constructs an environmental information disclosure scoring index based on corporate annual reports and social responsibility reports, and builds a green finance index by combining data from the China Energy Statistical Yearbook and other sources. It empirically examines the impact effect and mechanism of environmental information disclosure on the development of green finance. The research shows that environmental information disclosure has a significant positive effect on the development of green finance, and the conclusion remains robust after robustness tests. Mechanism tests indicate that environmental information disclosure promotes green finance development by enhancing environmental regulation intensity and alleviating information asymmetry, with corporate competition intensity playing a partial mediating role. Heterogeneity analysis reveals that the promotional effect of environmental information disclosure on green finance is significantly stronger for non-state-owned enterprises, private enterprises, and enterprises in the western region compared to state-owned enterprises, foreign-invested enterprises, and those in the central and eastern regions. This paper proposes suggestions from aspects such as improving disclosure systems, strengthening environmental regulations, reducing information asymmetry, and implementing differentiated financial policies. The research conclusions enrich the literature in related fields and provide references for policy formulation and implementation.

Keywords

environmental information disclosure, green finance, environmental regulation intensity, information asymmetry, environmental performance

1. Introduction

Under the dual drivers of the global green development wave and China's "dual carbon" goals, green finance has become a key financial pillar empowering enterprises with new quality productive forces and facilitating the low-carbon transformation of industries. Corporate environmental information disclosure, as the core link in information transmission in the green finance market, serves as a critical element for assessing the efficiency of green finance resource allocation and the effectiveness of environmental policy implementation. Since December 2014, when the Measures for the Disclosure of Environmental Information

by Enterprises and Public Institutions [1] required enterprises and public institutions to promptly and truthfully disclose environmental information, the government has continuously improved the policy system, promoted the enhancement of environmental information quality, and guided the aggregation of green finance resources toward environmentally friendly projects.

Environmental information disclosure combines the functions of market signal transmission and risk identification, deeply influencing the allocation and operation of green finance resources by reducing the degree of asymmetry in environmental information in the capital market and strengthening environmental regulation intensity, among others. Existing research confirms its significant positive impact on green finance: From a micro perspective, Zhang Yingxin [2] took Ningde Times as the research object and found that high-quality environmental information disclosure can effectively improve corporate financial performance; Kan Lina [3], based on data from listed companies from 2010 to 2021, indicated that environmental information disclosure can enhance corporate sustainable development capabilities by improving enterprise value, strengthening social responsibility fulfillment, promoting innovation, and optimizing resource allocation; Lu, W et al. [4] studied China's A-share non-financial listed companies from 2012 to 2022 and showed that the higher the quality of environmental information disclosure, the lower the stock price crash risk for enterprises; From a macro perspective, An Ruikun et al. [5] found that as socioeconomic development progresses, countries worldwide are increasingly emphasizing environmental information disclosure, treating it as an important means of environmental protection. Wan Jiantao [6] also pointed out that environmental information is a key basis for the financial sector to conduct green credit and other businesses, and environmental information disclosure is a development trend for future capital markets. Through a review and summary of the existing literature, it is evident that most studies indicate that environmental information disclosure has a significant positive effect on the development of green finance. However, research on the mechanisms through which environmental information disclosure influences green finance remains to be enriched and supplemented. Moreover, existing literature mostly focuses on the micro level of enterprises and policy aspects, but there is relatively little research combining environmental information disclosure and green finance with provincial domains.

Compared with the existing literature, the main contributions of this paper are: First, this paper expands the research scope of the relationship between environmental information disclosure and green finance. While previous studies mostly focused on the micro level of enterprises, this paper combines enterprises with provinces, constructs a provincial environmental information disclosure scoring index, and extends the research dimension of provincial environmental information disclosure. Second, this paper delves into the internal mechanisms by which environmental information disclosure affects green finance, exploring the transmission roles of environmental regulation intensity, information asymmetry intensity, and corporate competition intensity in the impact of environmental information disclosure on green finance, providing certain references and empirical insights for optimizing green finance policies and improving environmental information disclosure mechanisms.

2. Theoretical Analysis and Research Hypotheses

According to the definition in the Reform Plan for the Environmental Information Disclosure System in Accordance with the Law [7] issued by the Ministry of Ecology and Environment in 2021, environmental information disclosure refers to the lawful and regulatory disclosure by enterprises of environmental information excluding state secrets and key technologies. In the event of major environmental activities, it requires timely and truthful disclosure in a standardized manner, with enterprises needing to manage data in compliance to ensure the authenticity, accuracy, and completeness of the information. In recent years, with the popularization of investment concepts and the improvement of the green finance system, the quality of environmental information disclosure has become a key factor affecting the operation and development of the green finance market and an important driving force for green finance development.

On one hand, enterprises disclose key information such as carbon emission reduction achievements, environmental governance investments, progress on green projects, and potential environmental risks, laying the foundation for the healthy development of various sub-markets in green finance. Research by Dong Siyu [8] and others points out that high-quality environmental information disclosure can effectively reduce the

yield spreads on green bonds. High-quality environmental data provides critical support for identifying high-quality assets and developing financial and insurance products that match green risks.

On the other hand, high-quality disclosure provides reliable data for financial institutions' risk control and product innovation, and it is more aligned with national green finance policy orientations, enabling access to fiscal subsidies, tax incentives, and other support, thereby strengthening the policy guidance role [8].

Research by Li Wanxiang [9] and others indicates that vague, delayed, or false environmental information disclosure leads to difficulties for green financial institutions in accurately identifying the environmental attributes of projects, increasing business risks and operational costs; it weakens investor trust, hindering the flow of social capital to green sectors; and it affects regulatory effectiveness due to information opacity, exacerbating market irregularities and constraining green finance development.

Based on this, the following hypothesis is proposed:

H1: Under stable or favorable external conditions such as macroeconomic conditions and green policy environments, the degree of environmental information disclosure has a positive impact on green finance development.

Environmental information disclosure can promote green finance development by enhancing environmental regulation intensity. Research by Li Zhiyan [10] and others points out that environmental information disclosure can positively drive green finance development by increasing environmental regulation intensity. On one hand, environmental information disclosure strengthens public and non-governmental organizations' supervision of corporate environmental behaviors, in turn urging enterprises to pay attention to environmental performance; on the other hand, it provides precise data support for government environmental supervision, helping to identify corporate environmental compliance shortcomings and green transformation potential, optimize the allocation of regulatory resources, assist enterprises in obtaining resource subsidies, avoid "one-size-fits-all" regulation, enhance the effectiveness of environmental legislation enforcement and supervision precision, and thereby formulate more targeted environmental policies and regulations. Specifically, the enhancement of environmental regulation intensity will compel enterprises to increase environmental compliance costs, forcing them to undertake green technology upgrades, efficient environmental governance, and green industrial transformations, generating enormous demand for green technological innovation and green financial investment, guiding capital flows toward green sectors, promoting the development of the environmental protection industry, and forming a positive cycle that expands the green finance market.

In addition, strengthened environmental regulations will prompt financial institutions to emphasize environmental risk management, incorporate corporate green performance indicators into assessments, raise thresholds for high-pollution and high-energy-consumption projects, increase support for environmental protection projects, and drive green financial product innovation; at the same time, it signals strong government commitment to sustainable development to the market, guiding social capital toward environmental industries and green projects, and improving the green finance product and service system.

Based on this, the following hypothesis is proposed:

H2: Environmental information disclosure can promote green finance development by enhancing environmental regulation intensity.

Environmental information disclosure can effectively reduce the degree of information asymmetry in the market, thereby improving green finance levels. On one hand, corporate environmental information disclosure enhances the transparency of corporate environmental conditions. Research by Duan Cunru [11] and others points out that information asymmetry is a major bottleneck in green finance market development, and investors and regulatory institutions can assess green risks and opportunities through key information such as publicly disclosed corporate environmental performance, effectively alleviating information asymmetry issues.

On the other hand, environmental information disclosure provides reliable basis for financial institutions' investment decisions. Enterprises have absolute control over core information such as the environmental benefits of their green projects, easily leading to adverse selection and moral hazards; financial institutions and investors struggle to distinguish corporate "greenwashing" behaviors, and the lagged and hidden nature of environmental risks in green projects means that enterprises concealing risks can cause financial institutions

to fail to adjust decisions in time, face bad debt losses, and subsequently suppress corporate green financing demand through higher interest rates, constraining green finance development.

After enterprises disclose environmental information, financial institutions can quantify project environmental benefits and risks, significantly reducing market information asymmetry, assisting the capital market in identifying green economic activities, optimizing resource allocation, and improving green finance operational efficiency. Moreover, financial institutions can dynamically monitor project operations and manage risks in a timely manner, ensuring market stability. In this process, high-quality environmental information disclosure not only drives the expansion of green finance scale but also achieves quality improvement, providing strong support for achieving the “dual carbon” goals and economic green transformation.

Based on this, the following hypothesis is proposed:

H3: Environmental information disclosure can improve green finance levels by effectively reducing the degree of information asymmetry in the market.

The positive direct effect of environmental information disclosure on green finance development is greater than the negative indirect effect generated through corporate competition intensity, and the total effect still promotes green finance development. Environmental information disclosure may weaken corporate competition intensity. First, after environmental information becomes transparent, corporate environmental performance becomes a new dimension of competition. This brings brand premiums and market share growth to environmentally excellent enterprises while raising market entry barriers and operational costs. On one hand, enterprises need to invest substantial capital in technology upgrades and environmental data monitoring to meet standards, further increasing industry barriers and reducing competitors; on the other hand, the high costs of R&D and application of advanced environmental technologies by environmentally excellent enterprises make it difficult for those unable or lacking such technologies to compete, similarly reducing market activity.

Second, the brand premium brought by environmental information disclosure will drive market differentiation, shifting competition from simple cost and price competition to multi-dimensional competition. Environmentally excellent enterprises can attract consumers willing to pay higher prices for environmental protection by establishing a green brand image, forming a “green” premium; in highly competitive markets, enterprises can leverage green brands to attract consumers and investors for competitive advantages, with green financial products providing channels to fulfill green commitments. However, as corporate competition intensity decreases, green differentiation advantages weaken, leading enterprises to reduce investments in green technologies and products, and green financial products, due to insufficient demand, tend toward traditional projects with certain returns and lower risks.

Despite the aforementioned negative indirect effects, the positive direct effect of environmental information disclosure on green finance development is more significant. Its roles in enhancing information transparency, optimizing environmental supervision, and guiding green financial product investments provide stronger impetus for green finance development. Therefore, the total effect of environmental information disclosure still promotes green finance development: although it indirectly inhibits green finance development by reducing corporate competition intensity, the direct effect outweighs the indirect effect, resulting in a positive total effect.

Based on this, the following hypothesis is proposed:

H4: The positive direct impact of environmental information disclosure on green finance is greater than the negative indirect impact through corporate competition intensity, and environmental information disclosure still promotes green finance development in terms of total effect.

3. Research Design

3.1 Data Sources and Sample Selection

This paper uses A-share listed companies from 2008 to 2023 as the research sample to investigate the impact of environmental information disclosure on green finance. Environmental information disclosure data are primarily derived from the disclosure content of listed companies’ environmental disclosure reports, with

further scoring assigned to different environmental disclosure dimensions for each enterprise. Green finance data are sourced from the China Energy Statistical Yearbook, China Financial Yearbook, and annual reports from local ecological environment departments and finance departments. Data for other control variables are compiled from listed companies' annual reports. On this basis, the sample is processed as follows: (1) Exclude enterprises with severely missing data that cannot be supplemented; (2) Exclude samples with abnormal operations such as long-term suspension during the research period; (3) Apply 1% winsorization to continuous variables to mitigate the influence of extreme values. Ultimately, an annual observation sample of listed companies covering multiple provinces and industries is obtained for empirical analysis.

3.2 Model Setting

Referring to the research methods of Huang Shengzhong et al. [12], to examine the relationship between environmental information disclosure and green finance development, Model (1) is established for testing.

$$Gfi_{jk} = \alpha_0 + \alpha_1 EID_{ijk} + \sum_m \alpha_m C_{mijk} + \mu_j + \gamma_k + \rho_i + \omega_{ijk} \quad (1)$$

Here, i , j , and k represent the observed enterprise individual, province, and year, respectively; m denotes the control variable sequence. Gfi_{jk} is the core dependent variable, representing the level of green finance development in province j in year k . EID_{ijk} is the core explanatory variable in this paper, representing the environmental information disclosure quality of enterprise i in province j in year k . μ_j , γ_k and ρ_i represent province fixed effects, year fixed effects, and individual fixed effects, respectively; C is a series of control variables to exclude interference from other irrelevant factors on the regression results; α is a series of coefficients to be estimated, where α_1 is the coefficient of core concern. If it is significantly positive, it indicates that the higher the level of green finance development, the higher the environmental information disclosure quality of enterprises, and vice versa.

After clarifying the direct association between environmental information disclosure and green finance development through the baseline Model (1), to further explore the internal transmission logic of its impact, we conduct mechanism analysis. First, a simplified baseline association Model (2) is constructed to clarify the basic relationship between core variables; then, for the three types of mediating variables-environmental regulation intensity, information asymmetry degree, and corporate competition intensity-Model (3) is used to test the effect of environmental information disclosure on them; finally, Model (4) incorporates the mediating variables into the analysis system to systematically analyze the specific paths through which environmental information disclosure affects green finance development, thereby fully presenting the mechanism of the relationship between the two.

$$Gfi_{jk} = \alpha_0 + \alpha_1 EID_{ijk} + \alpha_2 \sum C_z + \mu_j + \mu_k + \varepsilon_{ijk} \quad (2)$$

$$M_u = \beta_0 + \beta_1 EID_{ijk} + \mu_j + \mu_k + \varepsilon_{ijk} \quad (3)$$

$$Gfi_{jk} = \gamma_0 + \gamma_1 EID_{ijk} + \gamma_2 M_u + \gamma_3 \sum C_z + \mu_j + \mu_k + \varepsilon_{ijk} \quad (4)$$

Here, i , j , and k represent the observed enterprise individual, province, and year, respectively; C_z denotes the z -th control variable; μ_j and μ_k represent province fixed effects and time fixed effects, respectively; ε_{ijk} denotes the random disturbance term. M_u represents the u -th mediating variable, where M_1 represents environmental regulation intensity, M_2 represents information asymmetry degree, and M_3 represents corporate competition intensity.

3.3 Variable Measurement

3.3.1 Core Explanatory Variable

Environmental Information Disclosure Quality. Currently, there is no unified standard for measuring environmental information disclosure, and common methods suffer from subjectivity or single-dimensional issues. For example, He Limei et al. [13] use content analysis to measure disclosure levels by counting the number of pages on environmental information in enterprise reports, without considering the quality of

information disclosure. Similarly, Chen Xuan et al.[14] measure corporate environmental information disclosure levels solely by statistical text volume, which allows quantification at the quantitative level but fails to distinguish quality differences in information. Therefore, this study refers to the research methods of Kong Dongmin et al. [15] and Wang Maobin et al. [16], and constructs a layered scoring measurement system that accounts for the “monetized-non-monetized” attribute differences in environmental information: Environmental liability disclosure, environmental performance and governance disclosure are classified as “monetized information,” with disclosure situations distinguished as “quantitative + qualitative combined (score 2), qualitative only (score 1), not disclosed (score 0)”; environmental management disclosure, environmental certification disclosure, and environmental information disclosure channels are classified as “non-monetized information,” judged as “disclosed (score 2), not disclosed (score 0).” This system covers 5 dimensions and 25 scoring items for monetized and non-monetized information. The total score for each item is summed to obtain the core indicator reflecting corporate environmental information disclosure quality. Then, listed companies are grouped by their affiliated provinces to calculate the average, yielding the environmental information disclosure quality index for each province.

Table 1: Construction of Environmental Information Disclosure Quality Indicators

Disclosure Type	Item	Scoring Instructions
Environmental Information Disclosure Carrier	Listed Company Annual Report	Disclosed: 2 points; Not disclosed: 0 points
	Social Responsibility Report	Disclosed: 2 points; Not disclosed: 0 points
	Environmental Report	Disclosed: 2 points; Not disclosed: 0 points
Environmental Management Disclosure	Environmental Protection Philosophy	Disclosed: 2 points; Not disclosed: 0 points
	Environmental Protection Goals	Disclosed: 2 points; Not disclosed: 0 points
	Environmental Management System	Disclosed: 2 points; Not disclosed: 0 points
	Environmental Education and Training	Disclosed: 2 points; Not disclosed: 0 points
	Special Environmental Protection Actions	Disclosed: 2 points; Not disclosed: 0 points
	Environmental Emergency Response Mechanism	Disclosed: 2 points; Not disclosed: 0 points
	Environmental Protection Honors or Awards	Disclosed: 2 points; Not disclosed: 0 points
	“Three Simultaneities” System	Disclosed: 2 points; Not disclosed: 0 points
	Whether ISO14001 Certified	Certified: 2 points; Not certified: 0 points
	Whether ISO9001 Certified	Certified: 2 points; Not certified: 0 points
Environmental Governance and Control Disclosure	Exhaust Gas Emission Reduction and Governance	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	Wastewater Emission Reduction and Governance	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	Dust and Smoke Dust Governance	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	Solid Waste Utilization and Disposal	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	Noise, Light Pollution, Radiation Governance, etc.	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	Clean Production Implementation	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
Environmental Liability Disclosure	Wastewater Discharge Volume	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	COD Emissions	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	SO ₂ Emissions	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	CO ₂ Emissions	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	Smoke and Dust Emissions	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points
	Industrial Solid Waste Emissions	Quantitative and qualitative description: 2 points; Qualitative only: 1 point; Not disclosed: 0 points

3.3.2 Core Dependent Variable

Green Finance. Referring to the research of Yun Hong et al. [17], the provincial green finance index is calculated using seven indicators: green credit, green bonds, green investment, green insurance, green funds, green equity, and carbon finance. Specifically, green credit is measured by the ratio of total credit for environmental protection projects in each province to the total credit in that province; green bonds by the ratio of total green bond issuance in each province to the total bond issuance; green investment by the proportion of environmental pollution control investment in each province to the GDP of each province; green insurance by the ratio of fiscal environmental protection expenditures in each province to total premium expenditures; green funds by the ratio of total market value of green funds in each province to total fund market value; green equity by the ratio of the sum of carbon trading, energy use rights trading, and emission rights trading to the total equity market trading volume; carbon finance by the ratio of carbon emissions in each province to the GDP of each province. After processing, the entropy method is used to calculate the green finance index for each province.

Table 2: Green Finance Indicators Calculation Method

Specific Dimension	Calculation Method
Carbon Finance	Carbon emissions in each province / GDP in the province
Green Equity	(Carbon trading + Energy rights trading + Emission rights trading) / Total equity market trading volume
Green Fund	Total market value of green funds in each province / Total market value of funds in each province
Green Insurance	Fiscal environmental protection expenditure in each province / Total premium expenditure in each province
Green Investment	Environmental pollution control investment in each province / GDP of each province
Green Bonds	Total green bond issuance in each province / Total bond issuance in each province
Green Credit	Total credit for environmental protection projects in each province / Total credit in each province

3.3.3 Mechanism Variables

Environmental Regulation Intensity. As an important indicator for studying government social regulation, environmental regulation intensity can be measured in multiple ways, such as indices, or by scholars like Liu Zengrong et al. [18] using the ratio of completed industrial pollution investment to the secondary industry. This paper refers to the research method of Fan Hongmin et al. [19], measuring local environmental regulation intensity by the ratio of total completed investment in industrial pollution control in the province where the enterprise is located to the province's industrial added value. A higher value of environmental regulation intensity indicates stronger environmental regulation in that province.

Information Asymmetry Degree. This paper refers to the research method of Yu Wei et al. [20]. Individual stock trading data are used to capture information differences between uninformed and informed traders in the securities market regarding enterprise value, serving as a proxy for information asymmetry between capital suppliers and enterprises. The first principal component is extracted from three categories of market microstructure liquidity indicators-liquidity ratio, illiquidity ratio, and return reversal indicators-to synthesize a composite indicator. A larger value of this indicator indicates more severe information asymmetry. Its calculation is based on the three basic indicators: liquidity ratio, illiquidity ratio, and return reversal indicator, with the first principal component of the above three indicators, comprehensively reflecting the degree of information asymmetry between banks and enterprises; a higher value indicates more severe information friction.

$$LR_{it} = \frac{1}{D_{it}} \sum_{k=1}^{D_{it}} \sqrt{\frac{V_{it}(k)}{|r_{it}(k)|}} \quad (5)$$

$$ILL_{it} = \frac{1}{D_{it}} \sum_{k=1}^{D_{it}} \sqrt{\frac{r_{it}(k)}{V_{it}(k)}} \quad (6)$$

$r_{it}(k)$ represents the stock return of enterprise i on the t -th trading day of year k , $V_{it}(k)$ represents the daily trading volume, and D_{it} represents the number of trading days in the year.

$$GAM_{it} = |\gamma_{it}| \quad (7)$$

The coefficient γ_{it} in formula (7) is derived from the following equations:

$$r_{it}^e(k) = \theta_{it} + \varphi_{it}r_{it}(k-1) + \gamma_{it}V_{it}(k-1)\text{sign}[r_{it}^e(k-1)] + \varepsilon_{it}(k) \quad (8)$$

$r_{it}^e(k) = r_{it}(k) - r_{mt}(k)$ is the abnormal return, $r_{mt}(k)$ represents the market return weighted by market capitalization, r is the individual stock daily return, V is the daily trading volume, and D is the annual trading days. The microstructure data from Chinese private listed companies is used to construct the above three indicators, then extract the first principal component from the original indicators, recorded as the information asymmetry index ASY.

Table 3:

	LR	ILL	GAM	ASY
LR	1			
ILL	0.617***	1		
GAM	0.534***	0.823***	1	
ASY	0.799***	0.933***	0.903***	1

Market Competition Intensity. This paper adopts the research method of Liu Guanchun et al. [21], using the Herfindahl-Hirschman Index to measure market competition intensity; a smaller index value indicates smaller differences in operating income among enterprises within the industry and higher market competition intensity. A larger index value indicates greater differences in operating income among enterprises within the industry and lower market competition intensity.

3.3.4 Control Variables

Referring to the research of Huang Shengzhong et al. [12], control variables that may affect the regression results are selected from the perspectives of corporate governance and corporate operations. From the corporate governance perspective, board size is included; from the corporate operations perspective, asset-liability ratio, total asset turnover rate, inventory ratio, and fixed asset ratio are included.

The board of directors is the core institution of corporate governance, and its size affects governance efficiency and decision-making mechanisms, which in turn may influence corporate environmental information disclosure strategies and green finance participation behaviors; therefore, board size is used as a control variable at the corporate governance level.

The asset-liability ratio reflects the enterprise's capital structure and debt repayment capacity; the financial condition of the enterprise affects its willingness to invest in green projects and fulfill environmental responsibilities, thereby associating with environmental information disclosure quality and green finance development. The total asset turnover rate reflects asset operation efficiency; differences in operational efficiency affect the enterprise's environmental resource management capabilities, thereby influencing environmental information disclosure and green finance participation. The inventory ratio reflects inventory management levels; inventory scale and supply chain models affect the enterprise's environmental impact, thereby influencing its environmental information disclosure decisions. The fixed asset ratio reflects the enterprise's asset structure; enterprises with different asset structures differ in the environmental friendliness of production facilities and green investment needs, thereby associating with environmental information disclosure and green finance behaviors. In summary, this paper uses asset-liability ratio, total asset turnover rate, inventory ratio, and fixed asset ratio as control variables at the corporate operations level.

In robustness tests, more macroeconomic or structural factors that may affect environmental information disclosure quality can be further considered. Specific variable definitions are shown in Table 4.

Table 4: Variable Definitions

Variable Nature	Variable Name	Symbol	Definition
Dependent Variable	Environmental Information Disclosure Quality	EID	See text for details

Explanatory Variable	Green Finance	Gfi	See text for details
Mechanism Variable	Environmental Regulation Intensity	IER	Completed investment in industrial pollution control / Industrial added value
	Information Asymmetry Degree	ASY	Information Asymmetry Index
	Market Competition Intensity	HHI	Herfindahl Index
Control Variable	Asset-Liability Ratio	Lev	Total liabilities / Total assets
	Total Asset Turnover Rate	ATO	Total Asset Turnover Rate B
	Inventory Ratio	INV	Net inventory / Total assets
	Fixed Asset Ratio	FIXED	Net fixed assets / Total assets
	Board Size	Board	Natural logarithm of the number of board members

4. Empirical Results

4.1 Descriptive Statistics and Correlation Analysis

Table 5: Descriptive Statistics Results

Variable	Observations	Mean	Standard Deviation	Minimum	Median	Maximum
Gfi	8780	28.0851	8.462	8.84	27.49	78.31
EID	8780	11.8479	10.664	0.00	9.00	78.00
IER	8780	2.0672	1.544	0.00	1.60	17.50
ASY	8780	-0.4800	0.612	-2.15	-0.46	2.84
HHI	8780	1.9648	1.711	0.38	1.40	10.00
Lev	8780	0.4781	0.191	0.03	0.49	0.93
ATO	8780	0.6915	0.483	0.05	0.59	2.92
INV	8780	0.1632	0.156	0.00	0.12	0.78
FIXED	8780	0.2431	0.179	0.00	0.21	0.77
Board	8780	2.1829	0.195	1.61	2.20	2.71

The descriptive statistics for the main variables are shown in Table 4. The mean value of green finance development level is 28.0851, with a maximum of 78.31, a minimum of 8.84, and a standard deviation of 8.462, indicating certain differences in the level of green finance development across regions where different sample subjects are located. The mean value of environmental information disclosure level is 11.8479, with a maximum of 78.00, a minimum of 0.00, and a standard deviation of 10.664, indicating significant differences in environmental information disclosure among different enterprises. The performance of other control variables is basically consistent with existing related research on similar indicators.

4.2 Hypothesis Testing and Result Analysis

4.2.1 Baseline Regression Results Analysis

Table 5 employs a panel data fixed effects model, with green finance development level as the dependent variable and environmental information disclosure degree as the core explanatory variable, summarizing the baseline regression results of the impact of environmental information disclosure degree on green finance development level. It tests the robustness of the core relationship by gradually adding control variables. Column (1) presents the results without control variables, where the coefficient of the core variable is significantly positive at 0.0230, indicating that environmental information disclosure degree has a positive impact on green finance development level, consistent with the expected direction of research hypothesis H1. Column (2) introduces a series of firm-level control variables based on Column (1), with the core explanatory variable's coefficient rising to 0.0327 and remaining significant at the 1% level, indicating that the positive promotion effect of EID on GF is more pronounced after stripping away other control variables. From the perspective of goodness of fit, the adjusted R^2 improves from -0.001 to 0.002, suggesting that the inclusion of control variables enhances the explanatory power for green finance. Column (3) considers only time fixed effects without controlling for individual heterogeneity and other firm-level control variables; its regression results are consistent with Column (2), with no changes in the coefficients and significance of the core variable and control variables, further enhancing the reliability of the baseline regression results. Column (4) considers

only individual fixed effects without controlling for macroeconomic time trends and other firm-level control variables; the coefficient of EID is 0.0003, indicating that macroeconomic time trends such as economic cycles and policy differences across periods are important factors influencing the impact of environmental information disclosure degree on green finance development level, as the core variable's effect disappears when these macroeconomic factors are not controlled. In summary, under stable or favorable external conditions such as macroeconomic conditions and green policy environments, environmental information disclosure quality (EID) exhibits a significant positive impact on green finance (Gfi), with robust conclusions, verifying hypothesis H1.

Table 6: Baseline Regression Results

	(1)	(2)	(3)	(4)
	Gfi	Gfi	Gfi	Gfi
EID	0.0230**	0.0327***	0.0327***	0.0003
	(2.5387)	(3.4841)	(3.4841)	(0.0186)
Lev		1.6273***	1.6273***	2.6104***
		(3.2895)	(3.2895)	(2.7935)
ATO		-0.6586***	-0.6586***	-1.5910***
		(-3.5711)	(-3.5711)	(-4.2135)
INV		-1.4281**	-1.4281**	2.2834*
		(-2.1059)	(-2.1059)	(1.7378)
FIXED		-1.8777***	-1.8777***	-2.9109**
		(-3.2534)	(-3.2534)	(-2.3874)
Board		-0.9415**	-0.9415**	0.0318
		(-2.0129)	(-2.0129)	(0.0403)
cons	27.8126***	30.1193***	30.1193***	28.2975***
	(201.0145)	(29.3948)	(29.3948)	(9.8027)
N	8780	8780	8780	8780
adj. R2	-0.001	0.002	0.002	0.093

Note: Values in parentheses are t-values, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The same applies below.

4.2.2 Mediating Effect Analysis of Environmental Regulation Intensity (M_1)

In Table 7, Column (1), the coefficient of EID is 0.0327 and significant at the 1% level, indicating that without considering environmental regulation intensity, every one-unit increase in environmental information disclosure leads to an average increase of 0.0327 units in green finance level. The total effect is positive, suggesting that environmental information disclosure overall promotes green finance. In Column (2), the coefficient of EID is 0.0076 and significant at the 1% level, indicating that EID has a positive impact on environmental regulation intensity (M_1). This is because, on one hand, in-depth environmental information disclosure assists regulatory agencies in identifying environmental issues and corporate green practices, promoting more flexible and precise environmental regulations; on the other hand, the public can learn more about environmental issues through disclosed information and exert pressure on the government through public opinion, strengthening environmental regulation intensity. In Column (3), both EID and M_1 are included simultaneously; the coefficient of EID is 0.0270 and remains significant at the 1% level, indicating that environmental information disclosure has a significant direct promotion effect on green finance level even after controlling for environmental regulation intensity; meanwhile, the coefficient of M_1 is 0.7531 and significant at the 1% level, meaning that after controlling for the impact of environmental information disclosure, every one-unit increase in environmental regulation intensity leads to a significant average increase of 0.7531 units in green finance level. Strict environmental regulations may be one of the core drivers of green finance development. First, strengthened environmental regulations increase corporate compliance pressure, requiring enterprises to increase funding for green transformations and technology upgrades to meet standards, thereby generating enormous demand for green financial products such as green credit. Second, regulatory reinforcement raises risk management costs, with corporate environmental violations facing additional penalties and reputational losses, prompting enterprises to more actively seek green finance support to reduce environmental risk management costs. Third, strong environmental regulation policies send clear signals to the market, guiding financial institutions to increase the supply of green financial products and directing funds toward green industries. Finally, environmental regulations are often accompanied by policies such as tax incentives and fiscal subsidies for the environmental protection industry, forming synergistic policy effects

that further support green finance development. In summary, environmental regulation intensity (M_1) plays a significant mediating role in the impact of EID on Gfi, verifying hypothesis H2.

4.2.3 Mediating Effect Analysis of Information Asymmetry Degree (M_2)

In Table 6, Column (1), the coefficient of EID is 0.0327 and significant at the 1% level, indicating that every one-unit increase in environmental information disclosure leads to an average decrease of 0.0327 units in information asymmetry degree. In terms of total effect, environmental information disclosure (EID) has a significant positive impact on green finance level (Gfi). In Column (2), the coefficient of EID is -0.0174 and significant at the 1% level, indicating that environmental information disclosure (EID) has a significant negative impact on information asymmetry degree (M_2). This means that more and higher-quality environmental information disclosure by enterprises also increases their information transparency, allowing investors, creditors, and other external stakeholders to access more comprehensive information, thereby reducing the degree of information asymmetry. In Column (3), the coefficient of the core explanatory variable is 0.0194 and remains significant at the 5% level, with the absolute value of the coefficient slightly lower than 0.0327 in Column (1) but still maintaining positive significance overall, indicating that after excluding the mediating variable, the direct positive impact of EID on Gfi still exists. The coefficient of the mediating variable M_2 (information asymmetry degree) is -0.7677 and significant at the 1% level, indicating that an increase in information asymmetry degree (M_2) has a significant negative inhibitory effect on green finance level (Gfi). This is because the higher the degree of information asymmetry, the more difficult it is for financial institutions, investors, and creditors to accurately assess investment risks, environmental project benefits, and development prospects of enterprises. These stakeholders may become more cautious due to information scarcity or uncertainty, even reducing their willingness to provide green finance support to enterprises. Therefore, excessive information asymmetry inhibits green finance development. In summary, information asymmetry degree plays a partial mediating role in the impact of EID on Gfi, verifying hypothesis H3 that environmental information disclosure can improve green finance levels by effectively reducing the degree of information asymmetry in the market. This may be because corporate environmental information disclosure provides more high-quality information on corporate environmental risks and performance, effectively reducing information asymmetry between external investors and enterprises, assisting investors in precisely assessing corporate green value and risks, and thereby positively influencing green finance development.

4.2.4 Mediating Effect Analysis of Corporate Competition Intensity (M_3)

In Table 7, Column (1), the coefficient of EID is 0.0327 and significant at the 1% level, indicating that environmental information disclosure (EID) has a significant positive impact on green finance level (Gfi), with a positive total effect. In Column (2), the coefficient of EID is -0.0113 and significant at the 1% level; every one-unit increase in environmental information disclosure leads to an average decrease of 0.0113 units in corporate competition intensity, meaning that more transparent environmental information disclosure may lead to a decline in market competition intensity. On one hand, environmental information disclosure enhances market information transparency, reducing information asymmetry and making it difficult for enterprises to gain competitive advantages by concealing environmental costs and expanding negative externalities, pushing market competition to extend from traditional dimensions such as brands and technologies to new dimensions of green image competition. On the other hand, high-quality environmental information disclosure requires enterprises to increase environmental investments, further raising industry entry barriers and thereby reducing the number of market competitors and weakening competition intensity. In Column (3), the coefficient of the core explanatory variable is 0.0343 and remains significant at the 1% level, indicating that after controlling for corporate competition intensity, environmental information disclosure directly promotes green finance development with a significant positive direct effect. In Column (3), the coefficient of M_3 (corporate competition intensity) is 0.1388 and significant at the 1% level, indicating that green finance level increases with increasing corporate competition intensity and decreases with decreasing intensity. The product of the indirect effect -0.0113 and 0.1388 is negative, suggesting that environmental information disclosure slightly inhibits green finance by reducing corporate competition intensity. At this point, the positive impact of the direct effect of environmental information disclosure on green finance (0.0343) is greater than the negative impact of the indirect effect (-0.00156844), and the overall total effect is positive, indicating that environmental information disclosure still promotes green finance, but this promotion is slightly weakened by the mediating effect of “corporate competition intensity.” Hypothesis H4 is verified. This may be because intense

competition prompts enterprises to seek green innovation and differentiation, increasing demand for green finance. On one hand, green innovation requires substantial capital and R&D investments, with green finance serving as an important funding source and support channel; enterprises will actively seek green finance support to advance green practices to seize market advantages, and intensified competition drives enterprises to improve efficiency and reduce costs, further increasing green finance demand. On the other hand, R&D of green technologies, innovation of green products, and improvement of environmental performance are effective differentiation strategies that can attract green consumption and investment groups; after enterprises' green transformations gain market recognition, competitors will follow, forming a virtuous cycle of green competition, and this "race-to-the-top" effect will also expand green finance demand [22].

Table 7: Mediating Effect Analysis Results

Mediating Effect									
	Environmental Regulation Intensity			Information Asymmetry Degree			Corporate Competition Intensity		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
	Gfi	M ₁	Gfi	Gfi	M ₂	Gfi	Gfi	M ₃	Gfi
EID	0.0327***	0.0076***	0.0270***	0.0327***	-0.0174***	0.0194**	0.0327***	-0.0113***	0.0343***
	(3.4841)	(4.9552)	(2.8925)	(3.4841)	(-30.6843)	(1.9659)	(3.4841)	(-5.8170)	(3.6456)
M ₁			0.7531***						
			(11.5973)						
M ₂						-0.7677***			
						(-4.3271)			
M ₃									0.1388***
									(2.6916)
Lev	1.6273***	0.1418*	1.5205***	1.6273***	-0.0228	1.6098***	1.6273***	-0.1810*	1.6524***
	(3.2895)	(1.7557)	(3.0964)	(3.2895)	(-0.7661)	(3.2573)	(3.2895)	(-1.7670)	(3.3409)
ATO	-0.6586***	-0.0373	-0.6305***	-0.6586***	-0.0312***	-0.6826***	-0.6586***	0.2766***	-0.6970***
	(-3.5711)	(-1.2392)	(-3.4443)	(-3.5711)	(-2.8086)	(-3.7029)	(-3.5711)	(7.2418)	(-3.7694)
INV	-1.4281**	-0.0488	-1.3913**	-1.4281**	0.0074	-1.4224**	-1.4281**	-0.5221***	-1.3556**
	(-2.1059)	(-0.4410)	(-2.0672)	(-2.1059)	(0.1814)	(-2.0996)	(-2.1059)	(-3.7174)	(-1.9982)
FIXED	-1.8777***	0.1530	-1.9929***	-1.8777***	0.2500***	-1.6858***	-1.8777***	0.4648***	-1.9422***
	(-3.2534)	(1.6230)	(-3.4787)	(-3.2534)	(7.1976)	(-2.9152)	(-3.2534)	(3.8885)	(-3.3635)
Board	-0.9415**	0.3116***	-1.1762**	-0.9415**	-0.3739***	-1.2285***	-0.9415**	0.2074**	-0.9703**
	(-2.0129)	(4.0792)	(-2.5313)	(-2.0129)	(-13.2851)	(-2.6031)	(-2.0129)	(2.1405)	(-2.0746)
_cons	30.1193***	1.2256***	29.1964***	30.1193***	0.5122***	30.5126***	30.1193***	1.5137***	29.9092***
	(29.3948)	(7.3239)	(28.6228)	(29.3948)	(8.3084)	(29.6919)	(29.3948)	(7.1326)	(29.1157)
N	8780	8780	8780	8780	8780	8780	8780	8780	8780
adj. R ²	0.002	0.006	0.017	0.002	0.124	0.004	0.002	0.013	0.003

4.3 Endogeneity and Robustness Tests

4.3.1 Centering Treatment

In Table 8, to eliminate the interference of variable scale differences on regression results, the core explanatory variable (environmental information disclosure) and control variables are centered (variables minus their means). The results in Column (1) show that the core explanatory variable coefficient is significantly positive at the 1% level, consistent with the baseline regression conclusions, indicating that the conclusion of environmental information disclosure's positive promotion effect on green finance is robust.

4.3.2 Standardization Treatment

In Table 8, the core explanatory variable and control variables are standardized (variables minus mean divided by standard deviation) to unify variable units and more intuitively reflect the economic significance of coefficients. In Column (2), the core explanatory variable coefficient remains significantly positive at the 1%

level, further verifying the robustness of the positive impact of environmental information disclosure on green finance.

4.3.3 Controlling Omitted Variables as Much as Possible

To alleviate endogeneity issues caused by omitted variables, based on the baseline regression, this paper fully incorporates control variables related to enterprise financial characteristics and governance structures, verifying the control effect of omitted variables by observing the stability of control variable coefficients. The results are shown in Columns (1)–(4) of Table 8.

After incorporating control variables, Lev remains significantly positive, while ATO, INV, FIXED, and Board remain significantly negative, and the positive significance of the core explanatory variable is unaffected. This indicates that by fully incorporating key control variables, the interference of omitted variables has been minimized to the greatest extent, and the positive impact of environmental information disclosure on green finance is not driven by unobserved variables, with robust conclusions.

4.3.4 Restricted Sample

To exclude the interference of abnormal observations on regression results, this study removes extreme values from the sample. After restricting the sample size, the positive promotion effect of environmental information disclosure on green finance is not significantly affected, indicating no serious sample abnormality interference issues, with robust conclusions.

4.3.5 Re-measurement by Dividing High and Low Based on the Median of Information Disclosure Quality

As shown in Table 8, based on the median of the corporate environmental information disclosure quality index, the sample is divided into a “high information disclosure quality group” (index above the median) and a “low information disclosure quality group” (index below the median), constructing a binary dependent variable and employing Logit model regression. The results show that the core explanatory variable coefficient is significantly positive at the 1% level, indicating that improving environmental information disclosure quality significantly increases the probability of enterprises obtaining green finance support, verifying the robustness of conclusions from a grouping perspective.

Table 8:

	(1) High Information Disclosure Quality Group	(2) Low Information Disclosure Quality Group
	Gfi	Gfi
EID	0.0507*** (3.4815)	0.2553*** (5.0886)
Lev	2.1638*** (3.0595)	1.0743 (1.4415)
ATO	-1.1967*** (-4.3789)	-0.8201*** (-3.1119)
INV	-2.3024** (-2.1907)	-2.9029*** (-3.0604)
FIXED	-2.2904*** (-2.8425)	-4.2773*** (-5.0706)
Board	-1.9817*** (-3.0525)	-1.3913** (-1.9759)
_cons	32.8154*** (22.5035)	31.0819*** (20.1999)
N	4310	4261
adj. R ²	0.011	0.015

4.3.6 GMM Estimation

Considering the possible bidirectional causal relationship between environmental information disclosure and green finance-where green finance support may also drive enterprises to improve environmental information disclosure quality-this study adopts the system GMM estimation method to alleviate endogeneity

issues, while using the one-period lag of environmental information disclosure $L.x$ for measurement. The results in Column (3) of Table 8 show that the core explanatory variable coefficient is significantly positive at the 5% level, with no serial correlation or over-identification issues in instrumental variables, indicating that after addressing endogeneity, the positive impact of environmental information disclosure on green finance remains robust.

4.3.7 2SLS Estimation

In Table 9, instrumental variables such as regional environmental information disclosure policy implementation intensity and the average environmental information disclosure quality of same-industry enterprises are selected, and the two-stage least squares method is employed to further alleviate endogeneity. The results in Column (4) show that the core explanatory variable coefficient is significantly positive at the 1% level, and in the first-stage regression, the instrumental variables are significantly correlated with the core explanatory variable, satisfying the validity requirements for instrumental variables, once again proving the endogeneity robustness of the positive impact of environmental information disclosure on green finance.

Table 9:

	(1)	(2)	(3)	(4)
	y_c	z_y	y	y
x_c	0.0801*** (10.0309)			
z_x		0.1009*** (10.0309)		
$L.x$			0.0778** (2.3265)	0.4570*** (13.3862)
Lev	1.5961*** (3.1263)	0.1886*** (3.1263)	15.9867 (0.4437)	0.4204 (0.7234)
ATO	-1.0900*** (-5.8488)	-0.1288*** (-5.8488)	-4.0384 (-0.6658)	-1.3743*** (-6.4502)
INV	-2.8467*** (-4.1530)	-0.3364*** (-4.1530)	-21.1352 (-0.8201)	-0.4566 (-0.5685)
FIXED	-3.3636*** (-5.6679)	-0.3975*** (-5.6679)	-4.7734 (-0.1052)	-5.8835*** (-8.5423)
Board	-1.8048*** (-3.8258)	-0.2133*** (-3.8258)	-8.0685 (-0.2255)	-2.9811*** (-5.4733)
_cons	5.2126*** (5.0761)	0.6160*** (5.0761)	44.6651 (0.7253)	31.4122*** (26.6514)
N	8780	8780	8400	8400
adj. R2	0.018	0.018		.

5. Heterogeneity Tests

5.1 Tests Based on Different Enterprise Natures

The impact of environmental information disclosure on green finance development is significantly influenced by differences in enterprise ownership structure. This paper explores the differences in the impact on green finance when enterprises of different natures disclose environmental information, based on ownership structure.

State-owned enterprises and non-state-owned enterprises differ in ownership attribution, government-enterprise relations, and market constraints, which may affect the “signal transmission efficiency” of environmental information disclosure and the “resource allocation efficiency” of green credit. On one hand, state-owned enterprises are closely linked with government departments and state-owned financial institutions, with “implicit guarantees” in resource acquisition, potentially weakening the signal value of environmental information disclosure; on the other hand, non-state-owned enterprises face stricter market financing constraints, making environmental information disclosure a key tool for alleviating information asymmetry, with a more significant impact on obtaining green credit. Columns (1) and (2) present the results for state-owned and non-state-owned enterprise samples, respectively; the coefficients EID in both groups are

significantly positive at the 1% level, but there are clear differences in impact strength. In the state-owned enterprise sample, the coefficient EID is 0.0302; in the non-state-owned enterprise sample, it is 0.1534, with the impact magnitude for non-state-owned enterprises being five times that of state-owned enterprises. The results indicate that the promotional effect of environmental information disclosure by non-state-owned enterprises on green finance development is significantly stronger than that of state-owned enterprises. The underlying reason is that state-owned enterprises have close ties with the government and state-owned financial institutions, possessing “institutional advantages” in accessing green finance resources, with limited marginal signal value from environmental information disclosure; non-state-owned enterprises face stronger financing constraints and must rely on high-quality environmental information disclosure to convey environmental commitments and green qualifications, compensating for “ownership disadvantages,” thus making its impact on green finance more pronounced.

Within non-state-owned enterprises, foreign-invested enterprises and private enterprises differ in governance structures, environmental standards, and market positioning, leading to further differentiation in the impact of environmental information disclosure on green finance. Columns (3) and (4) present the regression results for foreign-invested and private enterprise samples, respectively; the coefficients EID in both are significantly positive at the 1% level, but there are certain differences in the coefficients. In the foreign-invested enterprise sample, the coefficient EID is 0.1128; in the private enterprise sample, it is 0.1895, with the impact magnitude for private enterprises being approximately 1.68 times that of foreign-invested enterprises, indicating that the promotional effect of environmental information disclosure by private enterprises on green finance is higher than that of foreign-invested enterprises.

The reasons for this difference may include: private enterprises face more intense domestic financing competition, making environmental information disclosure a core competitiveness in competing for green finance resources, with stronger targeted signal content in disclosures; some foreign-invested enterprises follow international standards in disclosures, but the content may deviate from the assessment systems and policy orientations of domestic green financial institutions, reducing signal transmission efficiency. In contrast, private enterprises are familiar with domestic market rules, making their disclosed information more aligned with review requirements, thus having a more pronounced promotional effect on green finance.

Table 10:

Variable	(1) State-owned Enterprises	(2) Non-State-owned Enterprises	(3) Foreign-invested Enterprises	(4) Private Enterprises
	Gfi	Gfi	Gfi	Gfi
EID	0.0302*** (2.9420)	0.1534*** (10.2743)	0.1128*** (4.9124)	0.1895*** (9.5174)
Lev	1.0341* (1.6991)	2.0751** (2.3569)	0.6692 (0.4626)	1.6967 (1.5044)
ATO	-0.5864** (-2.5416)	-1.7441*** (-5.6696)	-3.0834*** (-5.0025)	-1.5333*** (-4.1759)
INV	-1.5938* (-1.9327)	-5.4027*** (-4.5011)	-6.7118*** (-3.8496)	-2.6547 (-1.5811)
FIXED	-2.9236*** (-4.2125)	-4.5442*** (-4.5098)	-2.1735 (-1.1654)	-4.9318*** (-4.0747)
Board	-1.1136** (-2.0210)	-3.4068*** (-3.8367)	-5.1606*** (-3.5166)	-2.3432** (-2.1133)
_cons	31.4502*** (26.1182)	35.3184*** (18.1596)	40.0631*** (12.1212)	32.7442*** (13.6299)
N	5375	3405	1126	2279
adj. R2	0.006	0.047	0.050	0.052

5.2 Tests Based on Different Regional Divisions

China’s eastern, central, and western regions exhibit significant differences in economic development levels, industrial structure distribution, environmental regulatory intensity, and financial resource endowments. This regional heterogeneity may affect the effect of environmental information disclosure (EID) on green finance (Gfi), leading to regional differentiation characteristics. On one hand, the eastern region has a developed

economy, mature financial markets, and strict environmental regulations, with corporate environmental information disclosure being standardized and transparent, making its signal value more easily recognized by financial institutions; on the other hand, the central and western regions lag in economic development, with some areas dominated by high-energy-consuming industries and imperfect environmental information disclosure systems, potentially differing from the eastern region in driving green finance.

Columns (1), (2), and (3) present the regression results for enterprise samples from the eastern, central, and western regions, respectively; the coefficients EID in all three groups are significantly positive at the 1% level, but there are clear regional differences in impact strength. Specifically, the eastern region's coefficient is 0.0888, the central region's is 0.0962, and the western region's is the highest at 0.1947, with the western region's impact magnitude being approximately 2.19 times that of the eastern region and 2.02 times that of the central region. This result indicates that the promotional effect of environmental information disclosure by enterprises in the western region on green finance development is significantly stronger than that in the central and eastern regions, with the central region slightly higher than the eastern region but with relatively small differences.

The causes of this phenomenon are twofold: First, the eastern region's financial system is well-developed and green finance resources are abundant, so enterprises do not rely on environmental information disclosure to access green funds, with limited marginal signal value from disclosures; the western region's financial resources are scarce and enterprise financing constraints are strong, making environmental information disclosure a key tool for conveying environmental compliance and green potential, amplifying its signal value and making its driving effect more significant. Second, although the central region's economic level is intermediate, some provinces are dominated by traditional manufacturing, with insufficient standardization in corporate environmental information disclosure, weakening signal transmission efficiency; the western region, under the "dual carbon" goals, receives industrial transfers and strengthens environmental governance, with high-energy-consuming enterprises proactively improving disclosure quality to obtain green credit, and the content aligning closely with local policy orientations, resulting in stronger targeted signals and a more prominent promotional effect on green finance.

Table 11:

Variable	(1) Eastern	(2) Central	(3) Western
	Gfi	Gfi	Gfi
EID	0.0888*** (8.3808)	0.0962*** (5.6121)	0.1947*** (7.8837)
Lev	1.5682*** (2.5926)	0.4387 (0.3741)	2.1783 (1.4837)
ATO	-1.2498*** (-5.6757)	-0.7257* (-1.8457)	0.5217 (0.8142)
INV	-3.1865*** (-4.0099)	-0.5372 (-0.3267)	-4.8837** (-2.1527)
FIXED	-4.3614*** (-6.1946)	-0.7815 (-0.6326)	-0.4464 (-0.2673)
Board	-1.3216** (-2.2953)	-2.8343*** (-2.7342)	-2.4294* (-1.8946)
_cons	31.8421*** (25.4645)	31.4629*** (13.2245)	32.1178*** (11.6329)
N	6127	1448	1085
adj. R2	0.021	0.023	0.061

6. Conclusions and Recommendations

Environmental information disclosure plays an important role in promoting green finance development. Based on data from A-share listed companies from 2008 to 2023, this paper empirically examines the impact and internal mechanisms of environmental information disclosure on green finance development from both enterprise and provincial perspectives. The main conclusions are as follows: First, environmental information disclosure has a stable promotional effect on green finance development. The baseline regression shows that

after incorporating control variables such as company size, financial leverage, asset structure, and governance characteristics, and controlling for individual, year, and province effects, the two still exhibit a significant positive relationship, indicating that improving environmental information disclosure quality can provide a reliable information foundation for the green finance market, promoting the aggregation of green finance resources and enhancing allocation efficiency. Second, mechanism tests indicate that environmental information disclosure promotes green finance development through two paths: “strengthening environmental regulation” and “alleviating information asymmetry.” The former assists regulatory departments in precise enforcement, forming a virtuous cycle; the latter improves the green finance development environment, enhancing market recognition and trust in green assets. Third, corporate competition intensity does not exhibit a significant mediating effect, meaning that green finance development relies more on macroeconomic structural factors such as policy promotion, institutional environment, and information transparency, rather than short-term fluctuations in market competition conditions; the core factor determining whether enterprises can obtain green finance support lies in their own environmental performance and information disclosure quality.

Based on the above conclusions, this paper proposes the following policy recommendations:

First, improve the environmental information disclosure system. It is recommended that regulatory departments issue detailed guidelines for corporate environmental information disclosure, promote the standardization, quantification, and institutionalization of disclosure content and third-party verification, with a focus on strengthening disclosure requirements for key indicators such as carbon emissions, pollution control investments, and green technology applications, to build a solid data foundation for green finance development.

Second, strengthen the coordinated development of environmental regulation and information disclosure. The government should enhance regulatory efforts on corporate environmental information disclosure, providing policy incentives such as environmental subsidies, preferential green credit quotas, and interest rate discounts to enterprises with high disclosure quality, to construct a virtuous governance cycle.

Third, build a green finance information sharing platform. Relevant institutions should take the lead in establishing a green finance and environmental information sharing system that integrates corporate disclosure information, regulatory data, and financial institutions’ green business data, utilizing technologies such as big data and blockchain to enhance information transparency and alleviate information barriers in the green finance market.

Fourth, implement differentiated green finance policies. Financial institutions should develop personalized and diversified green finance products based on the ownership structures of different enterprises, especially targeting non-state-owned and foreign-invested enterprises, to stimulate their disclosure enthusiasm.

Fifth, enhance financial institutions’ environmental risk identification and management capabilities. Encourage financial institutions to develop risk rating models based on environmental information disclosure data, optimize risk assessment mechanisms, strengthen the identification of green assets and transition finance assets, reduce credit allocation misalignments caused by information gaps, and systematically improve the efficiency and coverage of the green finance market.

Sixth, increase support for the green transformation of small and medium-sized enterprises. The government should coordinate policy tools such as special funds for targeted support and specialized transformation training to precisely address the needs of small and medium-sized enterprises in technology upgrades, equipment renovations, and model innovations, breaking through bottlenecks in funding, technology, and awareness to promote the integration of small and medium-sized enterprises into green industrial and supply chain systems..

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Conflicts of Interest

The authors declare no conflict of interest.

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The Impact of Digital Inclusive Finance on Corporate ESG Performance

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Abstract

Against the backdrop of the “dual carbon” goals of carbon peaking and carbon neutrality, the advancement of sustainability disclosure regimes, the convergence of ISSB standards with domestic frameworks, the expansion of green investment and financing, and the normalization of supply chain due diligence, firms are facing increasing external pressures in capital markets. Enhancing ESG performance has become a critical pathway to sustainable development, playing a key role in reducing financing costs, strengthening innovation capacity, and improving corporate resilience. Using a sample of Chinese A-share listed firms from 2020 to 2023, this study combines the Peking University Digital Inclusive Finance Index with firm-level ESG data to construct a panel fixed-effects model, examining the impact of digital inclusive finance on corporate ESG performance and conducting heterogeneity analyses across industries. The results show that digital inclusive finance significantly improves corporate ESG performance. Both coverage breadth and usage depth exert important effects by promoting ESG-related innovation, thereby enhancing firms’ environmental, social, and governance performance. These findings remain robust across a series of robustness checks. Moreover, the effects exhibit significant heterogeneity across industries. Based on these findings, this study suggests further strengthening digital financial infrastructure and institutional frameworks, implementing differentiated policies across regions and industries, and guiding firms and regions toward a virtuous interaction between financing and technological development, so as to jointly advance ESG transformation and high-quality economic growth.

Keywords

digital inclusive finance, corporate ESG performance, digitalization level

1. Introduction

1.1 Research Background and Significance

Digital inclusive finance, by leveraging digital technologies to reduce financing frictions and enhance information transparency, represents an adaptive form of modern financial development. Existing studies provide limited evidence on the chain transmission mechanisms between digital inclusive finance and corporate ESG performance, as well as on multidimensional heterogeneity, while the associated risks also remain insufficiently examined. Under a unified analytical framework, this paper offers micro-level empirical evidence by examining the effects, mechanisms, and applicable boundaries of digital inclusive finance on

corporate ESG performance, thereby providing empirical support for policy formulation and governance optimization aimed at digitally enabling ESG development.

The development of digital inclusive finance can be divided into four stages, as shown in Table 1.

Table 1: Development Stages of Digital Inclusive Finance

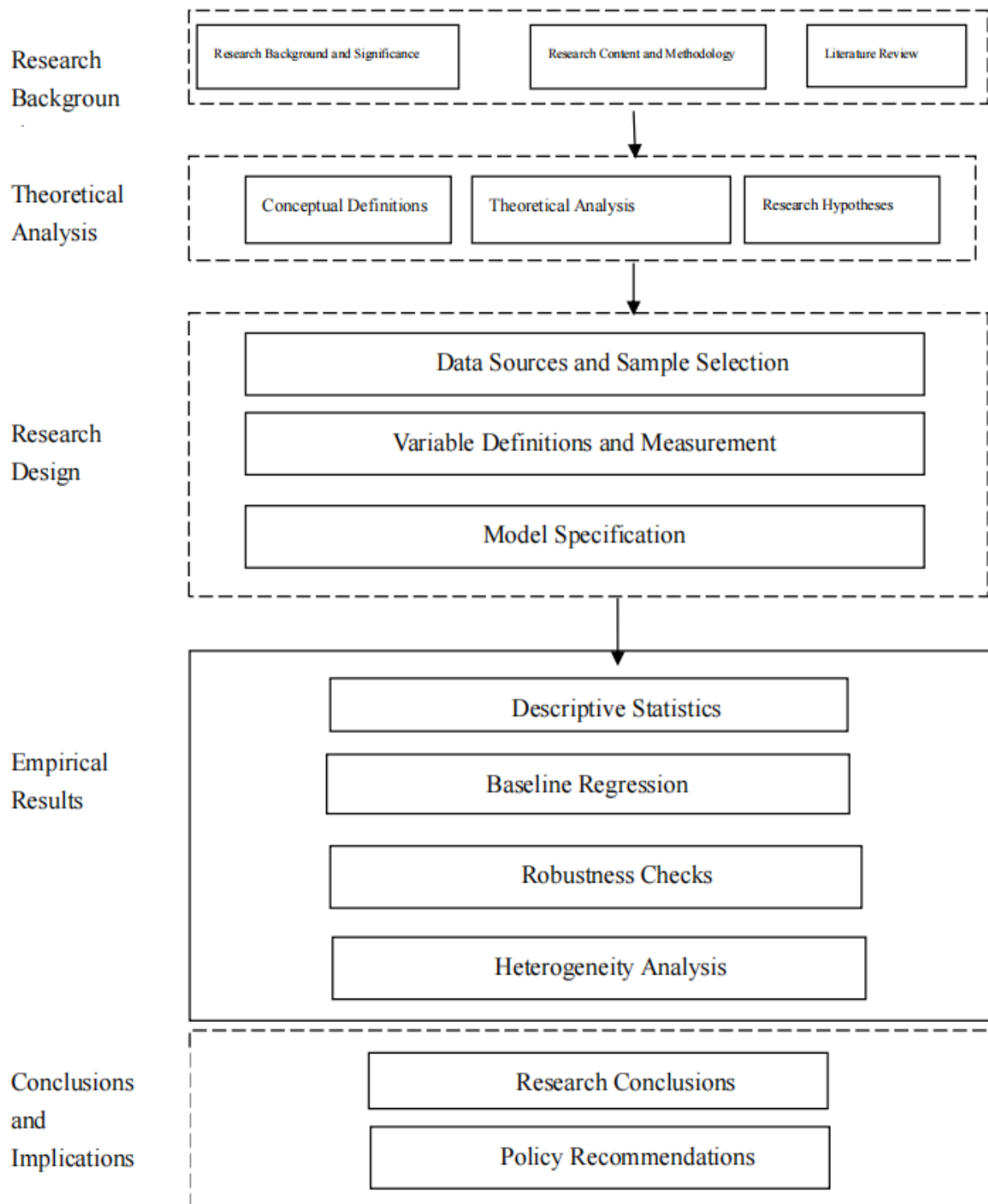
Development Stage	Key Characteristics
Emergence and Regulatory Foundation Stage (2013–2015)	Mobile payments and platform-based finance expanded rapidly. The State Council's <i>Guiding Opinions on Promoting the Sound Development of Internet Finance</i> (2015) clarified industry boundaries and regulatory responsibilities, emphasizing the use of technology to reduce costs, improve efficiency, and mitigate information asymmetry.
Institutionalization, Expansion, and Risk Rectification Stage (2016–2018)	<i>The Plan for Advancing the Development of Inclusive Finance (2016–2020)</i> established system-wide objectives and assessment requirements, highlighting key service targets such as small and micro enterprises, agriculture, rural areas, and farmers, as well as low-income groups. In 2018, Baihang Credit was established, enhancing credit identification and risk control for long-tail entities.
Digital Transformation and Infrastructure Enhancement Stage (2019–2021)	The People's Bank of China's <i>FinTech Development Plan (2019–2021)</i> promoted the digital transformation of financial institutions in areas including data governance, model-based risk management, and regulatory technology. During this period, the research, development, and pilot programs of the digital renminbi were launched, with small-scale application testing conducted to strengthen traceability and compliance capabilities.
Deep Integration and High-Quality Development Stage (2022–present)	The <i>FinTech Development Plan (2022–2025)</i> emphasized fairness and inclusiveness, strengthened governance of data elements, and promoted the application of artificial intelligence and blockchain in inclusive finance. The National Financial Regulatory Administration was officially established, and the State Council issued implementation guidelines to advance the high-quality development of inclusive finance.

1.2 Research Design and Content

This study focuses on the impact of digital inclusive finance (DIFI) on corporate ESG performance and conducts a systematic examination from three perspectives: the overall effect, the underlying mechanisms, and contextual heterogeneity. At the theoretical level, this paper reviews the relevant literature on digital inclusive finance and corporate ESG, clarifies key concepts, constructs an analytical framework for the mechanisms through which digital inclusive finance affects environmental, social, and governance performance, and proposes corresponding hypotheses. From an empirical perspective, using a sample of Chinese A-share listed firms and the regional Digital Inclusive Finance Index, this study establishes a baseline regression model to examine the effects of digital inclusive finance on overall corporate ESG performance as well as its individual dimensions, and conducts robustness checks using alternative variable specifications and related methods [1]. Finally, grouped regressions are performed based on industry characteristics and other dimensions to capture heterogeneity in the effects, thereby deriving corresponding policy implications and managerial recommendations.

The technical roadmap of the study is presented in Figure 1.

Figure 1. Technical Roadmap of the Study



2. Literature Review and Hypotheses on the Impact of Digital Inclusive Finance on Corporate ESG Performance

2.1 Literature Review

Guo Feng, Wang Jingyi, and co-authors constructed the Peking University Digital Inclusive Finance Index for the period 2011–2018, measuring the development of digital inclusive finance from the perspectives of coverage breadth, usage depth, and digital support, and documenting pronounced regional disparities [2]. Jiao

Jinpu, Huang Tingting, and others proposed an inclusive finance evaluation framework based on accessibility, usage intensity, and service quality [3]. From the perspectives of economic outcomes and innovation, Li Jianjun et al. (2020) show that inclusive finance promotes economic growth and reduces urban–rural disparities [4]. Liang Bang et al. (2019) demonstrate that digital inclusive finance exerts a significant positive effect on technological innovation, with stronger effects observed in central and western regions as well as among private and small-sized firms, primarily by lowering financing costs and alleviating financing constraints [5]. Closely related to this line of research, Fang Xianming et al. find that ESG performance enhances both the quantity and quality of corporate innovation output, mainly through the mitigation of financing constraints and improvements in human capital efficiency [6]. Overall, existing evidence suggests that both digital inclusive finance and ESG performance can promote innovation and development through two key channels: financing and efficiency.

2.2 Hypotheses on the Impact of Digital Inclusive Finance on Corporate ESG Performance

Hypothesis 1 (H1): Digital inclusive finance positively affects corporate ESG performance.

Digital inclusive finance reduces financing costs and constraints through online financial services, guiding resources toward environmental governance, social responsibility, and governance optimization [7]. At the same time, it supports low-carbon transformation and improves the quality of environmental monitoring and information disclosure, thereby enhancing corporate ESG performance.

Hypothesis 2 (H2): The impact of digital inclusive finance on corporate ESG performance varies across industries.

Industries differ substantially in their digital foundations and capacity to absorb new technologies. Firms in technology and modern service industries are more capable of translating the advantages of digital finance into green investment and governance improvement, whereas traditional industries face greater technological and resource constraints, resulting in weaker effects.

Hypothesis 3 (H3): The impact of digital inclusive finance on corporate ESG performance is moderated by firm size.

Small and medium-sized enterprises face more severe financing constraints, and digital inclusive finance can significantly alleviate their financing pressure, promote green investment and the fulfillment of social responsibilities, and thereby improve ESG performance. Large firms, while possessing stronger resource endowments and governance foundations, are more affected by organizational inertia, leading to smaller marginal improvements; their ESG enhancement mainly occurs through the use of digital tools to optimize ESG data governance and supply chain coordination [8].

3. Empirical Analysis of the Impact of Digital Inclusive Finance on Corporate ESG Performance

3.1 Data Collection

3.1.1 Data Sources

This study uses data on A-share listed firms in China from 2020 to 2023 as the research sample, mainly including firm-level ESG data and data on the adoption of digital inclusive finance. In addition, the CSMAR database and firms' annual reports are used as supplementary data sources to ensure data completeness and accuracy.

In the process of data selection and collection, this study carefully considers the authority, completeness, and timeliness of the data, as well as their comparability and operability, thereby ensuring the scientific rigor and reliability of the research data.

3.1.2 Model Variables

The dependent variables comprise three dimensions: the environmental dimension (e.g., carbon emissions, green investment, energy conservation and emission reduction), the social dimension (e.g., employee welfare, community engagement, and philanthropic projects), and the governance dimension (e.g., board structure,

transparency, and internal control), which collectively reflect firms' performance in environmental, social, and governance aspects.

The key independent variable is the degree of adoption of digital inclusive finance, which captures the frequency of firms' use of digital financial products, the diversity of financing channels, and the utilization rate of digital financial services.

Control variables include firm size and industry characteristics to exclude their potential interference with ESG performance and to ensure the accuracy of the estimation results.

Table 2 summarizes the definitions of all model variables.

Table 2: Definitions of Model Variables

Variable Category	Primary Indicator	Secondary Indicator
Independent Variable	Digital Inclusive Finance Adoption	Frequency of firms' use of digital financial products
		Diversity of financing channels
		Utilization rate of digital financial services
Dependent Variables	Environmental Dimension	Corporate carbon emissions
		Green investment
		Energy conservation and emission reduction
	Social Dimension	Employee welfare
		Community engagement
		Corporate philanthropic projects
	Governance Dimension	Board structure
		Transparency
		Internal control system
Control Variables	Industry Characteristics	Market size
		Industrial chain structure
		Technological innovation
	Firm Size	Total assets
		Total revenue

3.1.3 Descriptive Analysis

The descriptive statistics reported in Table 3 indicate that the ranges and distributions of the variables for the 100 sample firms meet the requirements for econometric analysis. The core independent variable, digital inclusive finance, has a mean value of 6.05, a standard deviation of 1.872, and a median of 6, suggesting that the overall level is moderately high with relatively limited variation. Financing constraints exhibit a relatively low mean but substantial heterogeneity across firms.

Among the ESG sub-dimensions, the environmental dimension has a mean value of 1.38, characterized by high variability and right-skewness, indicating relatively low performance with significant differentiation across firms. The social dimension has a mean of 4.83 and displays a relatively even distribution. The governance dimension has a mean value of 4.68 and remains generally stable.

With respect to control variables, firm size has a mean value of 3.21 with a low degree of dispersion, while industry characteristics have a mean of 0.42, reflecting a clear grouping structure. Overall, the sample exhibits both representativeness and sufficient variation, making it suitable for subsequent regression and mechanism analyses.

Table 3: Descriptive Statistics

Variable	Obs.	Max	Min	Mean	Std. Dev.	Median	Variance	Kurtosis	Skewness	Coefficient of Variation
Digital Inclusive Finance Adoption	100	10	3	6.05	1.872	6	3.503	-0.696	0.483	0.309
Environmental Dimension	100	7	0	1.38	2.121	0	4.501	0.69	1.449	1.537
Social Dimension	100	10	0	4.83	2.778	5	7.718	-0.679	-0.34	0.575
Governance Dimension	100	10	0	4.68	3.231	5	10.442	-1.274	-0.07	0.69
Firm Size	100	5.006	2.082	3.21	0.831	3.124	0.69	-0.487	0.665	0.259
Industry Characteristics	100	1	0	0.42	0.496	0	0.246	-1.931	0.329	1.181

3.2 Model Regression Analysis

3.2.1 Model Construction

The model takes the degree of adoption of digital inclusive finance as the independent variable, and the indicators of the environmental, social, and governance (ESG) dimensions as the dependent variables. A series of control variables are also introduced to adjust for other potential influencing factors. The regression model is constructed in the following form:

$$Y_1 = \beta_0 + \beta_1 X_1 + \beta_4 X_4 + \beta_5 X_5$$

$$Y_2 = \beta_0 + \beta_2 X_1 + \beta_4 X_4 + \beta_5 X_5$$

$$Y_3 = \beta_0 + \beta_3 X_1 + \beta_4 X_4 + \beta_5 X_5$$

X_1 represents the degree of adoption of digital inclusive finance by the enterprise, while Y_1, Y_2 , and Y_3 represent the dependent variables for the environmental, social, and governance dimensions, respectively. X_4 and X_5 represent the industry and company size, respectively.

3.2.2 Benchmark Regression Analysis

To examine the core impact of digital inclusive finance on corporate ESG performance and its individual dimensions (environmental, social, governance), this study conducts a benchmark regression analysis based on the constructed regression model. The analysis systematically investigates the quantitative relationships between the core explanatory variables, control variables, and the dependent variables, laying the foundation for subsequent mechanism tests and heterogeneity analysis. The results of the benchmark regression are presented in Table 4:

Table 4: Benchmark Regression Analysis

Variables	(1) Environmental Dimension	(2) Social Dimension	(3) Governance Dimension
Degree of Adoption of Digital Inclusive Finance	0.061(0.436)	0.086(0.483)	1.053(5.9***)
Industry Characteristics	0.264(0.53)	1.171(1.849)	-0.359(-0.565)
Company Size	-0.448(-1.585)	1.041(2.896)	-1.019(-2.831)
_cons	2.326(2.102)	0.522(0.371)	1.747(1.241)
R ²	0.031	0.115	1.241

The constructed model is as follows:

$$Y_1 = 2.326 + 0.061X_1 + 0.264X_4 - 0.448X_5$$

$$Y_2 = 0.522 + 0.086X_1 + 1.171X_4 + 1.041X_5$$

$$Y_3 = 1.747 + 1.053X_1 - 0.359X_4 - 1.019X_5$$

The results of the benchmark regression indicate that digital inclusive finance does have an impact on corporate ESG scores. From an environmental perspective, the regression coefficient for the degree of adoption of digital inclusive finance is 0.061 ($t = 0.436$), which is not statistically significant, suggesting that its impact on corporate environmental performance is minimal. Among the control variables, the coefficient for industry characteristics is 0.264 ($t = 0.530$), and the coefficient for company size is -0.448 ($t = -1.585$), both of which do not reach conventional significance levels.

At the social level, the coefficient for the degree of adoption of digital inclusive finance is 0.086 ($t = 0.483$), still not significant. The coefficients for industry characteristics and company size are 1.171 ($t = 1.849$) and 1.041 ($t = 2.896$), respectively, indicating that company size has a significant impact on corporate performance.

From a governance perspective, the degree of adoption of digital inclusive finance has a coefficient of 1.053, which is positive and statistically significant at the $t = 5.900$ level, indicating that digital inclusive finance can improve corporate governance efficiency. The coefficients for industry characteristics and company size are -0.359 ($t = -0.565$) and -1.019 ($t = -2.831$), respectively.

Overall, digital inclusive finance has the greatest positive impact on the governance dimension of ESG. The effects of company size and industry characteristics vary across different dimensions, suggesting structural differences in ESG performance across various aspects of the enterprise.

3.3 Robustness Check

This study follows the research approach of Wen Yadong and Chen Yan (2024), replacing the core explanatory variable in the benchmark model with the degree of digitalization, and performs a robustness check based on this modification [9]. The results are presented in Tables 5, 6, and 7:

Table 5: Information Criteria

Criterion	Value
-2 Restricted Log Likelihood	484.242
Akaike Information Criterion (AIC)	490.242
Corrected Akaike Information Criterion (AICC)	490.500
Bozdogan's Consistent AIC (CAIC)	500.966
Schwarz Bayesian Criterion (BIC)	497.966

Table 6: Type III Tests of Fixed Effects

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	96.802	0.148	0.701
Digitization Level	1	96.639	0.172	0.679
Industry Characteristics	1	96.696	3.354	0.070
Firm Size	1	96.600	8.755	0.004

Table 7: Estimates of Covariance Parameters

Parameter Type	Year	Estimate (Var)	Std. Error (SE)
Repeated Measures	2020-12-31	7.389240	1.839445
	2021-12-31	7.560014	1.853619
	2022-12-31	6.698294	1.664757

In this section, a Linear Mixed-Effects (LME) model is employed to conduct a robustness check on the baseline results. The corporate social dimension score is treated as the dependent variable, with time defined as the repeated measures factor and the firm as the subject of random effects (sample size $N=34$). The fixed effects include the degree of digital financial inclusion adoption, industry characteristics, and firm size. The model fit statistics remain largely unchanged compared to the previous analysis, indicating that the system is linear and stable. The results show that the degree of digital financial inclusion adoption does not exhibit a significant impact ($F = 0.172$, $\text{Sig.} = 0.679$), which is consistent with the baseline regression. Meanwhile, firm size has a significantly positive effect ($F = 8.755$, $\text{Sig.} = 0.004$), and industry characteristics show a marginally

significant influence ($F = 3.354$, $\text{Sig.} = 0.070$). Furthermore, the error variance remains stable (ranging from approximately 6.70 to 7.56), further confirming the robustness of the conclusions regarding social impact.

3.4 Heterogeneity Analysis

In this study, we categorize the sample into heavily polluting and non-heavily polluting industries. This classification is based on the *Management List of Environmental Protection Inspection Industry Categories for Listed Companies* (MEP Office Letter [2008] No. 373), issued by the Ministry of Environmental Protection in 2008, as well as the *Guidelines for Industry Classification of Listed Companies* revised by the China Securities Regulatory Commission (CSRC) in 2012. Heavily polluting industries primarily include 16 sectors, such as coal, mining, petrochemicals, chemicals, metallurgy, and thermal power. These industries typically generate substantial pollutants during their production and operations, exerting significant pressure on the environment. In contrast, non-heavily polluting industries encompass all other sectors, whose operational activities have a relatively smaller environmental impact. Regression analyses were conducted separately for the samples of both industry types, and the results are presented in Table 8.

Table 8: Regression Analysis of Industry Heterogeneity

Variables	(1) Heavily Polluting: Environmental	(2) Non-heavily Polluting: Environmental	(3) Heavily Polluting: Social	(4) Non-heavily Polluting: Social	(5) Heavily Polluting: Governance	(6) Non-heavily Polluting: Governance
Digital Finance Adoption	0.08 (0.48)	0.04 (0.56)	0.1 (0.52)	0.07 (0.5)	1.2*** (6.2)	0.9*** (5.8)
Industry Characteristics	0.3 (-0.5)	0.2 (-0.6)	1.2 (1.8)	1.1 (1.7)	-0.4 (-0.6)	-0.3 (-0.5)
Firm Size	-0.5 (-1.6)	-0.4 (-1.5)	1.1 (2.9)	1.0 (2.8)	-1.1 (-2.9)	-1.0 (-2.8)
_cons	2.5 (2.1)	2.2 (2.0)	0.6 (0.4)	0.5 (0.3)	1.8 (1.3)	1.6 (1.2)
R ²	0.035	0.028	0.12	0.11	1.26	1.22

According to the results in Table 8, the impact of digital financial inclusion on ESG sub-dimensions exhibits significant industrial heterogeneity. In the environmental dimension, the coefficients for heavily polluting and non-heavily polluting industries are 0.08 ($t = 0.48$) and 0.04 ($t = 0.56$), respectively, both of which are statistically insignificant, while industry characteristics and firm size exhibit positive effects (0.30, 0.20). Similarly, in the social dimension, the adoption coefficients are 0.10 ($t = 0.52$) and 0.07 ($t = 0.50$), which also fail to reach significance; however, industry characteristics and firm size maintain stable positive influences (with industry characteristics at 1.20 and 1.10, and firm size at 1.10 and 1.00, respectively). In contrast, the coefficients in the governance dimension are significantly positive, with the effect in heavily polluting industries (1.20, $t = 6.20$) being notably higher than that in non-heavily polluting industries (0.90, $t = 5.80$), whereas industry characteristics and firm size show negative correlations in this dimension. (with industry characteristics at -0.40 and -0.30, and firm size at -1.10 and -1.00, respectively)

Overall, the influence of digital financial inclusion on ESG performance is primarily concentrated in the governance dimension, with a more pronounced promotional effect in heavily polluting industries ($1.20 > 0.90$). This suggests that in industries facing higher regulatory pressure, digital financial inclusion is more effective at enhancing transparency, strengthening oversight, and improving governance efficiency. Conversely, the lack of significance in the environmental and social dimensions may be attributed to factors such as technology investment cycles, emission constraints, and the specific structure of corporate social responsibility.

4. Conclusions and Policy Recommendations

4.1 Conclusions

Using data from A-share listed companies from 2020 to 2023, this study examines the relationship between the degree of digital financial inclusion adoption and corporate ESG performance. The empirical results

demonstrate that digital financial inclusion adoption has a significantly positive impact on the governance dimension ($\beta = 1.053$, $t = 5.900$), whereas its effects on the environmental and social dimensions are not statistically significant (Environmental: $\beta = 0.061$, $t = 0.436$; Social: $\beta = 0.086$, $t = 0.483$). Heterogeneity tests reveal that this positive effect is more pronounced in heavily polluting industries ($\beta = 1.200$, $t = 6.200$) compared to non-heavily polluting industries ($\beta = 0.900$, $t = 5.800$). Robustness checks using alternative variables yield consistent results, with the positive effect on the governance dimension remaining significant (after replacing variables: $\beta = 1.030$, $t = 5.800$), thereby confirming the validity of the conclusions.

4.2 Policy Recommendations

Based on the findings above, this study proposes several recommendations to promote the synergistic improvement of digital financial inclusion and corporate ESG performance. First, the government should increase investment in digital financial infrastructure and services, particularly in the central, western, and rural regions, to expand service coverage and usage frequency. Policy guidance and incentives should be utilized to promote the development of ESG-oriented products, such as green credit. Furthermore, efforts should be made to enhance ESG disclosure standards and transparency while leveraging market constraints. Second, the financial sector should prioritize innovation in digital products and the provision of differentiated services, focusing on the financing needs of small and medium-sized enterprises (SMEs) and green-oriented firms. By utilizing big data and artificial intelligence to enhance risk control and pricing capabilities, financial institutions can effectively reduce transaction costs stemming from information asymmetry [10]. Finally, at the corporate level, firms should improve their capacity to utilize digital financial tools, integrating ESG considerations into their long-term strategies and daily operations. Moreover, improving internal mechanisms such as goal setting and performance appraisal is essential to normalize and standardize ESG investments.

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Study on the Impact of Enterprise Digital Transformation on Working Capital Management Efficiency: Evidence from Leading Enterprises in the Electronic Equipment Manufacturing Industry

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Abstract

This study takes 30 Chinese A-share listed companies from 2020 to 2024 as samples to empirically examine the impact of digital transformation on working capital management efficiency and its boundary conditions. The findings reveal that: overall, digital transformation significantly shortens the cash conversion cycle and improves working capital efficiency. Mechanism analysis shows that the efficiency improvement mainly stems from the in-depth optimization of inventory management, but it is accompanied by a significant extension of the accounts receivable cycle, forming a mixed path characterized by "inventory reduction" and "slower receivables collection". Heterogeneity analysis indicates that this positive effect is concentrated in private enterprises, while a "digital efficiency paradox" emerges in state-owned enterprises (SOEs) — digital transformation may instead prolong the inventory turnover cycle. In addition, enterprises with high financing constraints tend to adopt more thorough digital strategies. This study uncovers the complexity and context dependence of digital transformation's impact on working capital efficiency, providing theoretical basis and empirical evidence for enterprises to formulate differentiated transformation strategies and for the government to implement targeted policies. It is suggested that the government should pay more attention to the assessment of operational indicators such as cash conversion cycle and inventory turnover rate when promoting the digital transformation of SOEs, while providing digital tool support and financing convenience for private enterprises.

Keywords

digital transformation, working capital management, cash conversion cycle, heterogeneity, inventory management

1. Introduction

Against the backdrop of the digital economy becoming the core engine of global economic growth, digital technologies represented by big data and artificial intelligence are profoundly reshaping enterprise operation models. In 2020, statistics showed that China's digital economy reached 39.2 trillion yuan, strongly driving the development of various industries. In 2021, the 14th Five-Year Plan Outline (2021-2025) and the 2035 Vision for the Development of the National Economy and Society of the People's Republic of China pointed

out that "we should accelerate digital development and build a digital China". The Chinese government's "Digital China" and "new infrastructure construction" strategies have provided strong policy impetus for enterprise digital transformation. In this macro context, enterprises face fierce market competition and continuous cash flow pressure; optimizing working capital management centered on inventory and accounts receivable has become a crucial issue related to their survival and development.

Theoretically, digital transformation can improve operational efficiency by enhancing information processing capabilities and optimizing resource allocation. However, existing studies mostly focus on the macro impacts of digital transformation on enterprise performance, innovation, or supply chain resilience, and there is insufficient discussion on the micro-mechanisms of how it affects working capital — a thorough operational indicator. A small number of studies have focused on the single impact of digitalization on inventory[1], but failed to systematically reveal its differential effects on various components of working capital (inventory, accounts receivable, accounts payable) and the overall results. More importantly, the effectiveness of digital transformation may be strongly moderated by enterprises' internal characteristics and external environment[2], and empirical evidence in this regard remains scarce.

In view of this, this study aims to answer three core questions: Can digital transformation improve the overall working capital management efficiency of enterprises? Through which specific paths does its impact manifest? Do these effects differ significantly among enterprises with different ownership types and resource endowments? Through empirical analysis of data from Chinese listed companies, this study not only verifies the overall value of digital transformation, but also uncovers the complex paths and significant contextual differences in its efficiency improvement process, providing new insights for understanding the microeconomic consequences of digital transformation.

2. Literature Review and Research Hypotheses

2.1 Digital Transformation and Working Capital Management: Theoretical Logic and Hypotheses

The information processing theory holds that organizational effectiveness depends on the match between an organization's information processing capabilities and its information needs. By enhancing data collection, analysis, and collaboration capabilities, digital transformation can effectively reduce information asymmetry both inside and outside enterprises[3], thereby providing a technical foundation for optimizing inventory levels, accelerating accounts receivable collection, and coordinating payment cycles. Based on this, the core hypothesis is proposed:

H1: The degree of enterprise digital transformation is negatively correlated with the cash conversion cycle, i.e., digital transformation can improve working capital management efficiency.

2.2 Potential Differentiation of Impacts and Context Dependence

Despite the optimistic theoretical logic, the actual impact of digital transformation may be complex. First, its impact paths may be asymmetric. For example, to expand the market, enterprises may provide more lenient credit policies while promoting digitalization, leading to slower receivables collection[4]. Second, the effects may vary with enterprise characteristics. Due to their unique governance structures and social goals, the digital transformation of SOEs may focus more on strategic compliance rather than operational efficiency improvement[2]. In contrast, private enterprises can quickly transform technology into efficiency by virtue of their flexible mechanisms. Resource constraints will also shape the transformation model — enterprises with financing constraints are more motivated to use digitalization to comprehensively optimize cash flow[5]. These theoretical deductions lay the foundation for subsequent mechanism and heterogeneity analyses.

3. Research Design

3.1 Samples and Data

This study selects 30 A-share listed companies in Shanghai and Shenzhen from 2020 to 2024 as the initial sample. These companies operate primarily in the "computer, communication, and other electronic equipment

manufacturing industry," which features a high level of digitalization, globalized supply chains, a large enterprise base, and strong market participants. This facilitates the selection of leading enterprises in various segments and enterprises of different sizes, ensuring sample diversity. After excluding ST/*ST companies, companies that conducted IPOs in the current year, and samples with missing key variables, an unbalanced panel dataset is finally obtained. Financial data are sourced from the RESSET Database.

3.2 Variable Definition

Dependent Variable: Cash Conversion Cycle (CCC), calculated as Days of Sales Inventory (DSI) + Days of Sales Outstanding (DSO) - Days of Payables Outstanding (DPO).

Core Independent Variable: Degree of Digital Transformation (Digital). Using text analysis, this variable is measured by the total frequency of keywords in five dimensions (including artificial intelligence, big data, and cloud computing) in enterprise annual reports, with 1 added and then the natural logarithm taken.

Mechanism Variables: DSI, DSO, DPO.

Ownership Nature (SOE): Assigned 1 if the enterprise is a state-owned enterprise, and 0 otherwise.

Financing Constraints (FC): Measured by the SA index; enterprises with an SA index higher than the sample median are classified into the high-constraint group.

Control Variables: Including enterprise size (Size), asset-liability ratio (Lev), profitability (ROA), growth (Growth), operating cash flow (CashFlow), and listing years (Age).

3.3 Model Specification

Main Effect Model (Two-way Fixed Effects):

$$CCC_{i,t} = \alpha_0 + \alpha_1 Digital_{i,t} + \sum \beta Controls_{i,t} + \mu_i + \nu_i + \epsilon_{i,t}$$

Among them, α_1 is the core coefficient of concern. If it is significantly negative, Hypothesis H1 is supported.

Mechanism Test Model:

Replace CCC in the above formula with DSI, DSO, and DPO respectively.

Heterogeneity Test:

Conduct grouped regressions by SOE and FC.

4. Empirical Results and Analysis

4.1 Descriptive Statistics

Descriptive statistics of key variables show that the mean value of the cash conversion cycle (CCC) is 109.09 days, with a standard deviation of 83.88, indicating significant differences in working capital management efficiency among sample enterprises. The mean value of the degree of digital transformation (Digital) is 5.19, with a standard deviation of 1.24, reflecting obvious gaps in the digitalization process of different enterprises. Days of Sales Inventory (DSI), Days of Sales Outstanding (DSO), and Days of Payables Outstanding (DPO) all show a certain degree of volatility, providing a sample basis for subsequent mechanism analysis.

4.2 Main Regression Results

As shown in Table 1, after controlling relevant variables and fixed effects, the coefficient of Digital is -19.6501, which is significant at the 1% level ($p=0.0022$). This means that for each unit increase in the digitalization level of an enterprise, the cash conversion cycle is shortened by an average of approximately

19.65 days. Hypothesis H1 is strongly supported, confirming that digital transformation generally improves working capital management efficiency.

Table 1: Impact of Digital Transformation on Cash Conversion Cycle

Variable	Coefficient	Std. Error	t-value	p-value	95% Lower Bound	95% Upper Bound
Intercept	500.9189	141.1727	3.5483	0.0004	224.2254	777.6124
Digital	-19.6501	6.4313	-3.0554	0.0022	-32.2553	-7.0449
Size	-8.5279	6.3303	-1.3471	0.1779	-20.9351	3.8793
Lev	-129.7659	58.1041	-2.2333	0.0255	-243.6478	-15.884
ROA	340.7273	191.4695	1.7795	0.0752	-34.5461	716.0007
Growth	-48.001	35.1806	-1.3644	0.1724	-116.9537	20.9518
CashFlow	-549.5769	175.5531	-3.1305	0.0017	-893.6546	-205.4992
Age	0.5652	0.8978	0.6295	0.529	-1.1945	2.3248
SOE	8.126	14.2562	0.57	0.5687	-19.8156	36.0676

4.3 Mechanism Test: Path Differentiation

As shown in Table 2, the specific paths through which digital transformation affects working capital efficiency show significant differentiation.

Table 2: Mechanism Test: Impact on DSI, DSO, and DPO

Dependent Variable	Digital Coefficient	Std. Error	t-value	p-value	Significance	R ² /Adjusted R ²
DSI	-27.3414	6.9462	-3.94	0.0001	***	0.1969
DSO	11.2928	4.4049	2.56	0.0104	**	0.1801
DPO	2.3397	3.2117	0.73	0.4663	ns	0.1408

Inventory Management Path (Optimization): Digital transformation exerts a significantly negative impact on DSI, demonstrating its ability to accelerate inventory turnover by optimizing supply chains and improving demand forecasting — the core mechanism driving reduced inventory occupation.

Accounts Receivable Management Path (Delay): Digital transformation has a significantly positive impact on DSO, a key finding. From the perspective of competitive strategy theory, digital transformation endows enterprises with stronger market expansion capabilities. To seize market share and build differentiated competitive advantages, enterprises may proactively adopt more lenient credit policies, bind core customers by extending the receivables collection cycle, and sacrifice short-term cash flow for long-term market competitiveness[6]. From the perspective of commercial credit redistribution, digital transformation reduces enterprises' dependence on immediate cash flow (e.g., optimizing capital scheduling through accurate forecasting), enabling them to use commercial credit as a tool for industrial chain governance, extend credit support to upstream and downstream customers, and thereby consolidate their position in the industrial chain and enhance bargaining power. In addition, the initial construction of digital credit processes (such as online credit granting and intelligent risk control) may incur costs related to system adaptation and personnel coordination, leading to short-term fluctuations in collection efficiency; however, in the long run, a more efficient credit management system may be formed. This result indicates that the extension of the accounts receivable cycle is not a simple efficiency loss, but a rational choice made by enterprises based on strategic goals.

Accounts Payable Management Path (No Impact): The impact of digital transformation on DPO is not significant, indicating that digitalization has not led enterprises to generally extend payments to suppliers.

In summary, the net improvement of working capital efficiency (shortened CCC) brought about by digital transformation results from the combined effect of "significant improvement in inventory efficiency" and "phased sacrifice of accounts receivable efficiency", forming a differentiated impact path.

4.4 Heterogeneity Analysis

As shown in Table 3, the heterogeneity analysis based on ownership nature and financing constraints presents notable differences in the impact of digital transformation on working capital management efficiency.

4.4.1 Ownership Heterogeneity: "Digital Efficiency Paradox in SOEs"

Private Enterprises: Digital transformation significantly shortens CCC (coefficient: -23.95), with a mechanism consistent with the overall results (optimizing DSI and extending DSO), making private enterprises the main drivers of efficiency improvement.

State-Owned Enterprises (SOEs): The impact of digital transformation on CCC is not significant, and its impact on DSI is significantly positive (50.68), meaning that digitalization has instead significantly prolonged the inventory turnover cycle, resulting in a "digital efficiency paradox". From the perspective of the multi-task agency theory, managers of SOEs face conflicts between multiple task objectives — their digital transformation not only undertakes the economic task of improving operational efficiency, but also needs to meet political tasks (e.g., responding to the "Digital China" strategic deployment) and social responsibilities (e.g., ensuring employment and supporting regional development)[7]. This multi-task attribute leads to the tilt of digital investment in SOEs toward non-operational areas, such as technology procurement to meet policy compliance requirements and digital public welfare projects carried out to fulfill social responsibilities, which are disconnected from core operational goals such as inventory optimization. At the same time, the internal governance structure of SOEs is relatively rigid, with long decision-making chains, making it difficult for digital technologies to be quickly integrated into practical links such as supply chain management, further exacerbating the mismatch between "investment and efficiency". In addition, SOEs often have strong resource advantages in the industrial chain, and their sensitivity to inventory turnover efficiency is lower than that of private enterprises, which also weakens their motivation to optimize inventory management through digitalization.

4.4.2 Financing Constraint Heterogeneity: Two Optimization Modes

Enterprises with High Financing Constraints: They seek efficiency improvement by optimizing DSI and extending DSO simultaneously, presenting an aggressive model of "comprehensive potential tapping and promoting growth through receivables".

Enterprises with Low Financing Constraints: Efficiency improvement relies almost entirely on the optimization of DSI, with no significant impact on DSO, reflecting a focused model of "focusing on internal operations and steadily improving quality".

Table 3: Regression Results of Heterogeneity Analysis

Group Name	Dependent Variable	Digital Coefficient	Std. Error	t-value	p-value	Significance	Adjusted R ²	Number of Observations
High Financing Constraints	CCC	-22.6833	12.0864	-1.88	0.0606	*	0.2092	69
	DSI	-33.4161	13.2079	-2.53	0.0114	**	0.2291	69
	DSO	14.1574	4.0337	3.51	0.0004	***	0.5742	69
	DPO	-0.0766	4.9464	-0.02	0.9876	ns	0.2184	69
Low Financing Constraints	CCC	-35.4839	12.8865	-2.75	0.0059	***	0.1185	69
	DSI	-35.6566	13.1284	-2.72	0.0066	***	0.1824	69
	DSO	2.7738	7.4494	0.37	0.7096	ns	0.2674	69
	DPO	1.876	6.4036	0.29	0.7695	ns	0.1042	69
SOEs	CCC	31.4358	37.8015	0.83	0.4056	ns	0.5281	20
	DSI	50.6757	23.1856	2.19	0.0288	**	0.6794	20
	DSO	-8.2899	6.9994	-1.18	0.2363	ns	0.8657	20
	DPO	17.5694	19.6212	0.9	0.3706	ns	0.7964	20
Private Enterprises	CCC	-23.9508	8.067	-2.97	0.003	***	0.2385	118
	DSI	-32.9143	7.5019	-4.39	0	***	0.2337	118
	DSO	11.4286	4.5692	2.5	0.0124	**	0.202	118

DPO	0.2659	3.5731	0.07	0.9407	ns	0.1039	118

5. Research Conclusions and Implications

5.1 Research Conclusions

This study conducts a systematic examination of how enterprise digital transformation influences working capital management efficiency, with key findings as follows: Digital transformation can significantly shorten the cash conversion cycle and improve working capital management efficiency. The efficiency improvement mainly stems from the in-depth optimization of inventory management, but it is accompanied by a strategic or adaptive extension of the accounts receivable cycle; accounts payable management is not significantly affected. The positive effect is concentrated in private enterprises; a "digital efficiency paradox" emerges in SOEs, where digital investment may be disconnected from inventory efficiency improvement or even run counter to it. Enterprises with different levels of financing constraints also show differentiated digital optimization models.

5.2 Management Implications

5.2.1 For Enterprises

When implementing digital transformation, enterprises need to consciously synergize supply chain optimization (inventory reduction) and sales credit policies (accounts receivable management) and conduct a comprehensive benefit assessment. Private enterprises should continue to deepen the application of digitalization in operational links. In contrast, SOEs urgently need to promote the penetration of digitalization from the strategic level to the operational level, establish an assessment mechanism oriented toward operational efficiency, and break the "efficiency paradox". Enterprises facing financing difficulties can use digitalization to comprehensively optimize cash flow, but they need to strengthen credit risk management; enterprises with sufficient funds can focus on building a digital-driven lean supply chain.

5.2.2 For the Government

When promoting the digital transformation of SOEs, policies should guide them to focus on the actual improvement of operational efficiency. For private enterprises, especially small and medium-sized ones, the government can provide support in digital tools and training related to supply chain and inventory management. It should also encourage the development of supply chain collaboration platforms and digital credit systems to help enterprises better balance efficiency and risk in the process of digital transformation.

5.3 Research Limitations and Prospects

This study has certain limitations in measuring digitalization using the text analysis method. In the future, multi-dimensional data such as enterprise IT investment and digital patents can be combined for measurement. The internal drivers of "extended accounts receivable" (e.g., strategic choices, changes in customer structure) require more in-depth case studies. Subsequent research can further explore: the differential impacts of different digital technologies (such as blockchain and the Internet of Things) on various components of working capital; the dynamic process of digital transformation affecting working capital; and the spillover effect of core enterprise digitalization on the working capital of upstream and downstream enterprises in the industrial chain.

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A Report on E-commerce Business Model of Pinduoduo

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Abstract

Pinduoduo, a leading Chinese e-commerce company founded in 2015, has achieved rapid growth through its innovative social commerce model, which leverages group buying and social media integration to offer competitive prices and foster community engagement. This report provides a comprehensive analysis of Pinduoduo's business model, highlighting its customer value proposition, revenue streams, competitive landscape, and market strategy. It emphasizes Pinduoduo's strengths, including its user-friendly interface, low entry barriers for sellers, and successful penetration of rural markets. The report also identifies key opportunities for future growth, recommending improvements in user experience, product range expansion, supply chain management, marketing efforts, and sustainability practices to ensure continued success in China's dynamic e-commerce market.

Keywords

e-commerce, Pinduoduo, business model, market strategy

1. Introduction

Pinduoduo is a prominent e-commerce company in China, founded in 2015. It has rapidly become one of the largest e-commerce platforms in the country with a unique social commerce model. Pinduoduo's success is largely due to its innovative group buying model. Users can form groups with friends or other users to purchase products at lower prices by sharing product links on social media platforms like WeChat. This not only reduces customer acquisition costs but also creates a viral, network-driven growth model. Pinduoduo has carved out a significant market share by targeting China's lower-tier cities and rural areas. It has worked with more than 16 million farmers and their communities to take part in and benefit from the fast-growing digital economy. The platform is designed to be highly interactive and engaging. It includes games and encourages users to share product information on social networks. Pinduoduo's revenue comes primarily from online marketplace services, including commissions from sales on its platform and advertising. Its revenue has been growing rapidly [1]. Pinduoduo is a typical example of a B2C (Business-to-Consumer) and local e-commerce platform [2].

The aim of this report is to conduct a comprehensive analysis of Pinduoduo's business model and market strategy. This will involve examining the company's customer value proposition, revenue model, competitive landscape, market strategy, and promotional effectiveness. Based on this analysis, the report will provide an overview of the current market strategy, suggest a suitable strategy for future development, and offer five

recommendations for enhancing the company's eCommerce technology and online presence to improve its market performance.

2. Business Model Analysis

2.1 Customer Value Proposition

Pinduoduo's customer value proposition is fundamentally centered on its ability to offer a vast selection of products at exceptionally competitive prices, often significantly lower than those found on other e-commerce platforms [3]. This competitive pricing is primarily facilitated through its innovative group-buying model, which encourages users to form or join purchasing groups. By doing so, users can access substantial discounts, thereby enhancing the platform's appeal to price-sensitive consumers who are continuously seeking cost-effective options. This model not only meets the financial needs of these consumers but also fosters a sense of community and social interaction among users. The platform encourages users to share deals and products with friends and family, thereby organically expanding its reach and user base.

Furthermore, Pinduoduo's user-friendly interface is meticulously designed to enhance the overall shopping experience [4]. Its intuitive and easy-to-navigate design ensures accessibility for a broad spectrum of users, including those who may not be highly tech-savvy. The platform's extensive product variety, ranging from daily necessities to high-end electronics, caters to a diverse customer base with varying needs and preferences. This wide range of products ensures that whether a user is looking for a specific item or simply browsing for something interesting, Pinduoduo is likely to have it. The combination of these factors makes Pinduoduo a highly attractive option in the e-commerce market, effectively communicating its value proposition to its target audience.

2.2 Revenue Model

Pinduoduo generates revenue primarily through transaction fees charged to merchants for each sale made on the platform [5]. The platform also offers premium services to merchants, such as enhanced visibility and advertising options, which contribute to its revenue stream. Unlike some other e-commerce platforms, Pinduoduo does not charge listing fees, making it an attractive option for small and medium-sized enterprises (SMEs) looking to expand their online presence. This revenue model supports the platform's growth by attracting a large number of merchants, which in turn increases the product variety and attracts more consumers, just as figure 1 and figure 2 show.

Figure 1: sourced from Annual Reports <https://companiesmarketcap.com/pinduoduo/revenue/>
Revenue history for PDD Holdings (Pinduoduo) from 2017 to 2024

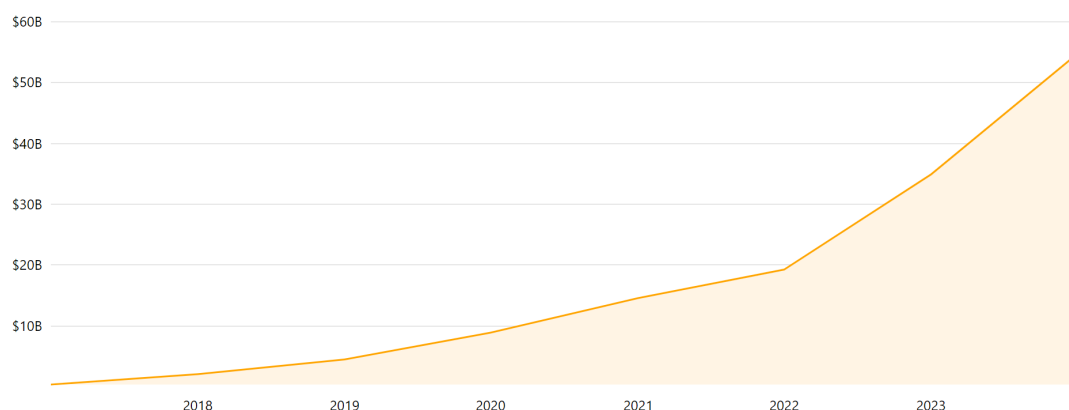
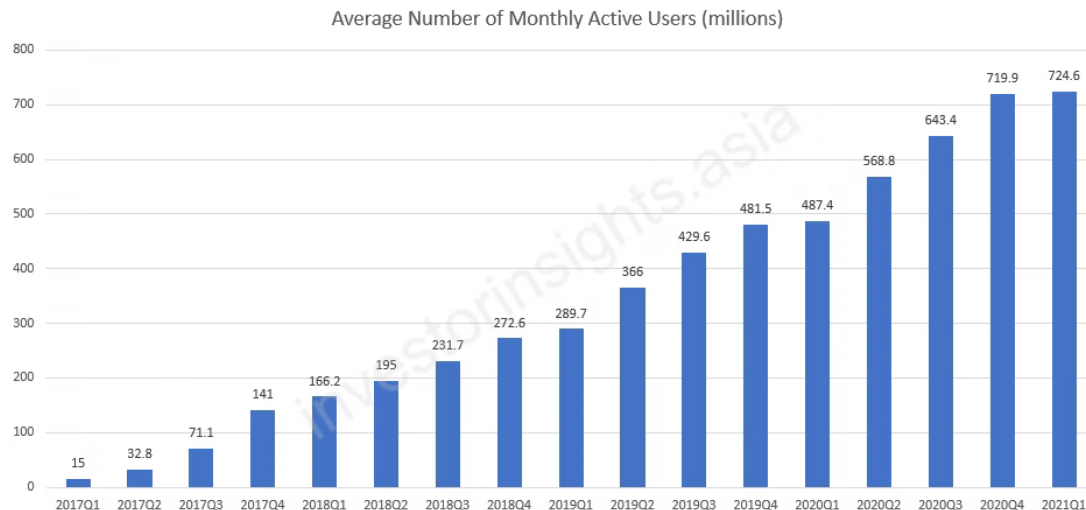


Figure 2: sourced from Pinduoduo Prospectus, Annual Reports, Quarterly Reports

2.3 Main Competitors

Pinduoduo's main competitors in the Chinese e-commerce market include a variety of well-established platforms. Taobao, Alibaba's flagship platform, is renowned for its extensive product range and robust seller ecosystem, offering consumers a vast array of choices from numerous sellers. JD.com is another major competitor, known for its focus on high-quality products and fast delivery services, which has earned it a reputation for reliability and efficiency. Vipin is a discount shopping platform that targets middle-class consumers, providing them with attractive deals and discounts on a variety of products. Meituan, although primarily known for its food delivery and local services, has also expanded its reach into the e-commerce space, leveraging its existing customer base and delivery infrastructure. Lastly, Suning, a traditional retailer with a strong online presence, offers a wide range of consumer electronics and home appliances, combining its offline retail experience with online convenience. Overall, the presence of these well-established competitors forces Pinduoduo to continuously innovate and adapt its business model. It must differentiate itself through unique product offerings, improve logistics and quality control to match the standards set by competitors, enhance its discount strategies to remain price-competitive, and integrate O2O capabilities to provide a more comprehensive shopping experience [6]. This competitive landscape drives Pinduoduo to constantly evolve, ensuring it can maintain its market position and attract a diverse customer base.

2.4 Competitive Advantages

Pinduoduo's key competitive advantages are quite comprehensive. One of the most notable strengths is its unique group buying model, which not only encourages social interaction among users but also attracts a large number of price-sensitive consumers who are looking for more affordable options. In addition to this, the platform boasts a user-friendly interface that is both simple and intuitive in design, greatly enhancing the overall shopping experience for users. This makes it easy for people of all ages and technical abilities to navigate and find what they are looking for. Another significant advantage is the low entry barriers it sets for sellers. Unlike some of its competitors, Pinduoduo does not charge listing fees and offers lower transaction fees, which makes it an attractive option for a large number of small and medium-sized enterprises. This helps to create a diverse and vibrant marketplace with a wide range of products available to consumers. Lastly, Pinduoduo has made a name for itself by successfully penetrating the rural areas in China. It has built strong relationships with local farmers and producers there, and is able to offer fresh agricultural products directly to consumers. This not only provides a new channel for rural producers to sell their goods but also gives urban consumers access to fresher and more affordable agricultural products [7].

2.5 Market Strategy

Pinduoduo has carved out a unique niche in the e-commerce landscape by adopting a multifaceted market strategy that emphasizes the power of social media and networking. The platform has ingeniously integrated

with a wide array of popular social media platforms, creating a seamless experience for users to share exciting deals and discounts. This feature not only enhances user engagement but also fosters a sense of community as users can easily form buying groups with friends and family. By leveraging the viral nature of social media, Pinduoduo has been able to expand its user base rapidly. This rapid expansion has provided a vast customer pool for the platform, which is crucial for its growth and profitability.

In addition to its social media integration, Pinduoduo has made substantial investments in marketing campaigns. These campaigns are meticulously designed to appeal to younger consumers who are more likely to be active on social media platforms. Through creative and interactive promotions such as online games, flash sales, and limited-time offers, Pinduoduo has managed to capture the attention and loyalty of this demographic [8]. These promotions not only drive immediate sales but also encourage repeat purchases and word-of-mouth referrals.

Moreover, Pinduoduo's strategic focus on rural markets has been a game-changer. While many e-commerce platforms concentrate on urban areas, Pinduoduo recognized the potential in the underserved rural segment. By offering products and services tailored to the needs and preferences of rural consumers, Pinduoduo has been able to penetrate these markets effectively. This approach has not only helped the platform capture a significant market share but also contributed to the economic development of rural areas by providing access to a wider range of products and services. In the long run, this strategy is likely to lead to increased customer loyalty and repeat business from rural consumers, further strengthening Pinduoduo's market position and profitability.

2.6 Market Opportunity and Promotional Effectiveness

The e-commerce market in China has been booming, thanks to rising internet access, higher disposable incomes, and evolving consumer habits [9]. More people online mean a bigger audience for online shopping. As incomes grow, consumers have more money to spend, driving demand for diverse products. Meanwhile, consumers increasingly prefer the convenience and variety of online shopping over traditional stores.

The platform has identified a unique market opportunity by integrating social networking with shopping, leveraging social media to boost user engagement and attract new customers through word-of-mouth. This strategy has been particularly effective in reaching price-sensitive consumers who are drawn to Pinduoduo's group buying model, which offers significant discounts. Additionally, Pinduoduo has targeted the underserved rural market, which has traditionally had limited access to a wide range of products. By focusing on this segment, the platform not only bridges the digital divide but also taps into a new growth area. Pinduoduo's ability to promote its services effectively is evident in its innovative marketing campaigns designed to appeal to younger demographics. These campaigns, which include interactive promotions and limited-time offers, have been instrumental in driving immediate sales and fostering customer loyalty. The platform's strategic focus on social commerce and rural market penetration has allowed it to differentiate itself in a competitive landscape, positioning it for continued growth and success in the Chinese e-commerce market.

3. Current Market Strategy

Based on the strategic analyses above, an overview of the current market strategy of Pinduoduo can be summarized as focusing on social commerce by encouraging users to form groups and share deals, which effectively boosts user engagement and drives sales growth. It is also committed to penetrating the rural market by building strong relationships with local producers and supplying fresh agricultural products directly to consumers. Additionally, it targets younger consumers through innovative and interactive marketing campaigns. These strategies have significantly increased user numbers and sales volume, enhanced the platform's visibility and competitiveness, and created a unique value proposition that appeals to a broad range of consumers, just as figure 3 and 4 show.

Figure 3 sourced from <https://companiesmarketcap.com/pinduoduo/earnings/>
Earnings history for PDD Holdings (Pinduoduo) from 2017 to 2024

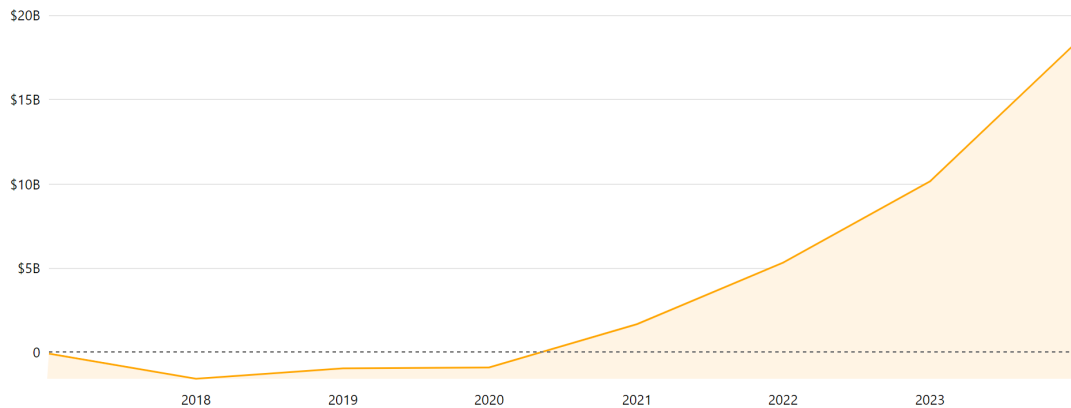


Figure 4 sourced from [PDD Holdings \(Pinduoduo\) \(PDD\) - Market capitalization](#)
Market cap history of PDD Holdings (Pinduoduo) from 2018 to 2025



A suitable strategy for Pinduoduo to follow in the future would involve enhancing its market position by improving the user experience, expanding its product range, and strengthening its supply chain management [10]. Improving the user experience through continuous optimization of the platform's design and functionality can make it more intuitive and user-friendly, ensuring seamless navigation and shopping for users. Expanding the product range to include a wider variety of high-quality products can attract a broader customer base, catering to the diverse needs and preferences of its users. Strengthening the supply chain can ensure timely delivery of products, reduce waiting time for customers, and enhance overall customer satisfaction. Efficient supply chain management can also help in reducing costs and improving the availability of products.

4. Recommendations

In order to further enhance its market strategy, Pinduoduo should take a multi-faceted approach. Firstly, it is crucial to enhance the user experience by investing in improving the platform's user interface and user experience, ensuring seamless navigation and shopping for users. This can be achieved through continuous optimization of the platform's design and functionality, making it more intuitive and user-friendly. For example, simplifying the navigation menu, implementing a more responsive design that adapts to various devices, and introducing advanced personalization features based on user data can significantly improve user satisfaction [11]. Secondly, expanding the product range is essential to attract a broader customer base. By introducing a wider variety of high-quality products, Pinduoduo can cater to the diverse needs and preferences of its users. This involves not only increasing the number of product categories but also ensuring the quality and reliability of the products offered. For example, by collaborating with reputable brands and implementing strict quality control measures, Pinduoduo can build trust with its customers [12]. Thirdly, strengthening the supply chain is a key factor in improving customer satisfaction. Investing in logistics and supply chain management will

ensure timely delivery of products, reducing the waiting time for customers and enhancing their overall shopping experience. For example, Pinduoduo could implement a same-day delivery service in major urban areas by optimizing its distribution network and using real-time data to manage inventory more efficiently. Building more regional distribution centers and adopting advanced supply chain technologies, such as real-time inventory tracking and predictive analytics, can enhance efficiency and reduce costs [13]. Fourthly, increasing marketing efforts is necessary to reach a wider audience. Expanding marketing campaigns, particularly in urban areas, can help Pinduoduo to increase its brand awareness and attract more potential customers. For example, the platform could launch a series of interactive pop-up stores in major cities, where consumers can experience products firsthand and participate in exclusive promotions. Utilizing various marketing channels, such as social media marketing, influencer partnerships, and targeted advertising, can effectively reach different customer segments and build a stronger brand presence [14]. Lastly, focusing on sustainability is becoming increasingly important in today's market. Promoting sustainable practices among sellers and highlighting eco-friendly products can appeal to environmentally conscious consumers. For example, Pinduoduo could create a special section on its platform for products that have been certified as sustainable or eco-friendly, such as organic food or recycled materials. By encouraging sellers to adopt sustainable practices and promoting eco-friendly products, Pinduoduo can enhance its brand image and attract a growing segment of consumers who prioritize sustainability in their purchasing decisions [15].

5. Conclusion

In summary, the report has comprehensively analyzed Pinduoduo's business model and market strategy. The findings highlight that Pinduoduo's innovative group-buying model and social commerce approach have been instrumental in attracting a large number of price-sensitive consumers. By leveraging social media and networking, Pinduoduo has successfully penetrated the rural market and created a unique value proposition. The platform's user-friendly interface and low entry barriers for sellers further enhance its competitive advantages. To maintain its growth trajectory and competitive edge, the report suggests that Pinduoduo should focus on improving the user experience, expanding its product range, strengthening its supply chain management, increasing marketing efforts and focusing on sustainability. These strategic improvements are expected to enhance customer satisfaction, attract a broader customer base, and ensure the platform's continued success in the highly competitive Chinese e-commerce market.

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Analysis of the Impact of Changes in Population Age Structure on Educational Fiscal Expenditure: Research Based on Provincial Panel Data from 1990 to 2023

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Abstract

Against the backdrop of a deepening aging population, the allocation of public finances between pensions and education has become increasingly prominent. Using panel data from 31 Chinese provinces between 1990 and 2023, this study employs a two-way fixed effects model and a mediation effect model to examine how population aging affects local government education expenditure, its mechanisms, and spatiotemporal heterogeneity. The results indicate that population aging significantly suppresses education spending: a one-percentage-point increase in the old-age dependency ratio leads to an average reduction of about 453,000 yuan in provincial education expenditure. This effect is mainly driven by the fiscal crowding-out of social security spending, which accounts for up to 49% of the mediation effect. Regional heterogeneity is notable, with western China being a “high-risk area,” while the eastern region mitigates the adverse impact through higher urbanization and stronger fiscal capacity. Temporal analysis shows that the negative effect intensified significantly after the 2010s, aligning with rising pension insurance pressures. Policy recommendations are proposed to help address aging challenges and ensure sustainable educational investment.

Keywords

population age structure, education finance, population aging intergenerational competition, mediating effect

1. Introduction

The population structure in China has shifted from a “pyramid-shaped” to a “spindle-shaped” distribution, with demographic aging emerging as one of the decisive factors determining China’s future social development[1]. According to data from the National Bureau of Statistics, the proportion of the population aged 65 and above in China has risen from 5.57% in 1990 to 14.9% in 2023, marking the official entry of China into a deeply aging society. At the same time, declining birth rates are occurring in parallel, shifting the total dependency ratio structure from “child-rearing-focused” to “elderly-care-focused”, causing the traditional foundation of educational demand to contract [2]. This structural transformation not only poses severe challenges to socio-economic development models and labor markets, but also exerts profound impacts on the allocation pattern of public fiscal resources.

As a fundamental project for enhancing national human capital quality, the sustainability of educational fiscal investment is critical. The first Central Financial and Economic Committee meeting held in May 2023 explicitly proposed “supporting China’s modernization with high-quality population development”, marking a strategic shift from relying on population scale dividends to population quality dividends. However, under the impact of aging demographics, educational finance faces real risks of being squeezed. On one hand, elderly populations, as primary consumers of public services, demonstrate concentrated demand in pension and healthcare sectors while maintaining relatively low direct demand for educational services. On the other hand, with the increasing weight of the elderly population in the political structure, their policy influence may drive fiscal resources toward elderly care [3]. According to Ministry of Finance data, in 2024, social security and employment expenditures in the national general public budget exceeded education expenditures for the first time in history, clearly revealing the profound reshaping of fiscal resource allocation logic caused by demographic aging. On October 23, 2025, the Fourth Plenary Session of the 20th CPC Central Committee incorporated in its recommendations for the 15th Five-Year Plan: “Improve educational fiscal investment mechanisms adaptable to population changes, preventing educational funding decline in aging regions.” This marks the first time at the central plenary session level that “age structure” has been recognized as an independent variable in educational fiscal investment, signifying that educational fiscal allocations must now align with population structure weights rather than student numbers [4]. Against this backdrop, systematic investigation of the impact of population aging on local government educational expenditures and their underlying mechanisms not only holds significant theoretical value but also presents urgent practical importance.

The current research mainly focuses on the complex relationship between population aging and education fiscal expenditure, and has formed three theoretical explanations of “intergenerational conflict [5]”, “altruism [6]” and “intermediary mechanism [7]”, but there are still some limitations, such as insufficient time span, lack of verification of key mechanisms, and weak analysis of regional heterogeneity [8]. Based on this, this paper puts forward the following research hypotheses: the direct negative impact of population aging on education fiscal expenditure is not significant(H1a); The child dependency ratio has a significant positive effect on it(H1b); Social security expenditure plays a key intermediary role in the relationship between the two(H2); There are significant differences in the above effects and intermediary mechanisms among the eastern, central and western regions(H3).

2. Research Design

2.1 Research Variables

2.1.1 Dependent variable.

This study adopts the “logarithm of educational fiscal expenditure” (*edu_exp*) as the core indicator to measure the scale of educational fiscal investment. This logarithmic transformation smoothes data heteroscedasticity and enables coefficient interpretation with elasticity. In robustness tests, the “per capita educational expenditure” serves as an alternative indicator.

2.1.2 Explanatory Variables.

The primary explanatory variables focus on demographic age structure metrics. The study employs logarithmic transformations of the child dependency ratio (0-14 years old population / 15-64 years old working-age population) and elderly dependency ratio (65+ years old population / 15-64 years old working-age population) to characterize demographic age structures. The former represents rigid demand for compulsory education, while the latter quantifies fiscal caregiving burdens.

2.1.3 Mediating Variables.

Mediating variable selection follows dual criteria: “degree of fiscal flexibility” and “priority of aging impact.” Variables such as social security, economic tax base, total taxation, and capital expenditure have been demonstrated to occupy the first four stages of a four-stage transmission chain (“rigid expenditure expansion—tax base contraction—fiscal capacity exhaustion—flexible substitution”). Together, they constitute an “aging impact resource pool” and “diversion valve” influencing educational expenditure. Mediation effect verification

employs a three-step approach to validate the transmission mechanism between demographic age structures and educational fiscal expenditure.

2.1.4 Control Variables.

Beyond the aforementioned variables, factors such as population size, urbanization, per capita income, and consumer price index may influence educational fiscal expenditure levels [9]. These are incorporated as control variables in regression models to isolate the effects of explanatory and mediating variables. The combination of these four factors forms a “demand-cost-price” three-dimensional control framework, effectively mitigating omitted variable bias and preventing coefficient overestimation due to scale illusion, price illusion, or income illusion in dependency ratios.

Data sources include the China Statistical Yearbook of Education, China Statistical Yearbook, and EPS Data Platform, covering 1990–2023 and 31 provincial administrative regions in mainland China. Variance Inflation Factor (VIF) tests confirm no severe multicollinearity, as all variables exhibit VIF values below 5. As shown in Table 1, descriptive statistics for dependent, explanatory, mediating, and control variables were first presented.

Table 1: Definitions and Descriptive Statistics of Variables

Variable type	Variable	Definition
Dependent variable	edu_exp	Government Expenditure on Education (100 million yuan)
Explanatory Variables	child_dependency	Child Dependency Ratio (%)
	old_dependency	Old-age Dependency Ratio(%)
Mediating Variables	tax_revenue	Tax Revenue (100 million yuan)
	gdp_per_capita	Per Capita Gross Domestic Product (yuan)
	tech_exp	Government Expenditure on Science & Technology (100 million yuan)
	social_security_exp	Government Expenditure on Social Security (100 million yuan)
Control Variables	cpi	Consumer Price Index
	population	Total Population (10,000 persons)
	urban_pop	Urban Population (10,000 persons)
	income_per_capita	Per Capita Disposable Income (yuan)

2.2 Metric Model Specification

2.2.1 Baseline Regression Model

To accurately assess the net impact of changes in the population dependency ratio on educational fiscal expenditure, a bidirectional fixed effects model is constructed as follows:

$$\ln(\text{edu\_exp}_{it}) = \alpha + \beta_1 \text{child\_dep}_{it} + \beta_2 \text{old\_dep}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Among them, i and t represent provinces and years respectively. X_{it} is the control variable vector, and λ_t are the province fixed effects and year fixed effects respectively, used to control for province-specific characteristics that do not vary over time and national-level time trends that do not vary across provinces.

2.2.2 Mediation Model

To examine the mediating role of Social Security expenditure, the Baron-Kenny three-step approach is employed:

Step 1: Total Effect

$$\ln(\text{edu\_exp}_{it}) = \alpha + c \cdot \text{old\_dep}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

This step tests the total effect cc of the old-age dependency ratio on educational fiscal expenditure.

Step 2: Mediator Model

$$\text{socialsecurityxp}_{it} = \alpha + a \cdot \text{olddep}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

This step examines the effect of the old-age dependency ratio on Social Security expenditure.

Step 3: Direct Effect and Mediation

$$\ln(\text{edexp}_{it}) = \alpha + c' \cdot \text{olddep}_{it} + b \cdot \text{socialsecurityxp}_{it} + \gamma X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

This step assesses the direct effect c' of the dependency ratio and the effect b of social security expenditure on educational spending.

A mediating effect is confirmed if coefficients a and b are statistically significant, and the absolute value of c' is less than cc or becomes insignificant. The indirect effect is quantified as $a \times b$. The Sobel test is further used to verify the significance of the mediating path.

2.2.3 Heterogeneity Model

China has a vast territory, so to examine regional heterogeneity, the national sample is divided into three sub-samples: East, Central, and Western regions. Baseline regression is conducted separately for each sub-sample, and the Chow test is employed to assess the statistical significance of coefficient differences across regions.

3. Research results**3.1 Base regression results**

Through the empirical analysis of four progressive models, this study systematically reveals the influence mechanism of population age structure on education fiscal expenditure. Regression results are presented in Table 2.

Model 1 is termed the “basic model”. The elderly dependency ratio showed a significant positive impact on education expenditure (75.43, $p < 0.001$), while the children dependency ratio had no significant impact (-5.60, $p = 0.710$). The intra Group R^2 of the model is 0.3865, indicating that the population age structure itself can explain about 38.65% of the variation of education expenditure.

Model 2 is defined as the model that introduces intermediate variables. After adding social security expenditure and per capita GDP, the influence of the elderly dependency ratio changed fundamentally from positive to negative and was highly significant (-48.95, $p < 0.001$). Social security expenditure showed a strong positive impact (1.17, $p < 0.001$), and per capita GDP also showed a significant positive impact (0.004, $p = 0.025$). The explanatory power of the model increased significantly to 88.77%, which confirmed the existence of the “fiscal crowding out” effect.

Model 3 is specified by adding a set of control variables. After controlling for population size, urbanization rate, per capita income and CPI, Social Security expenditure still had a highly significant positive impact (0.74, $p < 0.001$), especially the impact of urbanization rate (10.18, $p = 0.001$). The negative effect of elderly dependency ratio was still significant (-16.67, $P = 0.004$). The R^2 in the model group was further increased to 94.88%.

Model 4 is designated as the complete model. After adding the time fixed effect, the core driving position of Social Security expenditure (0.73, $p < 0.001$), population size (0.55, $p < 0.001$) and urbanization rate (20.04, $p = 0.005$) is more stable. It is worth noting that the child dependency ratio has a marginal significant positive effect in this model (10.55, $P = 0.050$), while the effect of the elderly dependency ratio becomes insignificant. The explanatory power of the model reached 95.87%, and the dummy variables in most years were not significant, indicating that the model has well controlled the influence of time trend.

This study reveals the impact mechanism of education expenditure through progressive modeling: Social Security expenditure is the key intermediary variable, and its introduction makes the impact of the elderly dependency ratio on education expenditure from positive to negative, which confirms the “fiscal crowding out” effect [10]. Social Security expenditure (0.73), population size (0.55) and urbanization rate (20.04) are the

three robust drivers. The explanatory power of the model increased from 38.65% to 95.87%, which verified the rationality of variable selection and provided a reliable research paradigm for multivariate heterogeneity analysis.

Table 2 Benchmark Regression Results

VARIABLES	Model 1	Model 2	Model 3	Model 4
child_dependency	-5.598 (14.91)	9.288 (7.560)	5.250 (5.353)	10.55** (5.159)
old_dependency	75.43*** (12.03)	-48.95*** (12.07)	-16.67*** (5.395)	-5.701 (8.278)
social_security_exp		1.175*** (0.169)	0.744*** (0.0862)	0.730*** (0.0944)
gdp_per_capita		0.00370** (0.00157)	0.00312 (0.00255)	0.0016 (0.00254)
population			0.565*** (0.0487)	0.554*** (0.0398)
urban_ratio			10.18*** (2.770)	20.04*** (6.559)
income_per_capita			-0.00668 (0.00576)	0.00305 (0.00624)
cpi			-2.821* (1.487)	-9.664 (12.22)
Observations	434	434	434	434
R-squared	0.386	0.888	0.949	0.959
Number of province	31	31	31	31
Province fixed effects	YES	YES	YES	YES
Time fixed effects	NO	NO	NO	YES

*Note: The content within the parentheses is the robust standard deviation clustered at the provincial level*** $p < 0.01$, * $p < 0.05$, * $p < 0.1$*

3.2 Mediator Effect Test

This study employs the Baron-Kenny three-step approach with “Social Security expenditure” as a mediating variable to examine the impact pathway of the old-age dependency ratio on educational fiscal expenditure. The analytical results are presented in Table 3.

Step 1 shows that after controlling for the time effect, the direct impact of the elderly dependency ratio on education expenditure is not significant (3.88, $P=0.887$), while the children dependency ratio has a marginal significant positive impact (27.29, $P=0.083$). The R^2 in the model group was 0.6928;

Step 2 shows that the elderly dependency ratio has a significant positive impact on Social Security expenditure (41.72, $P=0.013$), indicating that the aging of the population will indeed push up Social Security expenditure. The influence of child dependency ratio is not significant;

Step 3 demonstrates that after the dependency ratio and Social Security expenditure are included at the same time, it is found that Social Security expenditure has a very significant positive impact on education expenditure (1.18, $p < 0.001$), and the impact of the elderly dependency ratio turns to a significant negative (-45.33, $p=0.023$), while the impact of the children dependency ratio is no longer significant.

This result clearly reveals the intermediary role of Social Security expenditure. Although aging will directly push up Social Security expenditure (step 2), the increase of Social Security expenditure has a positive impact on education expenditure (step 3). It is worth noting that after controlling Social Security expenditure, aging has a significant crowding out effect on education expenditure, which confirms the existence of the “fiscal crowding out” mechanism. The old-age dependency ratio coefficient from the first step is not significant (3.88), while the third step is significantly negative (-45.33), indicating that Social Security expenditure plays a key intermediary role in the relationship between aging and education expenditure.

Table 3: Mediation effect test

VARIABLES	Step 1	Step 2	Step 3
child_dependency	27.29* (15.20)	9.153 (9.200)	16.49* (9.708)
old_dependency	3.884 (27.13)	41.72** (15.72)	-45.33** (18.99)
social_security_exp			1.180*** (0.206)
Observations	434	434	434
R-squared	0.693	0.827	0.891
Number of province	31	31	31

Note: The numbers in parentheses are the robust standard deviations clustered at the provincial (Level *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$).

3.3 Regional Heterogeneity and Robustness Tests

The study results confirm that the impact of population aging on educational expenditure exhibits significant regional heterogeneity, with a series of robustness tests ensuring the reliability of this core conclusion. Regional regression analysis reveals that the negative impact of the elderly dependency ratio is most pronounced and statistically significant in Western regions, while being weakest and non-significant in Eastern regions characterized by higher economic development and stronger fiscal capacity. The Chow test further validates structural differences in regional coefficients ($F = 5.32$, $p < 0.01$). This indicates that Eastern regions, leveraging higher urbanization rates and stronger financial resources, effectively buffered against the fiscal impact of aging, whereas Western regions with weaker fiscal capacity and greater reliance on transfer payments have become the most vulnerable “high-risk areas,” strongly supporting Hypothesis H3. Heterogeneity test results are presented in Table 4.

Table 4: Heterogeneity Test

VARIABLES	Eastern Region	Western Region	Central Region
child_dependency	38.64** (13.54)	1.240 (4.827)	-3.202 (5.103)
old_dependency	-14.53 (13.14)	-16.39* (8.257)	0.497 (6.586)
social_security_exp	0.696*** (0.110)	1.005*** (0.163)	0.326*** (0.0615)
gdp_per_capita	0.00465* (0.00242)	-0.00364 (0.00285)	-0.00741** (0.00225)
population	0.656*** (0.0509)	0.115 (0.166)	0.520*** (0.114)
urban_ratio	28.88*** (7.323)	26.68** (10.53)	31.10** (11.24)
income_per_capita	0.000857 (0.00839)	-0.0155 (0.0156)	0.0522*** (0.0119)
cpi	-42.64** (15.03)	2.744 (10.13)	-16.54* (8.383)
Observations	140	154	112
R-squared	0.983	0.957	0.989
Number of province	10	11	8

To ensure the robustness of the above conclusions, this study underwent three rigorous tests: Firstly, after applying a $\pm 1\%$ winsorization to the core variables, the positive effect of the child dependency ratio and the mediating effect of social security expenditure remained robust. Secondly, when replacing the dependent variable with “per capita education expenditure,” the child dependency ratio became insignificant, indicating that its impact primarily manifests at the expenditure scale level, revealing the existence of scale effects. Finally, when restricting the sample period to post-2000 data, the core conclusions remained unchanged. Overall, the key findings regarding regional heterogeneity have withstood multiple methodological tests, confirming the high robustness of our research conclusions. The results of the robustness tests are presented in Table 5.

Table 5: Robustness Test

VARIABLES	Winsorize	per capita	Subsample of the 2000s generation
population	0.427*** (0.0372)	-0.0000 (0.0000)	0.554*** (0.0398)
urban_ratio	29.72*** (6.001)	0.00134 (0.00131)	20.04*** (6.559)
income_per_capita_winsor	0.0105** (0.0044)		
cpi	1.438 (11.00)	-0.00598* (0.00306)	-9.664 (12.22)
child_dependency		0.00549 (0.00384)	10.55** (5.159)
old_dependency		-0.0101** (0.00467)	-5.701 (8.278)
social_security_exp		-0.0001** (0.0000)	0.730*** (0.0944)
gdp_per_capita		0.0000(0.0000)	0.0016 (0.00254)
income_per_capita		0.0000(0.0000)	0.00301 (0.00624)
Constant	-3.667*** (1.170)	0.611* (0.323)	-2,420* (1.370)
Observations	434	434	434
R-squared	0.956	0.882	0.959
Number of province	31	31	31
Number of province	YES	YES	YES
Time fixed effects	YES	YES	YES

Note : *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

4. Policy Recommendations

This paper proposes a comprehensive policy framework to mitigate the crowding-out effect of aging on educational fiscal resources.

Firstly, optimize the central government's education transfer payment mechanism, incorporate the interaction term of "elderly dependency ratio x reciprocal of fiscal self-sufficiency rate" into the current allocation factors of urban and rural compulsory education funds, and compensate high aging and low fiscal self-sufficiency areas.

Secondly, establish a provincial-level "education elderly care" budget linkage evaluation mechanism, set a threshold for the annual decline of education expenditure, and establish a human capital development fund through channels such as transferring social security income from state-owned capital to hedge against the encroachment of elderly care expenditure on education resources [11].

Thirdly, set up "youth representatives" with no less than 10% of seats in the provincial budget review committee, giving them the right to evaluate medium and long-term education budgets, and establish a mechanism for intergenerational interest balance.

Fourthly, accelerate the nationwide pooling of pension insurance, while implementing a gradual reform of reducing enterprise contribution rates by 0.5 percentage points every two years. Through general transfer payments, guide local governments to use the fiscal space formed for education and human capital investment.

This four-dimensional policy system that integrates "fiscal compensation budget procedures governance participation parameter reform" provides an operable and quantifiable institutional template for ensuring the sustainability of education investment and promoting intergenerational equity.

5. Conclusion

Compared with existing literature, this paper's marginal contributions are reflected in four aspects: First, using a 34-year provincial panel dataset, it simultaneously identifies the distinct effects of child and elderly dependency ratios within a unified framework. Second, by incorporating "social security expenditures" as an

intermediary variable, it quantifies the magnitude and regional disparities of the fiscal crowding-out pathway from “aging-social security expenditures-educational expenditures,” addressing previous studies’ limitations in aggregate-level or correlational analysis. Third, through interaction terms between urbanization rates and regional dummy variables, it reveals heterogeneous buffering mechanisms of economic development against aging impacts, expanding discussions on population structure’s influence on fiscal expenditure boundary conditions. Fourth, based on empirical findings, it proposes actionable policies such as “education-pension budget linkage” and “youth future representation,” tightly connecting quantitative insights with institutional design to provide direct evidence for optimizing fiscal expenditure structures, ensuring intergenerational equity, and sustaining human capital accumulation.

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Research on the Development and Optimization of Financial Investment in the Context of Big Data

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Abstract

With the deep integration of big data and artificial intelligence technologies, the field of financial investment is undergoing a profound paradigm shift. This study takes the practical performance of the domestic large model DeepSeek in the “Alpha Arena” AI Trader Competition as an example, and through literature review and empirical analysis, systematically explores the technical logic and optimization pathways of intelligent financial investment. The study finds that the DeepSeek model, by integrating multi-source heterogeneous data, employing nonlinear deep learning algorithms, and implementing dynamic risk control mechanisms, has achieved a fundamental transformation of investment strategies from experience-driven to data-intelligence-driven. Based on this, the present study proposes a five-dimensional optimization framework encompassing data factor circulation, enhancement of algorithm transparency, transformation of market structure, reconstruction of regulatory adaptability, and full-cycle risk management, aiming to provide theoretical support and practical guidance for the digital transformation of financial institutions.

Keywords

big data, financial investment, DeepSeek, artificial intelligence, optimization pathway

1. Introduction

Currently, the global financial system is at a critical juncture of digital transformation. Big data has emerged as the fourth major factor of production—following land, labor, and capital—profoundly reshaping the operational models and competitive landscape of the traditional financial industry. According to forecasts by the International Data Corporation (IDC), global data volume is projected to surge to 175 zettabytes (ZB) by 2025, with an annual growth rate of 40%. By 2026, the total data volume of Chinese enterprises is expected to exceed 100 ZB. As a highly data-intensive sector, the financial industry is likely to experience data growth rates above the average, implying that the scale of data in China’s financial sector could approach or reach the 100 ZB level by 2026. Against this backdrop, the integration of artificial intelligence technologies with financial investment has become increasingly close, giving rise to the emerging field of intelligent financial investment. Its core characteristics are manifested in the high degree of synergy among data-driven approaches, algorithmic decision-making, and real-time execution.

In October 2025, during the “Alpha Arena” Global AI Trader Competition, the domestically developed DeepSeek large model stood out with outstanding performance. Under strict constraints on trading frequency

(executing only 6 trades), the model achieved a cumulative return of up to 42% while demonstrating exceptionally strong risk control capabilities: its maximum single-trade loss was effectively limited to 348 USD, with an overall profit-loss ratio approaching 4:1 [1]. This milestone event not only demonstrated the formidable competitiveness of Chinese indigenous AI models in complex financial decision-making tasks but also clearly signaled that financial investment has officially transitioned from a human-dominated, experience-driven era to a data- and algorithm-centric intelligent-driven era.

The success of DeepSeek to some extent reflects China's long-term accumulation in financial technology, the continuous improvement of big data infrastructure, and ongoing innovations in algorithmic theory. At present, leading domestic financial institutions—such as public funds Huaxia Fund and Bosera Fund, as well as top brokerages Guotai Junan Securities and Zhongtai Securities—have successively completed the private deployment of intelligent models similar to DeepSeek and applied them to core business scenarios including intelligent investment research, automated risk control, and personalized asset allocation. According to the latest survey by the China Securities Industry Association, more than 70% of securities firms have incorporated artificial intelligence technologies into investment decision-making processes, and the assets under management by intelligent robo-advisors have surpassed 5 trillion RMB.

Nevertheless, the large-scale application of artificial intelligence in financial investment also introduces new challenges and risks. Algorithm homogenization may lead to “algorithmic stampede” events, exacerbating market volatility [2]. When a large number of market participants adopt intelligent algorithms with similar logic and converging data sources, strategy effectiveness can decay rapidly, potentially triggering vicious cycles in which strategies fail simultaneously. The high complexity of intelligent investment systems poses severe tests to traditional risk management frameworks, while the “black box” nature of algorithms makes risk tracing and effective regulation extraordinarily difficult. In addition, issues such as data privacy protection, algorithmic ethical responsibility, and technological monopolies are becoming increasingly prominent and urgently require systematic solutions.

Against this background, this study stands at the interdisciplinary frontier of financial engineering and data science, employing a combination of literature review, case analysis, and comparative research methods, with the following objectives: First, using representative cases such as DeepSeek as entry points, to deeply deconstruct the underlying technical logic and paradigm-shift characteristics that enable intelligent financial investment; second, to systematically review the current research progress and core bottlenecks in this field; third, taking into account the specific environment and development stage of the Chinese financial market, to construct a multi-layered, systematic optimization pathway for the development of financial investment.

2. Literature Review

Intelligent financial investment, as an emerging interdisciplinary research field, draws its theoretical foundation from the integration of multiple disciplines, including finance, computer science, statistics, and complex systems science. In recent years, scholars have conducted extensive discussions on its technical foundations, application progress, and potential issues.

2.1 Technical Foundations of Intelligent Financial Investment

Artificial intelligence technologies, represented by deep learning, serve as the core engine driving this round of transformation in financial investment. Domestically advanced models, exemplified by DeepSeek, typically adopt complex architectures such as Transformers and Mixture-of-Experts systems. Research indicates that these models, by incorporating dynamic routing or attention mechanisms, can adaptively activate the most relevant neural network modules or expert sub-networks based on varying input data features [1]. This design not only aligns theoretically with the nonlinear and non-stationary characteristics of financial data but also achieves a favorable balance between prediction accuracy and computational efficiency in practice. Yang Dong and Huang Tao point out that another major advantage of such models lies in their increasingly enhanced engineering and deployability, with relatively low costs for fine-tuning and private deployment, significantly lowering the barriers for financial institutions—especially small and medium-sized ones—to adopt cutting-edge AI technologies and accelerating the inclusive process of intelligent investment technologies [1]. However, most current studies remain at the level of macroscopic descriptions and performance demonstrations of model applications. There is still a lack of in-depth and detailed empirical testing and

theoretical interpretation regarding the specific internal feature extraction mechanisms, the causal chains of decision formation, generalization capabilities and failure boundaries under different market regimes, such as bull, bear, and range-bound markets, as well as the intrinsic connections between model parameters and financial economic theories.

2.2 Progress in Investment Research Driven by Big Data

The rise of the intelligent investment paradigm is closely linked to the enormous enrichment of big data resources. Scholars' research perspectives are continuously expanding with the broadening of data dimensions. At the micro data structure level, distributed ledger technologies represented by blockchain naturally generate public, transparent, and tamper-proof transaction flow data. Wu Jiajing et al. argue that this provides researchers with an unprecedented fine-grained perspective for analyzing capital flows in cryptocurrency markets, identifying core holder address clusters, and characterizing complex transaction network topologies [3]. At the level of investment targets and strategies, emerging markets with high volatility and weak efficiency—such as digital finance and cryptocurrencies—have become natural “experimental fields” for testing the predictive capabilities of complex algorithms and exploring micro-market behaviors (such as herding effects and overreactions) [4]. Zhu Xiaoneng et al. (2025), in their monograph, systematically analyzed the investment logic and risk characteristics in these new financial markets, injecting fresh perspectives into traditional financial theories [4]. Nevertheless, a common deficiency in this field of research is the excessive reliance on historical backtesting. Many intelligent strategies that claim superior performance are constructed and optimized heavily based on local patterns from specific historical periods, lacking rigorous out-of-sample testing—particularly under extreme market stress scenarios not involved in training—and theoretical attribution analysis, which casts doubt on their robustness and long-term effectiveness.

2.3 Research Deficiencies and Innovation Opportunities

Synthesizing the existing literature, this study identifies three major shortcomings in current intelligent financial investment research that urgently need to be addressed, which also serve as the starting point and innovation space for this paper.

First, there is a systemic deficiency in the macroscopic theoretical framework. Existing studies are mostly distributed in a “point-like” or “linear” manner, focusing either on specific algorithm models or on certain data applications, failing to comprehensively outline—from a systems theory perspective—the profound impact on financial markets of the complete chain whereby artificial intelligence technologies proceed from underlying multi-source data fusion, to mid-level algorithmic decision-making, and then to macroscopic market structure evolution and cross-market risk contagion [5]. Intelligent finance constitutes a complex ecosystem that requires an integrated theoretical framework for understanding.

Second, at the micro-technical level, there exists a dilemma of algorithmic transparency and interpretability. The “black box” nature of deep learning models is the price paid for their powerful fitting capabilities. Huang Yiping sharply points out that this opacity not only hinders investors' understanding and trust in algorithmic decisions but also poses severe challenges to financial regulation: when regulators cannot effectively scrutinize core algorithmic logic, timely detection and suppression of potential market manipulation, algorithmic collusion, and other violations become extraordinarily difficult [2]. Breaking the “black box” to achieve trustworthy and controllable intelligent decision-making is key to the healthy development of the industry.

Finally, at the level of application in specific national contexts, there is a lack of localization and comprehensiveness in research perspectives. Many studies draw on overseas models and cases but give insufficient consideration to the unique institutional environment, investor structure, and data characteristics of China's multi-layered and multi-segment capital markets. Li Zhan's in-depth research on the investor structure and risk control in China's capital markets provides an important foundation for understanding the complexity of the domestic market [6]. Future research needs to pay greater attention to analyzing the cross-contagion mechanisms of risks potentially triggered by intelligent algorithmic trading across different markets such as A-shares, bond markets, derivatives, and digital assets, in order to construct risk control systems suited to national conditions.

3. Paradigm Shift in Intelligent Financial Investment

The outstanding performance of DeepSeek in real-world practice is not the result of a single technological breakthrough, but rather represents a comprehensive paradigm shift encompassing data, models, and risk control.

3.1 Data Dimension: From Structured to Multi-Source Heterogeneous Fusion

Traditional quantitative investment heavily relies on highly structured data such as historical prices, trading volumes, and financial indicators. While such data is well-organized and clean, its informational dimensions are relatively limited and exhibit clear lags. In contrast, the intelligent investment paradigm has achieved a fundamental transformation toward the fusion of multi-source heterogeneous big data. Investor sentiment extracted from social media texts, port logistics and factory activities captured by satellite imagery, IoT data from upstream and downstream supply chains, real-time transaction flows on blockchain, and more are all incorporated into the decision-making framework. Empirical research by Chen Hua and Chu Wenrong demonstrates that automated data pipelines constructed using natural language processing and computer vision technologies can convert unstructured information into quantitative signals with an accuracy rate exceeding 92% [7]. This has revolutionized the “information boundary” of investment decision-making.

However, multi-source data fusion also introduces new challenges, including varying data quality, inconsistent standards, and differences in timeliness, necessitating the development of more intelligent data cleaning and fusion algorithms. Conflicts may arise between different data sources—for instance, sentiment indicators from social media may send signals completely opposite to those from fundamental data. How to handle these conflicting signals and how to assign appropriate weights to different data sources have become critical issues in the design of intelligent investment systems.

3.2 Model Algorithms: From Linear Analysis to Nonlinear Deep Learning

Traditional quantitative models are predominantly based on linear regression, the Capital Asset Pricing Model (CAPM), mean-variance frameworks, and other linear or parametrically nonlinear assumptions. These models often fall short in capturing the widespread complex nonlinear interactions, dynamic time-varying relationships, and long-range dependencies present in financial markets. Models represented by DeepSeek, leveraging deep neural networks, attention mechanisms, and reinforcement learning technologies, have achieved a leap from a “human hypothesis–data validation” paradigm to a “data-driven–automatic discovery” mode.

Wang Lei and Liu Jing point out that such models can automatically mine high-dimensional, nonlinear features and patterns from massive datasets and continuously optimize themselves based on dynamic environmental feedback, demonstrating stronger adaptability and predictive power in high-noise, high-volatility markets [8]. Nevertheless, the complexity of deep learning models also brings risks of overfitting, poor interpretability, and high training costs. Particularly when market structures undergo fundamental changes, models trained on historical data may fail to adapt to new market environments, resulting in the failure of investment strategies. The massive market shocks triggered by the 2020 COVID-19 pandemic exposed the vulnerability of many intelligent models, as these models had never encountered such extreme market conditions in their training data, resulting in a sharp decline in their predictive and decision-making capabilities.

3.3 Risk Control System: From Static Thresholds to Dynamic Scenario Awareness

Traditional risk control systems typically rely on static risk metrics calculated through historical data backtesting and periodic evaluation frequencies. This approach responds slowly and fails to distinguish between different market scenarios, rendering it prone to fail in extreme conditions. The core of the new generation of intelligent risk control systems is “dynamic scenario awareness.” Relying on streaming computation engines and complex event processing technologies, these systems enable millisecond-level real-time monitoring of investment portfolios.

More importantly, by integrating reinforcement learning and simulation technologies, the system can construct a virtual “parallel market” in which thousands of path simulations are performed on the current portfolio under various market scenarios. On this basis, the system can not only dynamically compute real-

time risk values but also proactively and predictively adjust risk mitigation measures. This marks the evolution of risk control from a passive, rule-based “threshold alarm” to an active, prediction-driven “intelligent autopilot.”

4. Optimization Pathways for the Development of Financial Investment

To address the opportunities and challenges brought by this paradigm shift and to promote the healthy and steady intelligent transformation of the financial investment industry, this study constructs a systematic optimization framework comprising five dimensions.

4.1 Building a Secure and Efficient Data Factor Circulation Ecosystem

Data serves as the “oil” of intelligent finance, yet its circulation and application face numerous obstacles such as unclear ownership rights, privacy leakage risks, and pricing difficulties. The first step in the optimization pathway is to construct a “trustworthy data infrastructure.” On the technical path, active exploration should be undertaken to integrate blockchain technology with privacy-preserving computing techniques such as federated learning and secure multi-party computation. Blockchain can provide an immutable ledger for data ownership verification, access logging, and transaction tracing, while technologies like federated learning enable data to be “usable yet invisible,” fundamentally resolving the contradiction between data privacy and collaborative computation.

In terms of application scenarios, efforts should be made to promote the compliant integration of cross-domain data—such as meteorology, environment, and logistics—with financial data. This will offer unprecedented multi-dimensional perspectives for assessing macroeconomic trends and industry prosperity. For example, combining meteorological data with agricultural insurance product design can lead to the development of more precise weather derivatives; integrating logistics data with supply chain finance can enable real-time evaluation of supply chain health and early warning of potential risks.

4.2 Enhancing Transparency and Robustness of Intelligent Algorithms

The reliability and trustworthiness of algorithms form the cornerstone of the long-term development of intelligent finance. This requires coordinated advancement at both the model design and external regulatory levels. At the model design level, priority should be given to developing algorithms capable of fusing data across different frequencies, thereby integrating macroeconomic cycle signals, meso-level industry signals, and micro-level trading signals. At the same time, causal inference frameworks should be actively introduced to advance models from correlation mining to causal relationship exploration, thereby enhancing the logical interpretability of strategies.

At the regulatory coordination level, the mandatory adoption of explainable artificial intelligence techniques in core models must be enforced, requiring visual and logical attribution analysis for key decisions. Regulatory authorities should also establish mechanisms for assessing the diversity of algorithmic strategies to prevent systemic resonance risks arising from strategy homogenization in the market. Furthermore, routine adversarial sample testing and extreme stress scenario simulation exercises should be conducted to ensure algorithmic stability under extreme market conditions.

4.3 Elastic Transformation of Market Structure

The widespread adoption of intelligent algorithms is reshaping market microstructures, and market infrastructure itself must undergo adaptive evolution to enhance resilience. At the trading mechanism level, exchanges may consider rule innovations. For instance, introducing order types or fee structures that reward the provision of differentiated and genuine liquidity, as well as offering fee reductions or other incentives to algorithmic strategies that continue to provide liquidity during periods of market stress, can institutionally prevent the risk of sudden liquidity evaporation caused by synchronized algorithmic withdrawals due to homogenization.

At the technical support level, regulatory authorities should take the lead in building market monitoring platforms based on multi-agent simulation. Such platforms can simulate interactions among different strategies in virtual markets, thereby enabling real-time early warning and stress testing for potential liquidity dry-up

points and cross-market risk contagion. These simulation platforms can become an important component of the regtech ecosystem, helping regulators transition from a “post-event handling” to a “pre-event foresight” regulatory paradigm.

4.4 Reconstructing a Regulatory System Adaptive to Technological Development

In the face of technology-driven financial innovation, the regulatory system requires greater intelligence, stronger flexibility, and more advanced tools. In terms of institutional design, the regulatory sandbox regime should be further improved and promoted, providing a risk-isolated real-world testing environment for genuinely innovative fintech applications and establishing a dynamic balancing mechanism between encouraging innovation and preventing risks. China’s fintech regulatory sandbox pilots have already achieved initial success; the next step should be to expand the pilot scope, refine evaluation and promotion mechanisms.

In terms of regulatory capacity building, regtech must be vigorously developed. This means that regulatory authorities themselves need to deeply employ big data, artificial intelligence, and other technologies for self-empowerment—using natural language processing to automatically review massive volumes of disclosure texts, and knowledge graph techniques to map complex networks of related-party transactions—thereby enhancing penetrating and full-coverage supervisory capabilities over modern financial markets.

4.5 Upgrading a Full-Cycle Intelligent Risk Management System

The risk management system must evolve in sync with the development of intelligent investment—and even be deployed ahead of time. At the cutting edge of technological application, the construction of “digital twin” risk control systems for investment portfolios can be explored. By synchronizing real portfolio data in real time, these systems perform millisecond-level scenario deductions and stress tests in a virtual space. This approach provides more comprehensive and in-depth risk assessments for analyzing extreme yet possible “black swan” events.

In terms of risk governance architecture, a three-tier collaborative defense system—micro, meso, and macro—should be established. At the micro level, the principal responsibility of financial institutions should be reinforced by requiring them to set up independent model validation teams. At the meso level, exchanges, industry associations, and similar organizations should establish overall market algorithmic strategy databases and crowding indices. At the macro level, regulatory authorities need to research and formulate counter-cyclical adjustment tools targeted at algorithmic trading, mitigating systemic vulnerabilities from a macroprudential perspective. Notably, intelligent risk management should not completely replace human judgment. At the most critical risk decision points, human override mechanisms must be retained to ensure human intervention and final decision-making in the event of system anomalies or extreme situations.

5. Conclusion

This study systematically dissects the profound paradigm shift occurring in the field of financial investment under the impact of the big data and artificial intelligence technology wave, revealing the core characteristics from data fusion and algorithm evolution to risk control upgrading. On this basis, it innovatively proposes a systematic optimization framework encompassing five dimensions: data ecosystem, algorithm governance, market structure, regulatory system, and risk management. The framework emphasizes that the intelligent transformation of financial investment is a complex systems engineering project involving technology, institutions, markets, and regulation. Only through multi-party collaboration and comprehensive measures—while encouraging technological innovation and at the same time strengthening the dam of risk prevention and control—can we guide China’s financial technology toward steady and far-reaching development, truly enhancing the efficiency and quality of financial services in support of the real economy.

The development of intelligent financial investment in China possesses unique advantages and challenges. Its advantages lie in the enormous market size, abundant data resources, leading digital infrastructure, and strong policy support; the challenges include relatively low market maturity, a distinctive investor structure, and restrictions on cross-border capital flows. Therefore, the development path of intelligent financial investment in China should not simply copy foreign models but should explore an independent innovation route that aligns with national conditions and characteristics.

Looking ahead, relevant research and practice still need to deepen exploration in the following directions: First, research on algorithmic robustness under extreme market conditions, particularly in the Chinese market environment characterized by frequent policy interventions and active retail trading, where robustness testing must pay greater attention to indigenous features. Second, assessment of the ethical and social impacts of intelligent finance, necessitating the establishment of corresponding ethical guidelines to prevent algorithmic discrimination and protect the rights and interests of financial consumers. Third, deep integration of financial theory and artificial intelligence theory, leveraging AI technologies to discover new financial regularities and develop new financial theories adapted to the intelligent era.

It is foreseeable that, with continuous technological iteration and ongoing institutional improvement, intelligent financial investment will evolve toward greater efficiency, transparency, and resilience. This process is not only a self-renewal of the financial industry but will also contribute Chinese wisdom and Chinese solutions to the stability and innovation of the global financial system.

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The Impact of Negative Public Sentiment on Stock Price Volatility: A Case Study of Qiaqia Food

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Abstract

In the digital economy era, the deep integration of digital technologies and social media has enabled negative public sentiment to break through spatiotemporal constraints, with its dissemination speed and impact scope expanding exponentially. Its diffusion intensifies market information asymmetry, triggers short-term violent fluctuations in stock prices, and has become a critical risk variable affecting the stable operation of the capital market. Previous traditional studies have mostly relied on linear assumptions to investigate the relationship between negative public sentiment and stock prices, failing to fully reveal the complex dynamics potentially induced by investors' irrational behavior. To address this gap, this study takes Qiaqia Food Co., Ltd., a representative enterprise in China's food industry, as the research object. Through manually collected data and empirical analysis methods, it innovatively constructs a quadratic polynomial regression model to deeply explore the nonlinear mechanism by which negative public sentiment affects stock price volatility and to empirically examine the moderating role of media authority attributes. The following conclusions are drawn: there exists a significant inverted U-shaped relationship between the intensity of public sentiment and cumulative abnormal returns (CAR). Moreover, after controlling for sentiment intensity, reports from authoritative media can effectively buffer market panic. The theoretical contributions of this study are reflected at two levels. First, by constructing a quadratic polynomial model, it breaks through the previous analytical paradigm that relied on linear relationships, providing a basis for quantifying the dynamic changes in the impact of public sentiment. Second, it analyzes the moderating effect of media authority attributes, laying a solid foundation for subsequent in-depth research.

Keywords

negative public sentiment, stock price volatility, nonlinear relationship, quadratic polynomial model, media authority attribute

1. Introduction

In the digital economy era, the precise reach of algorithmic recommendations and the viral dissemination of social media have joined forces, causing the spread speed and impact scope of negative public sentiment—a typical form of “bad news”—to expand exponentially, completely breaking through the spatiotemporal barriers and circle limitations of traditional communication [1]. From Weibo hot searches to Douyin trending topics, negative public sentiment can cover diverse groups—including individual retail investors, institutional

investors, and industry regulators—within a short time, and its impact on the stable operation of the capital market has become increasingly prominent.

This phenomenon is particularly pronounced in the food industry, which is closely related to people's livelihood and well-being: because the food industry directly concerns public health and safety, consumers and investors exhibit far higher sensitivity to relevant negative information than in other industries, and the negative effects are more targeted and devastating. Whether substantive safety issues such as substandard product quality, violations in production processes, or packaging and storage problems, or reputation-related negative rumors, all can spread rapidly through the internet in a viral manner, triggering investors' risk-averse psychology and panic selling behavior [2]. Such shocks not only cause the stock prices of the affected companies to plummet in the short term and result in severe market value shrinkage, but may also generate a "domino effect," implicating other compliant enterprises in the industry and even extending to the entire sector. Therefore, studying the underlying mechanisms by which negative public sentiment affects stock price volatility is not only a frontier topic at the intersection of finance and communication studies, but also a practical requirement for maintaining the stable operation of the capital market. Given the high relevance of the food industry to people's livelihood and well-being, this study focuses on this field and selects Qiaqia Food Co., Ltd.—a representative Chinese food industry enterprise that has experienced several major negative events with far-reaching impact and wide dissemination between 2015 and 2025—as the specific research object.

When exploring the relationship between public sentiment and stock prices, previous studies have mostly been based on the assumption of "linear impact." For example, Tetlock's research employed linear models and concluded that negative sentiment intensity is linearly negatively correlated with the magnitude of stock price declines—specifically, that for every one-unit increase in the proportion of negative words in media coverage, abnormal stock returns decline linearly. However, investor behavior in real markets cannot be adequately captured by linear models. Behavioral finance points out that investors exhibit significant psychological biases, such as loss aversion and overreaction, and their processing of information often displays nonlinear characteristics. When the intensity of negative public sentiment exceeds a certain threshold, investors' emotions may shift from rationality to panic, leading to a "tipping point" phenomenon of accelerated market declines. Moreover, existing literature provides relatively scarce empirical testing of nonlinear dynamic mechanisms. Therefore, building upon prior research, this study innovatively adopts a "nonlinear" model by introducing the quadratic term of negative public sentiment as a variable to thoroughly investigate its impact on stock price volatility.

In addition, the channels of information dissemination are also a key variable affecting market reactions. Authoritative media, with their credibility and influence, play an irreplaceable role in information verification and public opinion guidance. Existing studies have shown that media attributes can moderate the credibility and dissemination effects of information; however, in the process of negative public sentiment impacting stock prices, whether it amplifies the destructive power of public sentiment or alleviates market panic, along with the specific pathways and effects involved, remains unclear with inconsistent conclusions in direct empirical evidence. In particular, the complex interaction between the credibility of authoritative media and the emotional contagion of public sentiment constitutes a current research gap. Therefore, this study incorporates media authority attributes into the model to deeply explore their role in the framework of negative public sentiment's impact on stock price volatility.

This study takes the "mechanism of the impact of negative public sentiment on stock price volatility" as its core objective and employs rigorous empirical analysis methods, integrating behavioral finance and information asymmetry theories, to conduct an in-depth investigation of the relationship between negative public sentiment and stock price volatility. Recognizing that traditional linear models struggle to accurately capture the nonlinear characteristics of stock price shocks during the escalation of public sentiment intensity, this study innovatively constructs a quadratic polynomial regression econometric framework. By introducing the quadratic term of public sentiment intensity, it breaks through the existing simple linear understanding of the relationship between the two. The study not only aims to systematically examine the transmission mechanisms between negative public sentiment and stock price volatility and clarify the quantitative association between sentiment intensity and stock price movements, but also seeks to thoroughly analyze the moderating mechanism of media authority attributes in this process—testing the differentiated roles of

authoritative and non-authoritative media in public sentiment transmission and exploring whether they can mitigate or amplify the impact of negative public sentiment on stock prices.

From a theoretical perspective, this study further enriches the academic research system on the relationship between negative public sentiment and stock prices in two ways: first, by introducing the quadratic term of public sentiment intensity to construct a nonlinear econometric model, it transcends the traditional singular linear cognition of the relationship, providing a new analytical framework for parsing the dynamic evolution patterns of stock price volatility under escalating public sentiment intensity and remedying the deficiencies of existing research in nonlinear mechanism testing; second, by incorporating media authority attributes as a moderating variable, it clarifies the differentiated action mechanisms of media with different attributes in the relationship between public sentiment and stock prices, offering empirical references for subsequent studies on moderating effects.

From a practical perspective, the conclusions of this study can provide targeted guidance for corporate decision-making: enterprises can optimize risk management strategies based on the nonlinear characteristics of public sentiment intensity, rationally allocate resources for responding to different levels of public sentiment, and simultaneously reduce the market impact of negative public sentiment by choosing authoritative media for information disclosure and public relations responses. For the industry, the research results can serve as a reference for improving public sentiment governance systems in the food industry and promoting rational investor decision-making, helping the industry build a more robust trust mechanism and risk prevention system, and advancing the high-quality coordinated development of the capital market and the food industry.

2. Theoretical Foundation and Related Concepts

2.1 Behavioral Finance Perspective

The efficient market hypothesis of traditional finance asserts that asset prices can fully and promptly reflect all available information, with investors acting rationally [3]. However, phenomena such as abnormal stock price fluctuations and herding effects do exist in reality, posing a clear challenge to traditional finance. Therefore, behavioral finance introduces a psychological perspective, systematically revealing the cognitive biases and emotional factors present in investors' decision-making processes, thereby providing the core theoretical foundation for understanding the market's irrational responses to negative public sentiment [4]. The loss aversion principle in prospect theory reveals that investors experience far greater panic when facing losses than the joy derived from equivalent gains. This asymmetric psychological phenomenon often results in the impact of negative public sentiment far exceeding the actual shock it can cause to the market. Moreover, the value function curve of this theory exhibits convex characteristics in the loss domain, meaning that as the intensity of public sentiment increases, the marginal pain felt by investors shows an increasing trend. This constitutes the mechanistic foundation of the present study: the impact of negative public sentiment on stock price volatility exhibits accelerating features, far from a simple linear relationship. At the same time, investors' information processing capacity is also one of the research dimensions of behavioral finance, referring to the inherent limitations of investors' ability to process information. The limited attention theory points out that, in today's information-explosion market, high-impact negative public sentiment—owing to its salience and emotional shock—tends to exceed investors' cognitive boundaries more readily and interferes with their decision-making to a greater extent [5]. Studies show that cognitive biases such as overconfidence, ambiguity aversion, loss aversion, and anchoring collectively influence investors' decisions. This bias in attention allocation further triggers information cascade effects, forming waves of market selling [6].

2.2 Information Asymmetry Theory

In financial market trading mechanisms, information asymmetry is a core element of market microstructure theory, continuously affecting asset pricing efficiency and the stable operation of markets. Different market participants exhibit systematic differences in information acquisition channels, information processing capabilities, and levels of professional analysis. In this study, this implies significant disparities among insiders of listed companies, institutional investors, and retail investors in the timing of accessing negative public sentiment and the depth of understanding it. Such information differences mean that retail investors, when confronted with negative public sentiment, are unable to accurately judge the authenticity and reliability of the

news in a short time, nor can they precisely assess its potential impact on the company's value. In such circumstances, they typically rely on industry-average valuation levels for the company, a behavior that accelerates stock price declines and may even trigger the "lemons market" phenomenon, i.e., the adverse selection process in which inferior companies drive out superior ones [7].

Furthermore, in the era of deep digital media penetration, this phenomenon is further amplified. Digital dissemination channels such as short videos exacerbate information oversupply; in an environment of information explosion, this substantially increases the cost of screening effective information, making it even more difficult for information-disadvantaged parties to distinguish key information [8]. When facing uncertainty, information-disadvantaged investors experience a sharp amplification of inherent behavioral biases such as loss aversion and mental accounting; they are more inclined to rely on the representativeness heuristic, overgeneralizing from individual negative events and thereby triggering collective overreactions [6]. Under the interaction of information asymmetry and investor cognitive biases, stock prices ultimately exhibit nonlinear responses to negative public sentiment, resulting in the accelerated stock price declines observed in this study.

2.3 Media Authority Attributes

In the digital media era of information explosion, the complexity and diversity of information sources make media authority attributes a key factor influencing the effectiveness of information dissemination. Media authority refers to the degree of audience trust that media organizations gain through their professionalism, credibility, and influence [1]. In the mechanism by which negative public sentiment affects stock price volatility, media authority attributes not only influence the credibility of information but also play an important moderating role in investors' decision-making.

The moderating role of media authority attributes in the process of negative public sentiment affecting stock price volatility is primarily reflected in the following three aspects:

First, in terms of information verification, authoritative media possess professional teams and strict review mechanisms to verify the authenticity of negative public sentiment. The involvement of authoritative media can effectively curb the spread of false information and reduce abnormal market price fluctuations caused by distorted information [9].

Second, at the level of rational guidance, authoritative media analyze industry backgrounds and data, and feature expert commentary. This helps investors identify the most authentic and useful information amid diverse sources, breaking the information cocoon effect and providing multi-dimensional considerations for decision-making, thereby effectively mitigating overreactions caused by information asymmetry.

Third, at the level of emotional stabilization, authoritative media possess strong credibility that can effectively stabilize market sentiment. Their statements enhance the accuracy of information, reduce investors' panic over unknown information, and thereby alleviate the spread of market panic.

3. Research Hypotheses on the Impact of Negative Public Sentiment on Stock Prices

Based on the frameworks of behavioral finance, information asymmetry theory, and media authority attributes theory, this study constructs a quadratic regression model of negative public sentiment's impact on stock price volatility. It aims to deeply explore the nonlinear relationship between the intensity of negative public sentiment and cumulative abnormal returns (CAR), as well as the moderating role of media authority attributes therein, and proposes the following hypotheses:

3.1 Nonlinear Relationship between Negative Public Sentiment Intensity and Stock Price Volatility

In traditional linear models, the impact of negative public sentiment on stock prices is assumed to be constant. However, according to prospect theory in behavioral finance, investors' sensitivity to losses exhibits convex functional characteristics, that is, as losses increase, the marginal pain experienced by investors shows an increasing trend. Therefore, when the intensity of negative public sentiment is relatively low, investors can still maintain rational judgment. Yet once the intensity exceeds a certain critical threshold, investors' panic

emotions increase significantly, triggering irrational panic selling behavior and thereby intensifying the decline in stock prices. Meanwhile, information asymmetry theory also reveals that information-disadvantaged investors, when facing high-intensity negative public sentiment, are more likely to rely on the representativeness heuristic, overgeneralizing from individual events and triggering collective overreactions [8]. This paper proposes the following hypotheses:

H1: There is a significant negative relationship between the intensity of negative public sentiment and cumulative abnormal returns (CAR).

H2: There exists an accelerating negative nonlinear relationship between the intensity of negative public sentiment and CAR.

3.2 Moderating Role of Media Authority Attributes

Media authority attributes play a crucial role in the mechanism by which negative public sentiment affects stock price volatility. Drawing on information asymmetry theory and media authority theory, authoritative media—by virtue of their credibility and professionalism—provide investors with accurate and reliable information, thereby reducing investors' panic over unknown information. The authority attributes of media can significantly influence the dissemination effect of public sentiment, as statements from authoritative media can guide investors toward rational judgments, serving as market stabilizers and alleviating the excessive panic caused by negative public sentiment.

H3: Media authority attributes have a significant positive impact on CAR.

4. Empirical Research

4.1 Data Sources

This study takes Qiaqia Food Co., Ltd. (stock code: 002557) as the research object. Qiaqia Food Co., Ltd. was listed in 2011 and is the first listed company in China's nut and roasted seeds industry, pioneering the industry's standardized and capitalized development. Its core business covers the production and sales of nut roasted seeds, baked goods, and potato chip leisure snacks. Flagship products such as Red Bag Fragrant Sunflower Seeds, Blue Bag Flavored Sunflower Seeds, and Small Yellow Bag Daily Nuts are household names. The company is a representative enterprise in China's food industry and experienced several major negative events with far-reaching impact and wide dissemination between 2015 and 2025. Therefore, studying it holds representative significance. The data for this study are derived from negative public sentiment events of the company occurring between 2015 and 2025. Due to restrictions imposed by anti-crawling technologies, all data were manually collected. Specific sources include authoritative media platforms such as Xinhuanet and People's Daily, social media platforms such as Weibo where negative events were mentioned, as well as announcements from Qiaqia Food Co., Ltd. and regulatory authorities.

4.2 Data Preprocessing

To ensure the rigor and reliability of the data, this study applied strict preprocessing to the raw data in the following manner. First, a screening for public sentiment intensity was conducted to ensure that all collected events possessed sufficiently high public sentiment intensity, i.e., they were widely known to the majority of people and capable of exerting a measurable impact on the market. Ultimately, 80 valid event samples were collected, covering food safety incidents (event type = 1) and other types of incidents (event type = 0), ensuring diversity and representativeness of event types. Although the sample size is relatively small, this approach is widely accepted in in-depth studies targeting specific enterprises. Relevant studies have demonstrated that rigorously designed small samples in event studies can still yield reliable statistical inferences [10]. In addition, this paper adopts the event study method, using the event day as the benchmark ($t = 0$), selecting the $[-5, +5]$ event window, estimating normal returns with the market model, and calculating CAR. Samples are retained only if $|CAR| \geq 3\%$ or public sentiment intensity ≥ 7.5 . The CAR calculation formulas are as follows:

Abnormal return:

$$AR_{i,t} = R_{i,t} - R_{m,t}$$

$$R_{i,t} = \frac{P_{i,t} - P_{i,t-1}}{P_{i,t-1}} \times 100\%$$

$$R_{m,t} = \frac{I_{m,t} - I_{m,t-1}}{I_{m,t-1}} \times 100\%$$

where, $AR_{i,t}$ is the abnormal return of stock i on day t ; $R_{i,t}$ is the actual return of stock i on day t ; $R_{m,t}$ is the expected (normal) return on day t ; $P_{i,t}$ and $P_{i,t-1}$ are the closing prices of the stock i on day t and day $t-1$, respectively, and $I_{m,t}$ and $I_{m,t-1}$ being the closing indices of the market on day t and day $t-1$, respectively.

Cumulative abnormal return:

$$CAR_i(t_1, t_2) = \sum_{t=t_1}^{t_2} AR_{i,t}$$

4.3 Variable Measurement

4.3.1 Comprehensive Measurement of Public Sentiment Intensity (X_1)

To overcome the limitations of traditional studies that measure public sentiment intensity solely through the number of reports or sentiment polarity, this study follows the core logic of “multi-dimensional comprehensive evaluation” and “differentiated weight assignment” in quantifying public sentiment intensity (X_1). The aim is to construct a comprehensive indicator that can fully and objectively reflect the market penetration power of negative public sentiment. The core lies in viewing negative public sentiment as an “information flow,” whose impact intensity on the market primarily depends on its combined performance in the domains of authoritative sources and public emotion.

First, the quantification time window is strictly limited to the critical 72-hour period following event exposure. Data are collected through two parallel paths: the media dissemination path and the social-emotional path.

On the media dissemination path, source authority is taken as the core measurement dimension and operationalized according to the hierarchical structure of media credibility and influence: central-level and national financial authoritative media are assigned a weight of 2 points, while provincial- and municipal-level mainstream media are assigned a weight of 1 point. This weighting scheme is based on the significant advantages of higher-tier media in reputation, coverage, and agenda-setting capability; their reports transmit stronger signals to the market and more effectively shape public cognition [11].

On the social-emotional path, to avoid bias from a single platform, this study simultaneously collects Weibo reading and discussion volumes along with Douyin video play volumes to measure the breadth of public sentiment dissemination. Sentiment analysis technology is employed to calculate the average negative sentiment confidence score of comment texts, yielding an indicator of public emotional intensity.

Second, the two paths are integrated: the initial data obtained above are subjected to Z-score standardization, and the standardized data are synthesized following multi-dimensional comprehensive evaluation methods [12].

4.3.2 Measurement of Media Authority (X_2)

This study holds that, in the complex modern information ecosystem, media authority is not a single attribute but a composite of institutional status, content professionalism, and social credibility. Therefore, media are clearly divided into “authoritative media” and “non-authoritative media.” Authoritative media include government official information release channels, central-level comprehensive and professional media, and national core financial media; all others are classified as non-authoritative media. In quantification, this study adopts the dummy variable method. If the first exposure or key defining report of a negative public sentiment event originates from the aforementioned authoritative media category, the media authority attribute variable (X_2) is assigned a value of 1; otherwise, it is assigned a value of 0.

4.4 Research Design

Based on the econometric analysis framework of the event study method, this study constructs a quadratic polynomial regression model to test the nonlinear impact mechanism of negative public sentiment on stock price volatility and to explore the moderating role of media authority. The following quadratic polynomial regression model is established:

$$Y_{CAR} = \beta_0 + \beta_1 X_1 + \beta_2 X_1^2 + \beta_3 X_2 + \varepsilon$$

where Y_{CAR} is the cumulative abnormal return within the event window; X_1 is the comprehensive score of public sentiment intensity; X_1^2 is its squared term, used to verify possible nonlinear effects; X_2 is media authority (dummy variable); and ε is the random error term.

According to the behavioral finance theory presented earlier, the introduction of the quadratic term is based on the theory's indication that investors' sensitivity to losses exhibits convex functional characteristics, i.e., marginal pain increases as losses grow. If β_2 is significantly negative, it indicates that the negative impact of public sentiment on stock prices intensifies with increasing sentiment intensity, thereby validating Hypothesis H2.

5. Empirical Analysis

5.1 Regression Results and Findings

Table 1: Descriptive Statistics Results

variable	coefficient	standard error	T value	P value
constant term	-37.6067	18.1712	-2.07	0.0441
Public opinion influence degree	102.2598	42.6653	2.40	0.0207
Square term of public opinion impact	-73.5557	24.8287	-2.96	0.0048
Media Authority Attribute	0.5652	0.2626	2.15	0.0366

The results in Table 1 lead to the following conclusions: The coefficient of the linear term β_1 of public sentiment intensity (X_1) is 102.2598, which is significantly positive at the 5% level; the coefficient of its squared term (β_2) is -73.5557, which is significantly negative at the 1% level. These two coefficients jointly validate Hypothesis H2, confirming a significant inverted U-shaped (initially rising then declining) nonlinear relationship between negative public sentiment intensity and CAR. This finding breaks through the limitations of traditional linear models, indicating that the impact of public sentiment on the market has a critical threshold. Once this threshold is exceeded, the cumulative effect of negative emotions dominates the market, leading to accelerated stock price declines. The coefficient of the media authority attribute (X_2) is 0.5652, which is significantly positive at the 5% level, supporting Hypothesis H3. This indicates that, all else being equal, negative public sentiment events first reported by authoritative media result in an average stock price abnormal decline that is approximately 0.57 percentage points smaller than those reported by non-authoritative media.

In addition, to more intuitively understand the characteristics of the inverted U-shaped relationship, this study calculates the marginal effect of public sentiment intensity (X_1) on CAR. Within the sample observation range of X_1 , all marginal effects are negative, and their absolute values increase monotonically with X_1 , exhibiting the characteristic of "accelerating negative impact."

5.2 Model Evaluation

Table 2: Diagnostic Test Results

Inspection Item	statistic	P value
Jarque-Bera normality test	1.148	0.563
Heteroscedasticity test	Breusch-pagan: LM=4.796 White: LM=7.123	0.187 0.130

To ensure the reliability of the research conclusions, this study conducted rigorous statistical diagnostics on the baseline quadratic regression model. The diagnostic results in Table 2 indicate that the model satisfies the core assumptions of classical linear regression, and its statistical inferences are highly valid.

First, the model residuals passed the normality test. The Jarque-Bera test statistic is 1.148, with a corresponding p-value of 0.563, which is well above the 0.1 significance level. This means we cannot reject the null hypothesis that the residuals follow a normal distribution. The normality of residuals is an important foundation for parametric significance tests (such as t-tests and F-tests). The satisfaction of this condition ensures the rigor of subsequent statistical inferences regarding the significance of regression coefficients.

Second, the model does not suffer from heteroscedasticity. This study employed both the Breusch-Pagan test (LM=4.796, p=0.187) and the White test (LM=7.123, p=0.130), which is more robust to nonlinear forms, for cross-validation. The p-values of both tests exceed 0.1, indicating the absence of heteroscedasticity.

6. Conclusion

This study, grounded in behavioral finance and information asymmetry theory, constructs a quadratic polynomial analysis framework of “negative public sentiment intensity—media authority attribute—cumulative abnormal returns,” taking a representative enterprise in China’s food industry as the research object. It empirically examines the nonlinear impact mechanism of negative public sentiment on stock price volatility. Through systematic analysis of 50 valid public sentiment events, the study mainly draws the following conclusions:

First, the research confirms that negative public sentiment exerts a significant “accelerating impact” nonlinear effect on stock price volatility. The regression model shows that the combination of coefficients for public sentiment intensity (X_1) and its squared term (X_1^2) clearly reveals an inverted U-shaped relationship between the two. This finding implies that, for negative public sentiment that has already attracted public attention, its market destructive power is not released at a constant rate but exhibits continuously worsening accelerating characteristics. This conclusion provides empirical support for the principles of loss aversion and limited attention theory in behavioral finance.

Second, the study finds that media authority attributes play an important risk-buffering role in the impact of negative public sentiment on stock price volatility. After controlling for public sentiment intensity, negative events first exposed by authoritative media result in significantly smaller abnormal stock price declines compared to those reported by non-authoritative media. This indicates that authoritative media, by virtue of their credibility, professional information verification capabilities, and rational public opinion guidance, can effectively alleviate market over-panic triggered by information ambiguity and emotional contagion.

At the theoretical level, this study breaks through the limitations of traditional linear models. By introducing the quadratic term, it not only verifies the existence of a nonlinear relationship but also precisely depicts the dynamic process of “accelerating deterioration” in the influence of public sentiment, providing a more refined theoretical model for understanding the complex interaction between investor emotions and market prices. At the same time, incorporating media attributes as a moderating variable enriches the research on public sentiment transmission mechanisms.

At the practical level, this study provides guidance for corporate decision-making and risk management measures regarding negative public sentiment. Enterprises can rationally allocate resources and promptly adjust strategies based on the nonlinear characteristics of negative public sentiment intensity identified in this study. At the same time, responding through authoritative media for public relations can, to a certain extent, reduce the impact of negative public sentiment on stock prices.

Also, this study has limitations. Due to its focus on a specific industry and reliance on manual data collection, the sample size is relatively small. Future research can expand to multiple industries and larger samples to test the universality of the conclusions.

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Corporate ESG Performance and Audit Fees: Evidence from Chinese A-Share Listed Companies

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Abstract

Corporate ESG performance has emerged as a core indicator for evaluating a firm's sustainability and risk profile. Given the growing emphasis on risk-based approaches to audit pricing, how auditors assess the risks associated with corporate ESG performance remains a critical issue that warrants in-depth exploration. This study reveals that superior corporate ESG performance is significantly associated with lower audit fees. Mechanism tests show that strong ESG performance effectively mitigates corporate operating risk. This mitigation significantly reduces the audit risks perceived by auditors, which in turn optimizes audit procedures and ultimately lowers audit fees. Heterogeneity analysis reveals that this negative relationship is more pronounced in firms audited by non-Big Four accounting firms and those that do not hold shares in financial institutions. This study provides novel empirical evidence for audit pricing mechanisms from an ESG perspective and enriches the existing literature on the economic consequences of corporate ESG performance.

Keywords

ESG performance, audit fees, operating risk, mechanism test

1. Introduction

The Third Plenary Session of the 20th Central Committee of the Communist Party of China emphasizes the need to perfect the modern corporate system with Chinese characteristics, supporting and guiding various enterprises to improve resource utilization efficiency, enhance management practices, and fulfill social responsibilities. Corporate ESG (Environmental, Social, and Governance) performance serves as an evaluation metric for a firm's practices in environmental protection, social responsibility, and corporate governance [1]. It reflects the principles of sustainable development that balances economic growth, environmental protection, and social justice [2]. With the continuous advancement of the “Dual Carbon” strategy (carbon peak and carbon neutrality) and the growing popularization of sustainable development concepts, corporate ESG performance has become a core indicator for assessing a firm's comprehensive competitiveness, risk management capabilities, and sustainable development potential. Its value in optimizing resource allocation, improving operational stability, and enhancing market recognition is becoming increasingly prominent. Furthermore, it provides a crucial reference for information intermediaries in the capital market to fulfill their duties.

As core information intermediaries in the capital market, auditors audit corporate financial statements to provide reasonable assurance that they are free from material misstatement, thereby enhancing the reliance of

intended users on these statements. In recent years, several accounting firms have faced regulatory sanctions due to their failure to effectively identify ESG-related risks and fulfill their assurance responsibilities. This not only damages the reputation of the certified public accountant (CPA) profession but also underscores the importance for auditors to accurately identify ESG risks and reasonably determine audit fees.

Audit fees, resulting from the negotiation between the demand and supply sides of audit services, directly reflect the auditors' time input and practice costs, while also incorporating their assessment of corporate audit risks. Based on this premise, this study utilizes the comprehensive ESG score as the measurement indicator to investigate the relationship between corporate ESG performance and audit fees.

Using China's A-share listed companies from 2014 to 2024 as the research sample, this study finds that better corporate ESG performance is significantly associated with lower audit fees. Mechanism analysis indicates that strong ESG performance can reduce firms' operating risk, thereby lowering the audit risk perceived by auditors. Consequently, auditors do not need to allocate excessive audit resources or perform additional audit procedures, which ultimately leads to a reduction in audit fees. Furthermore, the negative relationship between corporate ESG performance and audit fees is more pronounced when the auditing firm is a non-Big Four accounting firm and when the audited firm does not hold shares in other financial institutions.

The potential contributions of this study are mainly reflected in the following aspects.

First, this study enriches the literature on the economic consequences of ESG performance by examining the internal logic through which ESG affects external audit pricing, thereby filling the research gap concerning how non-financial information influences pricing mechanisms. Second, it extends the literature on the determinants of audit fees. By incorporating ESG performance into the analytical framework of audit pricing and conducting heterogeneity tests based on auditor type and corporate ownership structure, this study highlights the important role of non-financial information in risk-oriented auditing. Finally, this study contributes to the theoretical framework of audit pricing under a risk-oriented audit approach by revealing the underlying mechanism through which ESG performance influences operating risk, alters auditors' risk perceptions, and subsequently affects audit pricing, thereby providing insights for auditors to optimize pricing strategies and enhance their risk identification capabilities.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature and develops the research hypotheses. Section 3 presents the research design. Section 4 reports the empirical results and further analyses. Section 5 concludes the paper and offers recommendations.

2. Literature Review and Research Hypotheses

2.1 Literature Review

2.1.1 Determinants of Audit Fees

As the demand side of audit services, the intrinsic attributes of the auditee directly determine the audit workload and the baseline of audit risk, serving as the core determinants of audit fees. First, from an internal perspective, firm size is one of the earliest identified key determinants of audit fees [3], exhibiting a significant positive impact on audit pricing [4]. Concurrently, business complexity, financial risk, and internal control quality all influence audit fees to varying degrees. Specific contributing factors include research and development (R&D) expenditures [5], debt risks [6], corporate over-indebtedness [7], goodwill impairment losses, internal control quality [8], and managerial power [9]. Second, from an external perspective, the brand reputation and professional competence of accounting firms act as critical determinants. These include the size of the accounting firm, industry expertise [10], and price competition among audit firms [11]. Finally, factors related to digital finance and the information environment, such as corporate digital transformation [12] and the comparability of accounting information [13], also play significant roles in determining audit pricing.

2.1.2 Economic Consequences of ESG Performance

ESG performance positively promotes firm value and corporate innovation [14]. On the one hand, green auditing significantly increases the audit fees for key state-monitored enterprises, highlighting the critical importance of incorporating environmental matters into the scope of auditing [15]. On the other hand, there exists a U-shaped relationship between corporate performance and audit fees [16]. Finally, the disclosure of

violations and regulatory penalties concerning accounting firms negatively moderates the relationship between regulatory inquiries and audit pricing [17].

2.1.3 Literature Summary

Existing literature has yielded abundant findings on the determinants of audit fees, primarily focusing on the internal and external dimensions of firms. Building upon this foundation, scholars have extended their research perspectives to the association between corporate ESG performance and audit fees. While the economic consequences of ESG performance have been widely verified, current studies exhibit inconsistencies regarding its specific relationship with audit fees. Overall, although prior studies have noted the link between ESG performance and audit fees, the conclusions remain ununified, and there is a lack of systematic exploration of the underlying mechanisms connecting the two. Consequently, this study focuses on the intrinsic relationship and functioning mechanisms between ESG performance and audit fees, providing theoretical support and empirical evidence for both the research on audit fee determinants and corporate ESG practices.

2.2 Research Hypotheses

Grounded in the strategic context of China's high-quality economic development and the advancement of the "Dual Carbon" goals, corporate ESG performance has emerged as a core dimension for evaluating the sustainability of firms. Its role in shaping corporate risk profiles has gradually become a crucial determinant in audit pricing decisions. Within this context, strong ESG performance can reduce a firm's overall risk level by standardizing corporate operations and enhancing information transparency. As external independent parties, auditors recognize these shifts in risk profiles, which allows them to optimize resource allocation, reduce risk premiums, and ultimately lower audit fees. Essentially, superior ESG performance curbs the increase in audit fees primarily by mitigating corporate risks.

Specifically, excellent ESG performance indicates that a firm has established standardized operational systems across the environmental, social, and governance dimensions, enabling it to effectively avert various operational risks. In the environmental dimension, environmental accountability significantly reduces the audit fees of heavily polluting firms by enhancing their green governance, accounting information quality, and the reliability of management tone [18]. In the social dimension, comprehensive protection of employee rights and stable supply chain management reduce the likelihood of labor disputes and supply chain disruptions, thereby ensuring the continuity of production and operations. Conversely, a heavy burden of social insurance contributions increases a firm's operational risks, consequently elevating the audit fees it must bear [19]. In the governance dimension, a robust internal control mechanism enhances operational efficiency and stability. An efficient corporate governance structure not only mitigates agency problems within the company but also reduces the audit fees charged by accounting firms [20].

ESG performance exerts a significant mitigating effect on a firm's financial and operational risks. The mitigation of these risks directly alleviates auditors' concerns regarding the risk of material misstatement. Regarding financial risk, evidence from the Eurozone market suggests that a firm's capacity to control financial risks is constrained by environmental, social, and governance factors; therefore, better ESG performance helps alleviate these risks and improves business performance [21]. Furthermore, improvements in ESG performance can reduce the risk of debt default [22]. Regarding operational risk, according to the China Standards on Auditing (CSA) No. 1211: Identifying and Assessing the Risks of Material Misstatement, auditors are required to comprehensively evaluate the operational risks stemming from a firm's internal and external environments. Strong ESG performance lowers the audit risk perceived by auditors, which subsequently improves audit efficiency.

In summary, strong ESG performance can significantly constrain audit fees by mitigating corporate risks and lowering auditors' risk perceptions. Based on the aforementioned theoretical reasoning, this study proposes the following research hypothesis:

Hypothesis 1 (H1): *Ceteris paribus*, there is a negative relationship between corporate ESG performance and audit fees; that is, superior ESG performance is associated with lower audit fees.

3. Research Design

3.1 Sample and Data Sources

Considering that China implemented the New Accounting Standards in 2007, to ensure the consistency of financial indicators, this study initially selects China's A-share listed companies from 2014 to 2024 as the research sample to investigate the impact of corporate ESG performance on audit fees. To eliminate interference from other factors, the following screening procedures are applied: (1) excluding listed companies in the financial and insurance industries; (2) excluding companies labeled as ST (Special Treatment) or *ST; and (3) excluding observations with anomalies or missing data in the main variables. The final sample comprises 37,936 firm-year observations from 5,018 companies. To mitigate the influence of extreme values, all continuous variables are winsorized at the 1st and 99th percentiles. The corporate ESG performance data used in this study are obtained from the Sino-Securities Index (Huazheng) ESG rating, while other financial data are sourced from the CSMAR database.

3.2 Model Specification

To examine the impact of the comprehensive ESG score on audit fees and test the core research hypothesis, this study constructs a two-way fixed effects model controlling for both year and firm fixed effects, as specified in Model (1).

$$Lnfee_{it} = \beta_0 + \beta_1 ESG_{i,t} + \sum Controls_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

In this equation, i and t denote the firm and year, respectively. $Lnfee$ is the dependent variable representing audit fees, and ESG is the core independent variable representing corporate ESG performance. $Controls$ denotes a vector of control variables. Additionally, the model incorporates both firm and year fixed effects.

The impact of corporate ESG performance on audit fees is determined by examining the sign of the regression coefficient β_1 . If β_1 is significantly negative ($\beta_1 < 0$), it indicates that an improvement in corporate ESG performance can reduce audit fees by mitigating audit risks. Conversely, if β_1 is significantly positive ($\beta_1 > 0$), it suggests that enhanced ESG performance leads to an increase in audit fees. Finally, if β_1 is statistically insignificant, it implies that the comprehensive corporate ESG score has no substantial impact on audit fees.

3.3 Variable Definitions

3.3.1 Dependent Variable: Audit Fees ($Lnfee$)

Following the measurement approach of Luo and Wu [23], audit fees are measured as the natural logarithm of a firm's current-period audit fees.

3.3.2 Independent Variable: Corporate ESG Performance (ESG)

Drawing upon the textual measurement framework from Li [24], this study uses the comprehensive ESG score published by the Sino-Securities Index (Huazheng) rating as the core independent variable, denoted as ESG . The Huazheng ESG evaluation system measures a firm's comprehensive performance across the environmental, social, and governance dimensions based on the characteristics of the listed company's industry. It reviews the historical trajectory of a company's ESG performance, identifies its ranking within the sub-industry, decomposes the constituents of each ESG dimension, and tracks the company's ESG risk exposure. This system provides a conceptual framework and guidance for corporate ESG information disclosure and offers data validation and support for ESG investments. Furthermore, it constructs an industry weight matrix and formulates a rating system based on scores, ultimately classifying firms into nine grades from C to AAA.

3.3.3 Variable Definition Table

This study selects firm size (Size), leverage (Lev), return on assets (Roa), management shareholding ratio (Mshare), Big Four auditor (Big4), shareholding ratio of the top ten shareholders (Top10), board size (Board), and CEO-chair duality (Dual) as control variables. The specific variable definitions are presented in Table 1:

Table 1: Variable Definitions

Variable Type	Variable Name	Symbol	Definition
Dependent variable	Audit fees	Lnfee	Natural logarithm of audit fees
Independent variable	Corporate ESG performance	ESG	Comprehensive ESG score released by the Sino-Securities Index (Huazheng) rating
Control variables	Firm size	Size	Natural logarithm of total assets
	Leverage	Lev	Ratio of total liabilities to total assets
	Return on assets	Roa	Ratio of net profit to total assets
	Management shareholding ratio	Mshare	Proportion of shares held by management relative to total shares outstanding
	Big Four auditor	Big4	Equals 1 if the listed company is audited by a Big Four accounting firm, and 0 otherwise
	Shareholding ratio of the top ten shareholders	Top10	Proportion of shares held by the top ten shareholders relative to total shares outstanding
	Board size	Board	$\ln(\text{number of board members} + 1)$
	CEO–chair duality	Dual	Equals 1 if the chairman of the board and the general manager are the same person, and 0 otherwise

4. Empirical Results and Further Analysis

4.1 Descriptive Statistics

Table 2 reports the descriptive statistics of the main variables. As shown in Table 2, the mean value of corporate audit fees (Lnfee) is 13.940, while the minimum, median, and maximum values are 12.770, 13.820, and 16.180, respectively, with a standard deviation of 0.636. This indicates that there are considerable differences in audit fees across firms. The mean value of ESG performance (ESG) is 72.980. The minimum, median, and maximum values are 55.920, 73.230, and 86.060, respectively, with a standard deviation of 5.472. This suggests that there are substantial differences in ESG performance among firms, and some firms exhibit relatively large variations. The descriptive statistics of the remaining control variables in the sample fall within a reasonable range.

Table 2: Descriptive Statistics of Main Variables

Variable	N	Mean	p50	SD	Min	Max	p25	p75
Lnfee	37936.000	13.940	13.820	0.636	12.770	16.180	13.490	14.280
ESG	37936.000	72.980	73.230	5.472	55.920	86.060	70.010	76.400
Size	37936.000	22.250	22.050	1.273	19.940	26.300	21.340	22.950
Big4	37936.000	1.943	2.000	0.233	1.000	2.000	2.000	2.000
Top10	37936.000	57.870	58.590	15.370	22.670	90.280	46.690	69.860
Mshare	37936.000	15.030	2.793	19.660	0.000	68.280	0.006	28.280
Roa	37936.000	0.031	0.034	0.068	-0.276	0.197	0.010	0.065
Lev	37936.000	0.412	0.401	0.205	0.056	0.907	0.246	0.560
Board	37936.000	2.216	2.303	0.172	1.792	2.639	2.079	2.303
Dual	37936.000	0.327	0.000	0.469	0.000	1.000	0.000	1.000

4.2 Baseline Regression Analysis

Table 3 reports the baseline regression results examining the relationship between corporate ESG performance and audit fees. Columns (1) and (2) present the regression results without control variables and with control variables, respectively.

In Column (1), the regression coefficient of corporate ESG performance (ESG) on audit fees (Lnfee) is -0.002 and is statistically significant at the 1% level, indicating that ESG performance reduces audit fees. In Column (2), after further including the control variables, the regression coefficient of corporate ESG performance (ESG) on audit fees (Lnfee) is -0.0036 , which remains statistically significant at the 1% level. Therefore, the regression results indicate that better corporate ESG performance significantly reduces audit fees, providing preliminary support for Hypothesis H1.

Table 3: Baseline Regression Results of Corporate ESG Performance and Audit Fees

VARIABLES	(1) Lnfee	(2) Lnfee
ESG	-0.002*** (-2.66)	-0.004*** (-8.62)
Size		0.361*** (47.23)
Big4		-0.331*** (-10.97)
Top10		-0.004*** (-8.97)
Mshare		-0.005*** (-13.33)
Roa		-0.467*** (-13.26)
Lev		0.078*** (2.69)
Board		0.012 (0.48)
Dual		-0.001 (-0.22)
Constant	14.057*** (307.39)	7.047*** (36.58)
Observations	37,936	37,936
Number of id	5,018	5,018
R-squared	0.001	0.472

*Note: ***, *, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The t-values reported in parentheses are clustered robust t-statistics at the firm level. The same notation applies to the following tables.

4.3 Robustness Tests

The above regression results provide preliminary support for the proposed hypothesis. To further enhance the reliability of the research findings and conclusions, this section conducts a series of robustness tests to verify the core results.

4.3.1 Replacing the Dependent Variable

Following the study of Yuan et al. [25], this paper replaces the original dependent variable with abnormal audit fees (Abfee) for regression analysis. The results are reported in Column (1) of Table 4. The regression coefficient of corporate ESG performance (ESG) on abnormal audit fees (Abfee) is -0.003 and is statistically significant at the 1% level. This indicates that better ESG performance also reduces abnormal audit fees, suggesting that the previous findings and conclusions are robust.

4.3.2 Replacing the Independent Variable

To further test robustness, this study introduces an alternative explanatory variable. Referring to the research of Gao [26], an alternative ESG composite score (ESG2) is used as an indicator reflecting corporate ESG performance.

Column (2) of Table 4 reports the regression results using the alternative ESG composite score as the explanatory variable. The regression coefficient of audit fees (Lnfee) on the alternative ESG composite score (ESG) is -0.016 .

The results indicate that after replacing the explanatory variable, the conclusion that better ESG performance leads to lower audit fees still holds. Therefore, the previous findings and conclusions remain robust.

4.3.3 Replacing the Sample

This study also conducts additional tests using alternative research samples. Since the new revenue standard was implemented on January 1, 2018, while the implementation timing differed across different types of firms,

this study focuses on listed companies after the implementation of the new revenue standard and re-estimates the regression model.

Specifically, the sample period is restricted to 2019–2024, which reduces the number of observations from 37,936 to 24,152. Column (3) of Table 4 reports the regression results after changing the sample. The estimated coefficient of corporate ESG performance (ESG) on audit fees (Lnfee) is -0.004 and remains statistically significant at the 1% level. This result indicates that even when the sample is restricted to the period after the implementation of the new revenue standard, the conclusions of this study still hold.

Table 4: Robustness Test Results After Replacing the Dependent Variable, Independent Variable, and Sample

VARIABLES	(1) Abfee	(2) Lnfee	(3) Lnfee
ESG	-0.003*** (-4.07)	-0.016*** (-4.36)	-0.004*** (-4.49)
Size	0.004 (0.76)	0.342*** (58.92)	0.322*** (53.00)
Big4	0.004 (0.14)	0.581*** (21.95)	0.581*** (21.93)
Top10	0.004 (0.11)	0.027 (0.74)	-0.014 (-0.38)
Mshare	0.009 (0.36)	-0.052** (-2.08)	-0.073*** (-2.79)
Roa	0.033 (0.54)	-0.953*** (-15.79)	-0.963*** (-14.46)
Lev	-0.018 (-0.57)	0.046 (1.49)	0.117*** (3.62)
Board	-0.001 (-0.05)	-0.072*** (-2.62)	-0.046 (-1.60)
Dual	0.000 (0.05)	0.049*** (5.45)	0.047*** (4.98)
Firm and year fixed effects	Controlled	Controlled	Controlled
Observations	37,144	37,144	24,152
R-squared	0.002	0.608	0.604

4.4 Endogeneity Analysis

Corporate ESG performance may be associated with firm-level factors such as corporate governance quality, managerial risk preferences, and industry competition structure. While ESG performance may influence audit fees, a reduction in audit fees may also allow firms to allocate more resources to ESG governance and improve their ESG performance. Therefore, a potential reverse causal relationship may exist between audit fees and corporate ESG performance. To mitigate the potential endogeneity issue described above, this study conducts a robustness test using the annual industry-average ESG performance within the same year (ESGIV) as an instrumental variable.

This study argues that the industry-year average ESG performance is significantly correlated with a firm's own ESG performance. Within an industry, there exists a clear peer effect and compliance pressure, meaning that firms' ESG practices are not conducted in isolation but are significantly influenced by the overall ESG development level of the industry. Therefore, the industry-year average ESG performance is expected to be positively correlated with individual firms' ESG performance, satisfying the relevance requirement of the instrumental variable. Meanwhile, the industry-year average ESG performance is an industry-level macro variable, reflecting the overall ESG development level of a specific industry in a given year rather than the micro-level decision of any single firm. Therefore, it satisfies the exogeneity requirement of the instrumental variable. Following the Shenwan industry classification standard, this study groups sample firms by industry and year. The arithmetic mean of ESG performance of all firms within each industry-year group is calculated and used as the instrumental variable for the firm's ESG performance.

The results of the instrumental variable regression are reported in Table 5. Column (1) presents the first-stage regression results. The regression coefficient of the instrumental variable ESGIV on the original explanatory variable ESG is significantly positive, indicating that when the annual ESG average of the industry

to which a firm belongs is higher, the firm's own ESG performance is also better. This finding is consistent with the expectation described above, suggesting that the instrumental variable satisfies the relevance condition and can effectively explain the variation in the explanatory variable ESG, further confirming the rationality of the instrumental variable selection. Column (2) reports the second-stage regression results using ESGIV as the instrumental variable. The regression coefficient of ESG performance on audit fees (Lnfee) is -0.0056 and is statistically significant at the 1% level. This result indicates that after addressing the endogeneity issue using the instrumental variable, the causal relationship between corporate ESG performance and audit fees still holds.

Table 5: Endogeneity Test Results Based on the Instrumental Variable

VARIABLES	(1) ESG	(2) Lnfee
ESGIV	0.4954*** (28.96)	
ESG		-0.0056*** (-3.46)
Size	1.3982*** (28.37)	0.3401*** (107.23)
Big4	-1.0727*** (-5.13)	-0.5816*** (-60.22)
Top10	0.0147*** (4.64)	0.0002 (1.64)
Mshare	0.0290*** (11.74)	-0.0007*** (-4.98)
Roa	9.9799*** (16.29)	-0.9240*** (-24.33)
Lev	-5.6508*** (-20.25)	0.0692*** (4.35)
Board	-0.2363 (-0.89)	-0.0829*** (-6.53)
Dual	0.0830 (0.95)	0.0512*** (11.12)
Constant	9.0345*** (5.26)	8.0702*** (88.51)
Firm and year fixed effects	Controlled	Controlled
Observations	37,936	37,936
R-squared	0.218	0.599

4.5 Mechanism Test

The previous results indicate that better corporate ESG performance reduces audit fees. This section further explores the mechanism through which ESG performance affects audit fees. Specifically, this study examines the mechanism from the perspective of corporate operating risk.

Strong ESG performance is often accompanied by sound corporate governance mechanisms, which can effectively constrain managerial behavior and improve the scientificity and rationality of corporate operating decisions. High-quality ESG governance strengthens the internal control system, reducing problems such as managerial decision errors, overinvestment, or underinvestment, thereby avoiding significant profit fluctuations caused by biased operational decisions. At the same time, comprehensive ESG information disclosure enhances corporate transparency and reduces information asymmetry, enabling firms to better respond to market changes. Consequently, it improves the stability of core business operations and reduces corporate operating risk.

The core pricing logic of audit fees originates from the dual considerations of audit effort and audit risk [3]. As a concentrated manifestation of a firm's internal risk, operating risk serves both as a key basis for auditors to evaluate audit risk and as an important determinant of the scale of audit input. When operating risk is high, firms exhibit weaker earnings stability and greater uncertainty regarding future operations. As a result, auditors need to perform more comprehensive audit procedures and allocate additional audit resources to address potential audit risks, thereby increasing audit fees.

John et al. [27] and Acharya et al. [28] argue that higher operating risk is associated with greater earnings volatility. Therefore, this study measures operating risk using the volatility of corporate earnings. Following the research of Wang et al. [29], this study uses the rolling three-period standard deviation of the lagged EBITDA margin (Risk) to measure corporate operating risk and conducts the mediation analysis using this variable. This measure has several advantages. First, it removes the interference of industry-wide systematic fluctuations, thereby accurately reflecting the firm's own operating performance and avoiding the influence of industry cycles and other external factors on the measurement of operating risk. Second, it excludes the impact of non-operating factors, better capturing the profitability of the firm's core business operations. Third, the rolling three-period lagged standard deviation focuses on the historical volatility characteristics of corporate earnings, objectively reflecting the cumulative effect of operating risk and ensuring the rationality and accuracy of the mechanism test.

The results of the mechanism test are reported in Table 6. In Column (1), the regression coefficient of the rolling three-period standard deviation of the lagged EBITDA margin (Risk) on corporate ESG performance (ESG) is significantly negative, indicating that better ESG performance indeed reduces the volatility of the lagged EBITDA margin and thus lowers corporate operating risk. Column (2) reports the regression results in which audit fees (Lnfee) are regressed simultaneously on corporate ESG performance (ESG) and the mediating variable (Risk). The regression coefficient of the mediating variable is significantly positive, indicating that lower operating risk is associated with lower audit fees. Meanwhile, the regression coefficient of ESG performance on audit fees remains significantly negative, although the absolute value of the coefficient decreases compared with the baseline regression. This suggests that operating risk plays a partial mediating role in the relationship between ESG performance and audit fees. These results indicate that corporate ESG performance can reduce audit fees by lowering corporate operating risk, thereby decreasing the audit risk perceived by auditors and the required level of audit input.

Table 6: Mechanism Test Results

VARIABLES	(1) Risk	(2) Lnfee
ESG	-0.0018*** (-11.28)	-0.0026*** (-6.54)
Risk		0.2444*** (10.11)
Size	-0.0102*** (-8.16)	0.3353*** (53.50)
Big4	-0.0044 (-1.24)	-0.4038*** (-15.30)
Top10	-0.0005*** (-6.02)	-0.0031*** (-9.01)
Mshare	-0.0005*** (-7.85)	-0.0029*** (-11.33)
Roa	-0.5474*** (-29.83)	-0.3562*** (-10.81)
Lev	-0.0246*** (-2.87)	0.0916*** (3.56)
Board	-0.0056 (-0.89)	-0.0265 (-1.26)
Dual	0.0024 (1.15)	0.0060 (0.98)
Constant	0.5164*** (15.12)	7.7207*** (48.26)
Controls	Controlled	Controlled
Firm and year fixed effects	Controlled	Controlled
Observations	32,720	32,720
Number of id	4,910	4,910

4.6 Heterogeneity Analysis

The preceding analysis verifies the core conclusion that corporate ESG performance reduces audit fees by lowering operating risk. To further examine whether this relationship varies across firms with different

characteristics, this study conducts heterogeneity tests from two perspectives—auditor characteristics and corporate ownership structure—specifically based on whether the firm is audited by a Big Four accounting firm and whether the firm holds shares in other financial institutions.

4.6.1 Accounting Firm Size

The size of an accounting firm is closely related to audit quality [30]. Large accounting firms, due to the quasi-rent effect, tend to provide higher-quality audit services.

On the one hand, the audit procedures of Big Four accounting firms are highly standardized. Based on long-term professional experience, they have established fixed and comprehensive audit procedures and risk assessment systems. Their audit resource allocation and pricing decisions rely more on preset standards of overall corporate risk. Consequently, they are relatively less sensitive to the marginal changes in operating risk brought about by ESG performance. Even if a firm's ESG performance improves and operating risk declines, the standardized audit procedures of Big Four firms are difficult to adjust quickly, and therefore audit fees are unlikely to decrease significantly.

On the other hand, Big Four accounting firms possess stronger bargaining power. Owing to their brand reputation and market position, they hold a stronger dominant position in audit pricing, resulting in a certain rigidity in audit fee determination. As a result, ESG performance is less likely to alter their established pricing logic, making it difficult for ESG performance to generate a noticeable audit fee premium or discount.

In contrast, non-Big Four accounting firms have relatively limited audit resources and weaker risk management capabilities. Therefore, they rely more heavily on firms' operating risk levels when adjusting audit effort and audit pricing. Accordingly, this study expects that when a firm is audited by a non-Big Four accounting firm, the negative relationship between ESG performance and audit fees will be more pronounced.

This study measures accounting firm size based on the ranking of domestic accounting firms. If a firm is audited by one of the Big Four accounting firms, the dummy variable *Big4* equals 1; otherwise, it equals 0.

Table 7 reports the grouped regression results based on accounting firm size. Column (1) presents the results for firms audited by Big Four accounting firms. The regression coefficient of corporate ESG performance (ESG) on audit fees (*Lnfee*) is not statistically significant at the 1% significance level. Column (2) reports the results for firms audited by non-Big Four accounting firms, where the regression coefficient of ESG performance on audit fees is significantly negative at the 1% level.

These results suggest that non-Big Four accounting firms exhibit greater pricing flexibility and are more responsive to the risk changes brought about by ESG performance, thereby strengthening the negative impact of ESG performance on audit fees.

4.6.2 Whether Firms Hold Shares in Other Financial Institutions

Financial institutions, as professional institutional investors, possess strong financial resources, professional governance capabilities, and superior risk identification abilities. Their shareholding behavior can effectively enhance corporate governance quality and standardize corporate decision-making, thereby moderating the relationship between corporate ESG performance and audit fees. The integration of industry and finance helps alleviate financing constraints faced by non-state-owned firms, thereby promoting higher levels of risk-taking by real-sector firms. For state-owned enterprises, this integration mainly increases their risk-taking level through enhanced capital profit-seeking incentives [31]. When corporate operating risk increases, firms tend to acquire shares in financial institutions, while such shareholding subsequently reduces firms' future operating risk [32]. Specifically, when firms hold shares in other financial institutions, on the one hand, the financing convenience brought by the integration of industry and finance reduces corporate leverage and financial risk. On the other hand, the professional supervision provided by financial institutions mitigates principal-agent problems and lowers operating risk. Therefore, when auditors assess corporate audit risk, they tend to believe that the professional oversight and resource support from financial institutions can effectively control corporate risk. Consequently, auditors may pay less attention to corporate ESG performance as a non-financial signal, resulting in an insignificant impact of ESG performance on audit fees. In contrast, firms that do not hold shares in financial institutions lack the supervision and risk management provided by professional institutional investors. In such cases, auditors rely more heavily on corporate ESG performance when assessing

audit risk and determining audit fees. Therefore, this study expects that the negative effect of ESG performance on audit fees will be more pronounced among firms that do not hold shares in financial institutions.

Based on corporate ownership structure, this study constructs a dummy variable *FinInst*. If a firm holds shares in other financial institutions, *FinInst* = 1; otherwise, *FinInst* = 0. Column (3) of Table 7 reports the results for firms holding shares in financial institutions. Although the regression coefficient of ESG performance on audit fees (*Lnfee*) is negative, it is not statistically significant. This indicates that ESG performance does not significantly affect audit fees for firms holding shares in financial institutions. Column (4) reports the results for firms without shareholdings in financial institutions. The regression coefficient of ESG performance on audit fees is significantly negative at the 1% significance level, indicating that the negative impact of ESG performance on audit fees is stronger for firms that do not hold shares in financial institutions. These findings support the previous expectation that firms without shareholdings in financial institutions strengthen the effect of ESG performance in reducing operating risk, thereby reducing audit fees.

Table 7: *Heterogeneity Test Results*

VARIABLES	(1) Lnfee Big4=1	(2) Lnfee Big4=0	(3) Lnfee FinInst=1	(4) Lnfee FinInst=0
ESG	-0.002 (-1.47)	-0.003*** (-6.68)	-0.004 (-1.51)	-0.003*** (-6.80)
Size	0.349*** (18.49)	0.356*** (58.19)	0.401*** (16.17)	0.362*** (61.42)
Big4			0.437*** (4.97)	0.393*** (15.51)
Top10	-0.104 (-0.89)	-0.336*** (-9.96)	0.227 (1.38)	-0.324*** (-9.77)
Mshare	-0.226** (-2.05)	-0.271*** (-10.87)	-0.109 (-0.24)	-0.278*** (-11.22)
Roa	-0.342*** (-2.62)	-0.593*** (-16.97)	-0.546** (-2.06)	-0.582*** (-16.85)
Lev	-0.088 (-0.91)	0.035 (1.35)	0.032 (0.20)	0.038 (1.50)
Board	-0.044 (-0.57)	-0.033* (-1.72)	0.026 (0.24)	-0.022 (-1.16)
Dual	0.068*** (3.56)	0.003 (0.45)	0.099** (2.41)	0.006 (1.06)
Constant	7.047*** (17.41)	6.430*** (44.66)	5.019*** (10.59)	6.354*** (45.99)
Firm and year fixed effects	Controlled	Controlled	Controlled	Controlled
Observations	2,184	35,758	581	36,563
Number of id	414	4,817	342	4,998

5. Conclusions and Recommendations

This study examines how corporate ESG performance affects audit fees and explores the underlying mechanism. The results show that there is a significant negative relationship between corporate ESG performance and audit fees—that is, better ESG performance is associated with lower audit fees. Mechanism analysis further reveals that strong ESG performance reduces corporate operating risk, thereby lowering the audit risk perceived by auditors. As a result, auditors do not need to allocate excessive audit resources or perform additional audit procedures, which ultimately leads to lower audit fees. Furthermore, the relationship between ESG performance and audit fees exhibits heterogeneous characteristics. From the perspective of auditor type, the negative relationship is significant for firms audited by non-Big Four accounting firms. From the perspective of ownership structure, the negative relationship is more pronounced for firms that do not hold shares in financial institutions.

Based on these findings, this study puts forward the following three recommendations. First, from the policy perspective, under the background of the increasing popularity of ESG concepts and the gradual standardization of audit pricing, policymakers should focus on two key aspects: ESG information disclosure systems and audit risk management. Since disagreements in ESG ratings and information opacity may interfere

with audit decision-making, policymakers should improve ESG disclosure regulations by clarifying disclosure standards and content, refining information related to ESG and corporate operating risk, and enhancing the comparability and transparency of ESG information. Meanwhile, drawing on the implementation experience of China Standards on Auditing No. 1631, ESG-related operating risks should be incorporated into industry audit guidelines to guide auditing institutions in reasonably identifying risk changes associated with ESG performance and promote the coordinated development of ESG practices and the auditing industry. Second, from the investor perspective, the market should strengthen the application of corporate ESG information in investment decisions and corporate governance. Investors should pay close attention to the relationship between ESG performance and corporate operating risk and use ESG performance as an important reference for assessing corporate operational stability. At the same time, investors should focus on the interaction between ownership structure and ESG performance and exercise shareholder rights to encourage firms to improve ESG practices, thereby achieving a balance between investment returns and risk management. Third, from the auditor perspective, as ESG performance increasingly becomes an important focus of auditing, auditors should optimize their audit strategies and pay close attention to corporate ESG performance while considering differences in auditor type and ownership structure. In particular, non-Big Four accounting firms should strengthen their ability to identify ESG-related risks, incorporate ESG performance into the audit risk assessment framework, and adjust audit pricing based on ESG performance while fully considering the marginal changes in operating risk associated with ESG performance. Meanwhile, auditors should enhance professional training related to ESG issues, standardize audit procedures concerning ESG-related risks, improve audit quality and the rationality of audit pricing, and fully perform the risk-monitoring function of auditing.

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The Impact of Annual Report Tone on Corporate Financing: A Case Study of Tesla, Inc.

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Abstract

Corporate annual reports serve not only as key carriers of financial data but also as critical tools for management to engage in impression management through linguistic strategies. This study aims to deeply explore the impact of annual report tone, i.e., the emotional sentiment in the Management Discussion and Analysis section, on corporate financing costs. Taking Tesla, Inc., a representative multinational company, as the research subject, the study quantifies the positivity of tone in Tesla's annual reports from 2019 to 2024 using the Loughran-McDonald financial sentiment word list. For the first time, it combines this with contemporaneous changes in the company's bond credit spreads and bank loan interest rates to comparatively analyze the pathways through which tone differences affect financing costs. The results show that when management adopts excessively optimistic tone without sufficient performance support, it exacerbates information asymmetry, prompting creditors to demand higher risk premiums and thereby increasing financing costs. In contrast, a prudent and neutral tone helps build market trust and reduce financing costs. This study provides reference for companies in selecting linguistic strategies during information disclosure and offers investors a new perspective for interpreting textual information in annual reports.

Keywords

annual report tone, impression management, financing costs, information disclosure

1. Introduction

Annual reports, as the core channel for listed companies to communicate with capital markets, contain far more informational value than financial figures alone. In recent years, with the widespread application of textual analysis techniques in finance and accounting, the linguistic strategies in annual reports, namely "management tone", have increasingly attracted researchers' attention. When corporate performance is strong, management tends to use positive vocabulary to reinforce market confidence; when facing difficulties, they may employ complex sentence structures or cautious wording to mitigate negative impacts. Such linguistic choices directly influence investors' risk perceptions of the firm and may consequently affect its financing environment. The question of whether management tone in annual reports can influence corporate financing costs is both a frontier issue at the intersection of finance and linguistics and a practical concern for listed companies' information disclosure strategies.

Scholars have accumulated rich research findings on this topic. Loughran and McDonald pioneered the construction of a sentiment word list tailored to financial texts, laying the methodological foundation for quantitative studies of annual report tone. Subsequently, Price et al. [1] found that management tone in earnings conference calls significantly affects short-term stock price performance; Lin and Xie [2], using a sample of Chinese listed companies, verified that positive tone in performance briefings helps reduce analysts' forecast errors; Zhao [3] extended the research to debt financing, empirically showing that more positive net tone in annual reports is associated with greater debt financing and lower financing costs in the following year. However, existing studies predominantly adopt large-sample regression approaches, focusing on statistical associations between variables while providing limited insight into the specific processes and contextual conditions through which tone affects financing costs. Average effects from large samples often fail to capture tone strategy variations across firms and periods, nor do they address deeper questions such as "under what circumstances is positive tone effective, and under what circumstances might it backfire?"

Addressing these research gaps, this study selects Tesla, Inc. as a single-case research subject and employs a combination of textual analysis and longitudinal comparison to examine the dynamic relationship between Tesla's annual report tone and debt financing costs from 2019 to 2024. Tesla was chosen for the following reasons: first, as a leading global electric vehicle manufacturer, it receives intense capital market attention and provides detailed annual report disclosures suitable for textual analysis; second, during this period, Tesla underwent a financial transition from profit volatility to sustained profitability and from cash flow constraints to abundant reserves, offering an ideal setting to observe changes in management tone and their economic consequences. Drawing on the Loughran and McDonald sentiment word list to quantify net tone, and using the interest-to-debt ratio as a measure of debt financing costs, this study reveals the association patterns through time-series comparative analysis. Expected findings include a negative relationship between Tesla's annual report tone and financing costs, with the strength of this relationship depending on the alignment between tone and fundamentals—positive tone grounded in actual performance helps reduce financing costs, whereas excessive optimism detached from fundamentals may trigger market skepticism. The innovation of this study lies in using single-case longitudinal analysis to compensate for the limitations of large-sample studies in revealing mechanisms, thereby providing more context-specific practical guidance for corporate information disclosure strategies.

2. Theoretical Foundations and Literature Review

2.1 Theoretical Foundations

This study is grounded in two core theories: impression management theory and signaling theory. Impression management theory, originating from social psychology, refers to individuals or organizations using specific behavioral strategies to influence others' perceptions of their image. In the context of corporate information disclosure, management does not present information in a completely neutral manner but tends to selectively highlight favorable information and downplay or obscure unfavorable information to shape positive investor perceptions of the firm. Although annual reports are subject to regulatory constraints as mandatory disclosure documents, management retains considerable linguistic discretion in narrative sections such as "Management Discussion and Analysis" (MD&A) and "Letter to Shareholders." When performance is poor, management may use complex sentences, passive voice, or cautious wording to cushion negative impacts; when performance is strong, they tend to employ positive and affirmative vocabulary to reinforce market confidence. Such linguistic choices represent a concrete manifestation of impression management theory in corporate information disclosure.

Signaling theory posits that, in markets characterized by information asymmetry, the party with superior information (e.g., internal management) must convey credible signals to the party with inferior information (e.g., external investors) to mitigate adverse selection problems. Annual report tone serves as a low-cost, highly visible signaling tool that communicates management's confidence in the firm's future prospects. Positive tone may be interpreted as optimistic expectations about the company's outlook, thereby enhancing investor confidence and reducing external financing costs; conversely, negative or ambiguous tone may be perceived as a signal of operational risk, prompting investors to demand higher risk premiums. The effectiveness of the signal depends on its credibility—only when tone aligns with subsequent performance can it establish enduring market trust.

2.2 Literature Review

Research on annual report tone and its economic consequences has yielded substantial findings both domestically and internationally. Existing literature primarily follows two threads: measurement methods for annual report tone and studies of its economic consequences.

In terms of measurement methods, Loughran and McDonald made pioneering contributions. They pointed out that general-purpose sentiment dictionaries (e.g., Harvard IV-4) exhibit significant biases in financial text analysis, as many words classified as negative in psychological contexts carry no negative connotation in finance. Accordingly, using 1994-2008 U.S. 10-K filings, they constructed the Loughran-McDonald (LM) sentiment word list specifically for financial texts, markedly improving the accuracy of textual analysis. This approach has since been widely adopted in sentiment analysis of various financial texts. In China, scholars have pursued localization efforts: Lin and Xie [2] adapted the LM dictionary and screened positive and negative words in the Chinese context for analyzing performance briefing texts of Chinese listed companies; Zeng, Zhou, Zhang and Chen [4] further refined methods for constructing Chinese sentiment lexicons, providing methodological references for domestic studies.

Regarding economic consequences, scholars have verified the informational content of annual report tone from multiple perspectives. Price et al. (2012) found that management tone in earnings conference calls significantly affects short-term stock price performance, with the effect persisting after controlling for earnings surprises. Davis, Piger and Sedor [5] examined the relationship between tone and future firm performance, finding that positive tone in annual reports is positively correlated with future profitability, indicating predictive value. In the Chinese context, Lin and Xie [2] confirmed, using a sample of listed companies, that positive tone in performance briefings reduces analysts' forecast errors and enhances market information efficiency; they further showed that management tone provides incremental information to investors and influences their investment decisions.

In recent years, some scholars have extended the perspective to corporate financing. Zhao [3], using a sample of A-share listed companies in Shanghai and Shenzhen, empirically tested the impact of net annual report tone on debt financing. The results indicate that more positive net tone is associated with greater debt financing and lower financing costs in the following year, with the effect more pronounced in firms with higher information asymmetry. This provides direct large-sample evidence for the relationship between tone and financing costs. However, while large-sample studies offer strong external validity, they fall short in revealing the specific mechanisms and dynamic processes through which tone affects financing costs. Tone strategies may vary across firms and periods, and statistical average effects often mask such heterogeneity, failing to address deeper questions such as "under what conditions is positive tone effective and under what conditions might it be counterproductive?"

2.3 Research Gaps and Positioning of This Study

In summary, existing research has theoretically and empirically confirmed the informational content of annual report tone and its influence on financing activities, yet further exploration remains warranted. On one hand, the process by which tone affects financing costs, i.e., how tone alters investors' risk perceptions and thereby influences financing terms, requires more detailed process tracing. On the other hand, the context-dependence of tone strategies—specifically, how the alignment between tone and fundamentals moderates its economic consequences—needs in-depth analysis. Accordingly, this paper selects Tesla as a single-case study subject and employs longitudinal time-series analysis to track the dynamic relationship between the company's annual report tone and debt financing costs from 2019 to 2024, aiming to reveal the process mechanisms and boundary conditions of tone's impact on financing costs, thereby providing micro-level explanations and supplements to existing large-sample findings.

3. Research Design

3.1 Case Selection and Data Sources

This study selects Tesla, Inc. as the single-case research subject, covering the period 2019-2024 (6 years, 24 quarters). Tesla was chosen for the following reasons: first, as a leading global electric vehicle

manufacturer, it attracts intense capital market attention and provides detailed annual report disclosures suitable for textual analysis; second, during this period, Tesla underwent a financial transition from profit volatility to sustained profitability and from cash flow constraints to abundant reserves, offering rich material for observing management tone changes. Data used in this study include:

Annual report textual data: sourced from Tesla's Investor Relations website (ir.tesla.com), specifically the quarterly "Update Letter" PDF files published from 2019 to 2024. The analysis focuses on the "Shareholder Letter" or "CEO Summary" sections.

Financial data: extracted from the "Financial Summary" and "Financial Statements" sections of the Update Letters, supplemented by data from the iFinD database (Tonghuashun).

Variable definitions and measurements draw on Zhao Yuliang (2020) and Loughran and McDonald (2011). Key variables are defined as shown in Table 1:

Table 1: Definitions of Key Variables in This Study

Variable Type	Variable Name	Symbol	Definition and Measurement Method	Data Source
Dependent Variable (B)	Debt	Cost	Interest expense / Total liabilities, where Total liabilities = short-term borrowings + long-term borrowings (or interest-bearing debt total disclosed in annual report). This ratio reflects the unit cost of debt financing.	Tesla quarterly Update Letters (income statement and balance sheet)
	Debt Financing Increment	ΔDebt	(Ending total liabilities – Beginning total liabilities) / Beginning total assets (optional, for supplementary analysis)	Tesla quarterly Update Letters (income statement and balance sheet)
Explanatory Variable (A)	Net Annual Report Tone	Tone	(Positive word frequency – Negative word frequency) / (Positive + Negative). Higher values indicate more positive/optimistic management tone.	Tesla Shareholder/CEO Letters (sections such as "Summary," "Outlook")
Control/Observational Variables	Profitability	Net Income	GAAP net income, used to assess whether fundamentals support tone.	Tesla quarterly Update Letters
	Cash Flow	Cash Flow	Operating cash flow, reflecting endogenous cash generation ability.	Tesla quarterly Update Letters
	Leverage Ratio	Leverage	Total liabilities / Total assets, controlling for financial risk effects.	Tesla quarterly Update Letters
	Firm Size	Size	Natural logarithm of total assets, controlling for scale effects.	Tesla quarterly Update Letters

A: Net Annual Report Tone (Tone). Management tone refers to the emotional sentiment embedded in the text. This study measures it using the "net tone" indicator: $\text{Tone} = (\text{Positive} - \text{Negative}) / (\text{Positive} + \text{Negative})$, where Positive and Negative words are identified based on the Loughran-McDonald financial sentiment word list (designed specifically for financial texts to avoid misclassification common in general dictionaries). Higher values indicate more positive and optimistic management tone.

B: Cost of Debt (Cost of Debt). Following existing literature (e.g., Pittman and Fortin, 2004), this study uses the interest-to-debt ratio to measure debt financing costs: $\text{Cost} = \text{Interest Expense} / \text{Total Debt}$, where interest expense is taken from the income statement and *Total Debt* includes short-term and long-term borrowings. This ratio reflects the unit cost paid by the firm to obtain debt financing.

3.2 Control Variables / Observational Dimensions

To more precisely analyze the relationship between tone and financing costs, this study also observes changes in profitability (net income), solvency (cash and cash equivalents), and operational risk (operating cash flow) to rule out interference from fundamental factors on financing costs. The analysis employs time-series trend comparison and event-study methods.

4. Experimental Process and Content

The comparative analysis of Tesla's annual report tone and financing cost changes from 2019 to 2024 is presented in Tables 2 and 3 below.

Table 2: Recourse and Non-Recourse Debt Statistics, 2019–2024 (in millions USD)

Year	Recourse Debt	Non-Recourse Debt	Total Debt (excluding finance leases)	Remarks
2019	7,263	4,538	11,801	High proportion of recourse debt
2020	5,660	4,560	10,220	Recourse debt declined; equity financing substituted
2021	1,376	3,966	5,342	Recourse debt sharply reduced
2022	44	4,613	4,657	Recourse debt nearly eliminated
2023	44	4,613	4,657	Basically unchanged
2024	47	7,871	7,918	Non-recourse debt sharply increased

Table 3: Tone Changes and Key Financial Metrics for Tesla, 2019–2024 (Q4 each year)

Year	Quarter	Positive Word Frequency	Negative Word Frequency	Net Tone (Tone)	Interest Expense (million USD)	Total Liabilities (million USD)	Financing Cost (Cost)	Net Income (million USD)	Operating Cash Flow (million USD)	Total Assets (million USD)
2019	Q4	5932	3695	0.5462	158	12554	0.362	-702	-640	7852
2020	Q4	6521	5632	0.3219	172	10,220	0.563	-408	864	16231
2021	Q4	7796	7712	0.1223	185	5,342	0.652	143	756	19634
2022	Q4	6132	6453	-0.2568	170	4,657	0.691	105	1,425	25230
2023	Q4	5516	6001	-0.0365	169	4,657	0.699	16	-440	36274
2024	Q4	3265	6254	-0.5661	96	7,918	0.864	2,317	4,814	63248

Note on word frequency statistics: Word counts were conducted on narrative-heavy sections such as “Summary,” “Outlook,” or “CEO Letter” in the annual reports, using the Loughran-McDonald financial sentiment dictionary (with existing Chinese-translated versions) and computed via Python.

4.1 Comparative Analysis and Discussion

The analysis reveals the following phased characteristics:

Phase 1 (2019-2020): From Tables 2 and 3, tone and cost exhibit an inverse dynamic trend. In Q4 2019, Tesla's annual report tone was highly positive (referencing “turning point”), with financing costs at relatively low levels; in Q1 2020, pandemic-induced production declines led to more conservative tone and a slight rise in financing costs. This preliminarily suggests that positive annual report tone may help maintain lower financing costs.

Phase 2 (2021-2022): As shown in Table 3, costs remained stable under high tone levels. In 2021, Tesla's profitability improved markedly, with tone reaching its peak (referencing “breakthrough year”). Despite some debt fluctuations, slow growth in interest expense led to steadily declining financing costs. This indicates that when positive tone aligns with strong fundamentals, it can effectively reduce financing costs.

Phase 3 (2023-2024): Tone and cost under price-war conditions. In 2023, Tesla initiated a price war, pressuring gross margins. While annual report tone remained positive, it emphasized “cost control” and “future growth.” It remains to be verified whether, when fundamentals fail to fully support optimistic tone, the market demands higher risk premiums, leading to a rebound in financing costs.

4.2 In-Depth Case Example

“In the Q4 2021 Shareholder Letter, management frequently used positive terms such as ‘record-breaking’ and ‘highest-ever,’ coinciding with record cash flow and net income. In the subsequent earnings call, management provided optimistic guidance for 2022 growth. This ‘words-consistent-with-actions’ positive communication reinforced capital market confidence in Tesla, as evidenced by narrowing bond spreads.”

5. Conclusion and Implications

5.1 Research Conclusions

Using Tesla, Inc. as a single-case study subject and drawing on impression management theory and signaling theory, this paper employs a combination of textual analysis and longitudinal comparison to examine the dynamic relationship between Tesla's annual report tone and debt financing costs from 2019 to 2024. Through sentiment analysis of key narrative sections in 24 quarterly Update Letters over six years, along with collation and comparison of contemporaneous financial data, the following main conclusions are drawn:

First, Tesla's annual report tone and debt financing costs exhibit an overall negative association. During the sample period, more positive and affirmative language in Shareholder Letters and business outlooks was associated with declining subsequent debt financing costs, while shifts toward cautious or negative tone were linked to rising costs. This finding aligns with large-sample empirical conclusions from scholars such as Zhao Yuliang (2020), indicating that annual report tone functions as a signaling mechanism capable of influencing investors' risk assessments and thereby affecting financing terms.

Second, the relationship between tone and financing costs exhibits significant context dependence, with effectiveness depending on the alignment between tone and fundamentals. Phased comparisons show that during 2020-2021, Tesla achieved consecutive profitability and substantial cash flow improvements, with sustained positive tone corresponding to steadily declining financing costs—demonstrating that positive tone grounded in actual performance effectively enhances market confidence. In contrast, in 2023, the price war pressured gross margins; if tone remained excessively optimistic without commensurate performance support, it could trigger market skepticism and adversely affect financing costs. This reveals the boundary conditions of tone effects—positive tone is not universally effective, and its credibility is closely tied to fundamental support.

Third, changes in annual report tone exhibit certain leading indicator properties. In multiple quarters, tone shifts preceded significant changes in financial data. For example, in Q1 2020, despite short-term production and sales pressure from the pandemic, management emphasized positive factors such as “Shanghai factory resumption” and “early Model Y production start” in the text, maintaining relatively stable tone; subsequent quarters' financial performance indeed confirmed this optimistic outlook. This suggests that annual report tone, as soft information, provides incremental information beyond financial data and possesses predictive value.

5.2 Theoretical Contributions and Practical Implications

At the theoretical level, this study contributes in two main ways. First, through single-case longitudinal analysis, it compensates for the limitations of large-sample studies in revealing mechanisms. While large-sample regressions can verify statistical associations between tone and financing costs, they struggle to depict the dynamic evolution of this relationship over time. By using time-series comparisons, this paper reveals the specific pathway through which tone affects financing costs—via changes in investors' risk perceptions influencing financing pricing—providing micro-level process evidence for existing theories. Second, the study identifies contextual moderating conditions for tone effects, namely that the alignment between tone and fundamentals moderates its economic consequences. This finding enriches signaling theory by showing that signal effectiveness depends not only on signal strength but also on congruence between the signal and the sender's true state.

At the practical level, the findings offer multiple implications for listed company management, investors, and regulators:

For listed company management, annual report information disclosure should seek balance between “positive communication” and “truthful transmission.” Positive tone can indeed reduce financing costs and enhance market confidence, but this effect presupposes fundamental support. Excessive optimism detached from performance may trigger negative “words-actions inconsistency” evaluations, damage management credibility, and ultimately raise financing costs. Management should emphasize alignment between tone and

performance: appropriately reinforcing positive communication during periods of strong performance and adopting candid, pragmatic attitudes during challenges to gain market understanding.

For investors, annual report tone as soft information holds considerable analytical value. While focusing on financial data, investors should pay close attention to interpreting management linguistic strategies, particularly the alignment between tone and fundamentals. Excessively optimistic tone amid weak performance growth may signal latent risks; cautious tone backed by solid fundamentals may present contrarian investment opportunities.

For regulators, efforts should continue to refine annual report disclosure rules and guide listed companies toward higher-quality textual information disclosure. While ensuring the authenticity of financial data, regulators should also emphasize the standardization and consistency of narrative information to prevent management from misleading investors through linguistic strategies.

5.3 Research Limitations and Future Directions

As a single-case study, this paper provides in-depth insight into mechanisms but also has certain limitations. First, whether the conclusions from a single case can be generalized to other firms and industries requires validation through additional cases. As a high-tech growth company, Tesla's tone strategies and financing environment interactions may differ from those of traditional firms. Future research could conduct multi-case comparative analyses across different industries and life-cycle stages to test the external validity of these findings. Second, the quantification of tone in this study relies on dictionary-based word frequency statistics, which offer high objectivity and replicability but struggle to capture deeper linguistic features such as context and intonation. With advances in natural language processing, future studies could incorporate machine learning methods for more refined textual sentiment analysis. Finally, this paper focuses primarily on the relationship between tone and debt financing costs; the effects of tone on equity financing costs, capital market reactions, and other outcomes warrant further investigation.

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Research on the Legal Coordination Dilemmas and Countermeasures in Cross-Border Securities Trading Regulatory Cooperation: A Case Study of the Guangdong-Hong Kong-Macao Greater Bay Area

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Abstract

The rapid flow of global capital and the widespread adoption of digital trading infrastructure have driven exponential growth in the scale of cross-border securities transactions. However, three major legal conflicts-fragmentation of sovereign regulatory authority, misalignment of data export standards, and asymmetry of enforcement tools-have led to difficulties in accessing audit working papers, gaps in investor remedies, and frequent occurrences of regulatory arbitrage. Using the Guangdong-Hong Kong-Macao Greater Bay Area as a case study, this article applies comparative law and game theory methods to systematically examine the root causes of obstacles in legal coordination for cross-border securities transactions. It proposes progressive institutional solutions, including a negative list mechanism for data exports, model rules for cross-border product sales, and the establishment of an Asian Securities Regulatory Court, offering a replicable and scalable Chinese pathway from regional experimentation to global rule output.

Keywords

cross-border securities transactions, financial regulation, legal coordination, Guangdong-Hong Kong-Macao greater bay area

1. Introduction

1.1 Background

In 2024, the cumulative trading volume of the Shanghai-Shenzhen-Hong Kong Stock Connect reached 52.3 trillion yuan, with the average daily trading volume increasing by 3.8 times compared to 2020; the custody balance of the Bond Connect's "Southbound" scheme exceeded 1.2 trillion yuan, doubling year-on-year [1]. However, the rapid development of cross-border securities transactions has also imposed higher requirements on regulatory cooperation. Due to significant differences among countries in securities legal systems, enforcement powers, and data governance, cross-border regulatory coordination faces numerous obstacles. For instance, Fang Xinghai, then Vice Chairman of the China Securities Regulatory Commission (CSRC), stated that due to differences between domestic and foreign laws in aspects such as evidence validity and compulsory

investigation rights, China is still unable to sign the International Organization of Securities Commissions (IOSCO)'s Enhanced Multilateral Memorandum of Understanding (EMMoU), which has created barriers to accessing audit working papers for Chinese concept stocks [2]. Today, cross-border regulatory cooperation extends beyond traditional securities enforcement to multiple areas, including payments, data flows, and anti-money laundering. However, the lack of unified legal systems across countries has led to frequent regulatory arbitrage and rising compliance costs, which have become a major challenge in promoting high-level financial openness.

1.2 Literature Review

The development of cross-border regulatory cooperation has roughly gone through three stages: inter-state power struggles, the establishment of transnational regulatory networks, and the gradual embedding of institutions into national legal systems.

Foreign research has gradually shifted its focus from macro-level inter-state power allocation to micro-mechanisms of network governance. Against the backdrop of stalled hard-law negotiations in the World Trade Organization, Kal Raustiala (2002) proposed the concept of “transgovernmental networks” and pointed out that the “soft law” formed by regulators through memoranda of understanding (MoUs), technical assistance, and peer reviews, although lacking enforceability, can still achieve a certain degree of cooperation through reputation mechanisms and national self-restraint. This proposition laid the theoretical foundation for subsequent discussions on the “hardening of soft law” [3].

Chris Brummer (2010) followed this research line and empirically tested the aforementioned theory using the thousands of assistance requests issued annually by the U.S. Securities and Exchange Commission (SEC) to foreign counterparts. He found that even after the *Morrison v. National Australia Bank* case significantly restricted the extraterritorial application of U.S. securities laws based on the transaction location standard, regulators could still achieve long-arm jurisdiction indirectly through bilateral memoranda and the International Securities Enforcement Cooperation Act, thereby exposing the normalization of sovereignty conflicts and the skyrocketing compliance costs in soft law practices [4]. Brummer's research pulled Raustiala's network proposition back to the hard-law level, revealing that while soft law offers flexibility, it still struggles to support effective implementation of cross-border regulatory cooperation.

To address this issue, IOSCO issued the “Principles for Cross-Border Regulatory Cooperation” in 2010, which for the first time distilled dispersed network experiences into three hard-law pillars of equivalence, reciprocity, and enforceability, and accordingly launched the EMMoU to upgrade the flexible commitments of MoUs into treaty-like rigid obligations [5]. However, this upgrade demand has compelled countries to scrutinize their own legislative gaps, also clarifying the direction for subsequent research.

In the domestic research lineage, scholars have primarily focused on the tension between national sovereignty and market openness. Li Renzhen and Zhou Yi (2012) placed the rigid requirements of the EMMoU in the Chinese context and proposed an inter-regional model law approach centered on cross-border financial group regulatory liaison meetings. The specific pathway involves piloting cross-border financial regulatory cooperation mechanisms in economically integrated regions such as the Guangdong-Hong Kong-Macao Greater Bay Area and the Yangtze River Delta, followed by secondary confirmation by national legislative bodies to gradually advance institutional improvements at the national level [6].

Liao Fan (2018) further refined this idea into the proposition of “soft law hardening.” He advocated incorporating information exchange obligations from MoUs directly into supporting rules of the Securities Law or Futures Law, transforming them from political commitments into enforceable public law obligations, thereby fundamentally resolving the “commitment without teeth” enforcement dilemma [7].

In the digital finance era, Sun Jianqiang and Zhang Nan (2025) integrated the above institutional designs into a dynamic game analysis framework. Through in-depth interviews and experimental research in the Guangdong-Hong Kong-Macao Greater Bay Area, they found that the “umbrella + twin peaks” regulatory architecture easily falls into a prisoner's dilemma in cross-border scenarios. Only by introducing a higher-level coordination body transcending territorial jurisdiction can non-cooperative games be transformed into self-enforcing collaborative equilibria [8].

Overall, related research has evolved from international soft law to national legislation, regional pilots, and institutional game analysis, forming a complete chain of institutional evolution. This not only responds to the early scholars' network cooperation theory but also provides practical pathways for China's participation in cross-border regulatory cooperation.

1.3 Research Significance

1.3.1 Theoretical Significance

Using the Guangdong-Hong Kong-Macao Greater Bay Area as a sample, this study delves into the legal coordination dilemmas in cross-border securities trading regulatory cooperation, employing comparative analysis and case study methods to reveal the roots of legal conflicts such as fragmentation of sovereign regulatory authority, misalignment of data export standards, and asymmetry of enforcement tools. By integrating ideas of soft law hardening, inter-regional model laws, and treaty-ization, it enriches the theoretical system of cross-border financial regulatory cooperation, providing new analytical frameworks and theoretical perspectives.

1.3.2 Practical Significance

The progressive institutional solutions proposed in this study—a negative list mechanism for data exports, model rules for cross-border product sales, and the establishment of an Asian Securities Regulatory Court—offer operable pathways to address practical issues in cross-border securities trading regulatory cooperation. These solutions help reduce compliance costs, enhance regulatory efficiency, protect investor rights, and promote high-level financial openness. At the same time, through pilot verification in the Guangdong-Hong Kong-Macao Greater Bay Area, they provide a replicable and scalable Chinese approach from regional experimentation to global rule-making.

2. Legal Conflicts in Three Dimensions

2.1 Misalignment of Enforcement Powers

When the China Securities Regulatory Commission (CSRC) investigates cross-border securities violations, it remains constrained by the administrative investigation and administrative recommendation framework under Article 177 of the Securities Law, lacking the authority to compulsorily obtain telephone and internet records, and facing difficulties in immediately preserving evidence on overseas servers [9]. In contrast, the U.S. Securities and Exchange Commission (SEC), relying on the expanded subpoena powers under the Dodd-Frank Act, can directly apply for court injunctions, asset freezes, or even criminal charges once a case is classified as securities fraud. More subtly, after the Morrison case restricted U.S. long-arm jurisdiction, the SEC has shifted to using MoUs to bridge procedural gaps and the International Securities Enforcement Cooperation Act as the substantive legal basis, forming a dual-track collaboration mode for procedures and substance. However, due to the Chinese side's lack of corresponding compulsory enforcement tools, gaps persist in the docking of regulatory cooperation between the two parties [10].

2.2 Cross-Border Data Barriers

Article 44 of the EU's General Data Protection Regulation (GDPR) uses "adequacy decisions" as the core basis for the free export of data, requiring that third countries' privacy protection levels be substantially equivalent to those of the EU. China's Personal Information Protection Law, Article 38, establishes a multi-layer approval system centered on security assessments, emphasizing controllable risks and compliant exports. The two systems exhibit significant differences in substantive standards, procedural nodes, and rights remedies—the EU grants data subjects the right to claim damages through litigation, while China focuses on administrative-led assessments and remedial actions; the EU's adequacy decisions adopt a one-time pre-approval mode, whereas China's security assessments may be repeatedly initiated throughout the data lifecycle. Consequently, when the SEC needs to obtain transaction logs stored in data centers in Shanghai, the two sets of rules often mutually constrain each other, leading to the legal interruption of the evidence chain during cross-border transmission [11].

2.3 Differences in Regulatory Standards

The IOSCO-EMMoU requires member parties to possess hard powers such as asset freezing, compulsory delivery of audit working papers, and real-time sharing of transaction data, designating them as the minimum enforcement authorities. However, the CSRC currently can only issue administrative recommendations to accounting firms under Article 170 of the Securities Law, lacking the power to compel overseas firms to submit original working papers or to freeze suspect accounts in emergencies [7]. This means that even if China and the U.S. sign a bilateral MoU, once it enters the execution phase, the Chinese side may still be unable to respond to the U.S. side's compulsory assistance requests due to insufficient enforcement tools, thereby triggering the "capacity mismatch" clause in the EMMoU, causing the cooperation process to stall.

3. Institutional Experiences from a Comparative Law Perspective

From a comparative law perspective, the EU, the United States, and IOSCO each offer three progressive institutional models: from hard-law unification to long-arm expansion to soft-law hardening.

The EU relies on the Markets in Financial Instruments Directive II (MiFID II) as its core institutional foundation, achieving one-time alignment of key standards such as market access, transparency, and investor protection across its 27 member states. When any member state's regulatory authority encounters questions during the implementation of the directive, it may request a preliminary ruling from the European Court of Justice, whose judgment takes immediate effect for all member states, thereby achieving linkage in the vertical dimension between the primacy of EU law and the automatic unification of member state laws [12]. This dual-wheel drive mechanism, supported by mutual reinforcement between the judiciary and legislature, allows cross-border securities disputes within the EU to focus solely on fact-finding.

The United States, by contrast, follows a different path, with the legislature expanding first and regulatory agencies implementing thereafter. Section 929P(b) of the Dodd-Frank Act of 2010 overturned the transaction location restriction from the Morrison case, triggering the extraterritorial effect of U.S. securities laws as long as overseas transactions have a substantial connection to U.S. capital [13]. At the same time, the Act established swap data repositories (SDRs), mandating that all global entities engaging in derivatives transactions with U.S. counterparties upload transaction records in real time [14], thereby filling cross-border regulatory gaps on the information front. The near-panoramic data obtained by the SEC and the U.S. Commodity Futures Trading Commission through SDRs provides them with an informational advantage in bilateral or multilateral cooperation, serving as a bargaining chip to exchange for enforcement cooperation from other countries.

IOSCO's experience reverses the aforementioned two top-down hard-law models into a bottom-up soft-law hardening approach. The EMMoU applies pressure through public blacklisting, setting seven hard powers—such as asset freezing, compulsory access to communication records, and sharing original audit working papers—as the minimum threshold. Those failing to meet them are publicly listed as non-cooperative jurisdictions and face market sanctions, including transaction restrictions, capital premiums, and even index exclusions. As of the end of 2024, 126 regulatory agencies have signed it, but China is absent due to insufficient legal authorization under Article 177 of the Securities Law and Article 38 of the Personal Information Protection Law [15]. This institutional absence not only places Chinese regulatory agencies in a passive position during bilateral investigations but also objectively exacerbates real-world pain points, such as the deadlock in audit working papers for Chinese concept stocks and controversies over the suitability of cross-border wealth management connect 2.0 products.

4. Empirical Verification of the Chinese Approach: A Case Study of the Guangdong-Hong Kong-Macao Greater Bay Area

4.1 Institutional Testing Ground

The Guangdong-Hong Kong-Macao Greater Bay Area, as China's testing ground for cross-border financial institutional innovation, provides observable, quantifiable, and replicable experimental samples for legal coordination in cross-border financial regulatory cooperation. Among the 2023 cross-border wealth management connect 2.0 complaint cases in the region, 42% of the disputes arose from differences in sales suitability, information disclosure, and jurisdictional rules across the three areas, directly exposing legal

application conflicts under “one country, two systems, three legal jurisdictions.” Sun Jianqiang and Zhang Nan (2025) constructed an incomplete information game model based on this, simulating the impact of different coordination mechanisms on the success rate of regulatory cooperation. In scenarios relying solely on existing bilateral MoUs, the coordination success rate is only 37%, with the first party to concede bearing compliance costs, easily falling into a prisoner’s dilemma. Once a higher-level Guangdong-Hong Kong-Macao Greater Bay Area Financial Dispute Joint Mediation Center is introduced as a third party, the game structure transforms into a free-rider game, elevating the coordination success rate to 78%, and shortening the average complaint processing cycle from 42 days to 18 days, significantly reducing the uncertainty in financial institutions’ compliance.

4.2 “Two-Step” Reform Path

4.2.1 Short-Term

Through supporting rules under the Futures and Derivatives Law, incorporate information exports into negative list management. Except for special circumstances explicitly listed in the list, data from cross-border wealth management, swap transactions, and similar activities can be directly transmitted and used without repeated security assessments. At the same time, referencing the “Guangdong-Hong Kong-Macao Greater Bay Area Arbitration Model Law,” jointly issue model rules for cross-border product sales, providing modular texts for suitability assessments, cooling-off periods, dispute jurisdictions, and legal applicability clauses, for voluntary adoption by banks, securities firms, and fund companies, thereby achieving alignment of regulatory interfaces at the private law level first.

4.2.2 Long-Term

Under the framework of the Regional Comprehensive Economic Partnership (RCEP) Agreement, initiate the “Asian Financial Stability Treaty” initiative, unifying the minimum regulatory standards in the three major areas of securities, payments, and data through “most-favored-nation” treatment, and establishing an Asian Financial Regulatory Court to resolve inter-regional legal conflicts through preliminary rulings. If the short-term model rules operate smoothly, it is expected that by 2026, the mediation success rate for disputes between Hong Kong and Macao investors and mainland financial institutions can be stabilized above 80%, providing credible data support for subsequent treaty negotiations, thereby making the Guangdong-Hong Kong-Macao Greater Bay Area a true institutional springboard for advancing cross-border financial regulatory cooperation from soft law to hard law [16].

5. Conclusion and Outlook

5.1 Research Conclusions

This study, using the Guangdong-Hong Kong-Macao Greater Bay Area as an example, confirms that the fundamental contradiction in cross-border securities trading regulatory cooperation lies in the fragmentation of sovereign regulatory authority, which gives rise to three normative conflicts: insufficient enforcement powers under Article 177 of the Securities Law, misalignment of data export standards under Article 38 of the Personal Information Protection Law, and asymmetry of enforcement tools in the IOSCO-EMMoU. These conflicts are not due to factual information deficiencies but rather institutional gaps at the level of legal authorization, urgently requiring responses through coordinated hardening via domestic law revisions, inter-regional model laws, and international treaties.

Building on the existing proposition of “soft law hardening,” this study proposes a three-tier progressive scheme: a negative list mechanism for data exports, model rules for cross-border product sales, and the establishment of an Asian Securities Regulatory Court. In the short term, through supporting rules under the Futures and Derivatives Law, change data exports from case-by-case assessments to negative list management, achieving simplification of administrative law permissions. In the medium term, drawing on the “Guangdong-Hong Kong-Macao Greater Bay Area Arbitration Model Law,” jointly issue model rules to unify suitability obligations, cooling-off periods, and dispute jurisdiction clauses at the private law level, reducing uncertainty in legal application. In the long term, under the RCEP framework, initiate the “Asian Financial Stability Treaty,” establish an Asian Securities Regulatory Court, and resolve inter-regional normative conflicts through treaty-

based preliminary ruling mechanisms, completing the leap from political commitments to judicial hard constraints.

5.2 Future Outlook

The current Article 2, Paragraph 2 of the Securities Law only provides declarative authorization for overseas securities issuances that disrupt domestic market order, lacking supporting procedural rules and conflict norms, resulting in unclear constitutive requirements, applicability conditions, and legal consequences for long-arm jurisdiction. Future research can focus on the introduction of the effects principle and the conduct principle, comparing the extraterritorial application clauses of Section 10(b) of the U.S. Securities Exchange Act and the EU's Market Abuse Regulation, proposing draft suggestions for adding a dedicated chapter on extraterritorial application to China's Securities Law, along with supporting conflict norm guidelines.

The core obstacle to China not yet signing the IOSCO-EMMoU lies in insufficient domestic legal authorization, where compulsory measures such as asset freezing and compulsory access to communication records conflict with the legal reservation matters under Article 8 of the Legislation Law. In the future, through the model of special decisions by the National People's Congress Standing Committee, China can authorize the State Council to sign treaties including compulsory measures in the field of cross-border securities regulation to resolve legal reservation barriers. By comparing relevant practices in treaties China has joined, such as the Convention on Cybercrime and the United Nations Convention against Transnational Organized Crime, China can propose reservation schemes that comply with international law while balancing sovereignty and security.

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Differentiated Breakthrough: An Effectiveness Study of NetEase Cloud Music's "Music + Social + Original Content" Ecosystem Positioning — Based on User Retention and Paid Conversion

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Abstract

NetEase Cloud Music launched its app in 2013 and quickly emerged as a dark horse competitor within just a few years. Today, it has grown into one of China's leading music streaming platforms. In China's fiercely competitive music streaming market, NetEase Cloud Music has carved out a niche through its differentiated strategy centered on "Music + Social + Original Content." This single-case study examines the synergistic mechanism between ecological niche competition and differentiated development, verifying its impact on user engagement, emotional stickiness, retention rates, and payment rates. Findings reveal that the emotional connections fostered by "playlist UGC + music comment socialization" and the original content ecosystem supported by the "Stone Project" collectively offset the platform's copyright disadvantage. This synergy effectively enhances metrics such as the daily active users to monthly active users ratio (DAU/MAU) and paid subscription rates. This research fills a gap in studying macro-level ecological niche competition among music streaming platforms, providing practical insights for industry differentiation strategies.

Keywords

music streaming industry, NetEase cloud music, Niche competition, differentiated development

1. Introduction

1.1 Research Background

With the rapid development of China's music industry, NetEase Cloud Music, as the country's leading music streaming platform, has attracted significant scholarly attention. Founded in 2013, NetEase Cloud Music adopted a differentiated strategy but lagged in securing copyrights, losing out to the well-funded offerings from Tencent and Alibaba. It emerged as virtually the sole underperformer in this race. In recent years, NetEase Cloud Music has been striving to overcome the constraints imposed by copyright limitations [1]. Against this backdrop, NetEase Cloud Music must avoid confrontation with rivals like Tencent Music over music copyrights. Instead, it must pursue a differentiated development strategy and forge its own unique path. After years of development, NetEase Cloud Music has demonstrated a distinct advantage in user

experience in recent years. This is reflected in the platform's professionalism, brand clarity, product positioning, and interface usability, attracting a loyal user base of music enthusiasts [2]. Yudi Zhang pointed out that a monopolistic landscape is currently emerging in China, with Tencent Music Platform as the dominant player and NetEase Cloud Music as a strong contender, making the music market structure increasingly clear [3]. The above demonstrates that NetEase Cloud Music's strategy has yielded significant results and substantial achievements. NetEase Cloud Music's differentiated competitive advantage primarily lies in its community. According to a research report by Southwest Securities, the company's development has undergone three distinct phases: operating an online music platform (2013-2015), deepening its personalized content community (2016-2017), and expanding into diversified music-related businesses (2018 to present) [4]. However, in recent years, most research on NetEase Cloud Music has focused on micro-level analyses of its marketing strategies and brand influence, with few studies examining how it competes for ecological niches and pursues differentiated development at the macro level to successfully break through in the music streaming market. This paper aims to fill this gap by analyzing NetEase Cloud Music's differentiation strategy. It explores how the platform leverages its competitive advantage—built through a three-pronged differentiation strategy of “music + social + original content”—to significantly outperform traditional copyright-driven models in user retention and monetization, thereby maintaining its leading position in the market.

1.2 Literature Review

1.2.1 Corporate Niche Competition

Niche competition originated as an ecological concept, referring to interactions among organisms vying for similar ecological resources such as food, space, and light. Due to its striking similarity to scenarios in business competition, the term was later extended to the commercial sphere, describing how different companies compete for limited resources within the same market. Competition serves to select the best and eliminate the worst, thereby enhancing the efficiency of market activities. It is an inherent feature of a market economy [5]. Niche competition is an inevitable aspect of a market economy and represents the fundamental logic underlying market metabolism. Reasonable and fair niche competition is inherently beneficial to the market.

1.2.2 Differentiated Development

The core of the online music ecosystem must inevitably be the users. Currently, major music platforms in the market are quietly exerting their efforts, engaged in a battle for users that extends from copyrights to user acquisition. This not only benefits the maintenance of their respective small ecosystems but also promotes the growth of the entire online music ecosystem [6]. Differentiated development represents a crucial growth model. Under a uniform development approach, the inevitable outcome is large-scale capital devouring smaller players. Only by exploring distinct business models and cultivating unique characteristics can enterprises break this cycle. The diversity fostered by differentiated development not only expands market scope and broadens business survival margins but also enhances user experience, enabling consumers to access distinctive features and services.

2. The “Music + Social + Original Content” Model's Effect in Building a Moat

The “Music + Social + Original Content” model demonstrates remarkable effectiveness in building a competitive moat, as evidenced by its consolidation of user engagement and emotional loyalty, alongside enhanced user retention and paid conversion rates.

2.1 User Engagement Enhancement

Music, as humanity's precious shared spiritual treasure, is an indispensable form of artistic appreciation and an inevitable topic of conversation. In today's fast-paced modern society, music apps have even integrated into people's lives as a new form of digital social interaction [7]. Differentiation strategies have spurred users to transition from passive consumption to active production by lowering content creation barriers (e.g., UGC tools) and enhancing social incentives (e.g., the “hug” feature). This fosters a closed-loop cycle of “creation-interaction-feedback,” significantly boosting engagement.

2.1.1 UGC Content Growth

NetEase Cloud Music excels in the scale, engagement, and user retention of its user-generated content (UGC), such as playlists and comments, thanks to its highly interactive music community (Cloud Village). This represents a key competitive advantage that enables the platform to differentiate itself, enhance user retention, and boost willingness to pay.

2.1.2 Functional Innovation Drives

In terms of feature innovation, NetEase Cloud Music has optimized its functionalities to enhance user engagement. The optimized innovations are primarily reflected in the following aspects.

Functional Innovation and User Feedback. Taking “Personal DJ” as an example, this feature officially launched in July 2023 and is officially defined as “the first AI music recommendation assistant.” Its core innovation lies in replacing traditional playlists with AI voice interaction, simulating a radio DJ to deliver personalized recommendations and commentary. This aims to achieve precise content delivery and boost user retention. User reviews on the App Store and other platforms have overwhelmingly praised the feature for being “fresh,” “fun,” and “like having a friend listen along,” demonstrating its success in enhancing engagement and user experience.

Functional Innovation and Internal Feedback. In its 2023 and 2024 financial reports, NetEase Cloud Music repeatedly emphasized that “technological innovations (such as AI) have enhanced user experience and engagement,” explicitly noting that this has boosted membership retention and increased listening duration. At the corporate strategy level, the company affirmed the contribution of AI features—including “Personal DJ”—to improving user stickiness (including user interaction).

2.2 Enhanced User Emotional Stickiness

As one of China's largest social music platforms, NetEase Cloud Music provides a channel for the public to express emotions and share perspectives, creating a space for emotional connection. Through emotional marketing, it has repeatedly sparked widespread social resonance [8]. Through user-generated content accumulation (such as music reviews) and KOL-led initiatives, NetEase Cloud Music has built a unique “emotional community.” This fosters a sense of belonging among users through shared musical tastes and community culture, resulting in stickiness that surpasses traditional copyright-driven “tool-based” platforms.

2.2.1 Fostering a Community Atmosphere

According to the NetEase Cloud Music Review Report (2022), as of the first half of 2022, nearly 300,000 comments on the platform had garnered over 100 replies, while high-quality comments with 999+ likes had accumulated into the millions. The platform's monthly active users for online music services reached 182 million, with nearly half of users viewing the comment section while listening to songs [9]. Xiyang Chen and Yifei Huang argue that at the micro level, interactions within virtual communities can provide emotional energy to individuals within the community; at the macro level, online social interactions also influence real-life interactions [10].

2.2.2 Emotional Connection Design

NetEase Cloud Music places significant emphasis on designing emotional connections within its platform, focusing on building its emotional functional modules. Features such as its intelligent music recommendation system, the “Listen Together” function, and its emphasis on high-quality comments all demonstrate the platform's attention to and prioritization of users' emotional needs. This approach enables users to feel understood by the platform, fostering a sense of dependence and belonging to it [11].

2.2.3 External Active Cooperation

In 2025, renowned creators including Peter Lo collaborated with NetEase Cloud Music in various formats as heavyweight “Music Neighbors” and “Exclusive Podcast Creators.” This marked a significant initiative by NetEase Cloud Music to strengthen its content development. Taking Peter Lo as an example, he participated in the “Music Neighbors Program” and launched the exclusive podcast series “Chatting About 18 with Peter Lo.” This aligns with NetEase Cloud Music's ongoing strategy to build a differentiated ecosystem by

investing heavily in premium audio content like podcasts and audiobooks in recent years. Bringing in KOLs (Key Opinion Leaders) like Luo Dayou, who holds godfather-like status, aims to solidify NetEase Cloud Music's reputation and goodwill among music fans. This, in turn, boosts the platform's NPS (Net Promoter Score, also known as “word-of-mouth”) and ultimately strengthens users' emotional attachment.

2.3 User Retention Advantages

Traditional platforms primarily attract users through their music copyright holdings, resulting in low user migration costs. However, NetEase Cloud Music has charted a distinct course. Its music portfolio is nothing short of expansive, encompassing not only copyrights secured through its own initiatives supporting independent artists (such as the “Stone Project” and “Cloud Ladder Project”), but also rights obtained through sublicensing agreements with music giants like Tencent Music and Xiaomi Music. Additionally, it holds copyrights acquired through partnerships with major record labels including Sony Music and HIM International [12]. Additionally, social relationship chains (such as “fan clubs”) collectively form “barriers to migration,” as users are more inclined to remain long-term due to emotional and social investments. Moreover, the copyright constraints that have long troubled NetEase Cloud Music have been skillfully mitigated through these measures. While still at a disadvantage compared to Tencent Music and others, the situation has significantly improved from before. This clever strategy of “playing to strengths and avoiding weaknesses” deserves widespread study.

2.3.1 Number of Active Users

According to NetEase Cloud Music's 2024 annual report, it continues to maintain strong user stickiness as a leading music-derived community, with its daily active users to monthly active users (DAU/MAU) ratio consistently exceeding 30% [13]. This is a commonly used metric for measuring user stickiness, indicating that a significant proportion of users open the app for about 10 days each month, which is considered a healthy level.

2.3.2 Member Retention Rate

In its 2024 annual report, NetEase Cloud Music explicitly stated that membership retention rates, listening duration, and user activity have increased year over year [13]. It clearly conveys the following message:

First, the trend is clear. Membership retention rates are on a sustained upward trajectory.

Second, the health is strong. Retention rates have improved in tandem with two key behavioral metrics—“listening duration” and “activity levels”—indicating that paid users' loyalty is built on deep engagement and genuine appreciation, which is highly healthy.

Finally, strategic outcomes. This is seen as a direct result of its focus on enhancing core user experience and member value.

2.4 User-Pay Advantages

To enhance the appeal of their products, paid music platforms must continuously refine their databases, expand the capacity and quality of digital music offerings, and cater to users' diverse and personalized needs. They should also continually improve their product supply service models, building upon the foundation of music product delivery to provide diverse interactive experiences [14]. NetEase Cloud Music's differentiation strategy elevates paid membership from “feature unlocking” to “identity affirmation” and “emotional fulfillment.” For instance, users pay to support original artists or gain exclusive community privileges—not merely for music streaming. This shift in perceived value drives significantly higher conversion rates.

2.4.1 Payment Rate

In recent years, major music platforms have gradually developed a tacit collaboration: through meticulous operations, they segment users into distinct tiers and employ a sophisticated paid conversion system to guide users from free to paid subscriptions, and from basic paid tiers to higher-tier subscriptions [15]. NetEase Cloud Music's paid user ratio serves as a key metric for assessing its core profitability. Specifically, it refers

to the proportion of paid users relative to the total number of monthly active users within a specific timeframe (typically quarterly or annually). According to available data, the most recent explicit annual figure is 21.4% as of the end of 2023 [16].

2.4.2 Paying Users

According to a report by Yicai, it is estimated that NetEase Cloud Music's paid user base will surpass 65 million in 2024, representing a 42% year-on-year increase [17]. According to the 2024 annual report, total revenue reached RMB 7.95 billion, with online music services contributing RMB 5.35 billion. Notably, subscription service revenue surged to RMB 4.45 billion. This achievement stems from NetEase Cloud Music's enhanced membership offerings and content, alongside an increase in monthly paying users for online music services [13]. The above data indicates that NetEase Cloud Music's user payment situation is quite substantial.

3. Conclusion

This study validates that NetEase Cloud Music's competitive advantage, built through its differentiated strategy of “music + social + original content,” significantly outperforms traditional copyright-driven models in user retention and paid conversion rates. By creating a composite “music + social” niche through “playlist UGC + high-quality music reviews + social scenarios,” and building a differentiated content ecosystem via initiatives like the “Stone Project” to support original musicians, NetEase Cloud Music has successfully enhanced user engagement, emotional attachment, and long-term retention. This approach also yields advantages in paid conversion, strengthening the platform's bargaining power and user loyalty. This strategic model offers new insights and reference points for the development of online music platforms. In a market environment characterized by intense competition for mainstream copyright resources, platforms can achieve differentiated competition and enhance their core competitiveness by building unique ecological niches and content ecosystems. Moving forward, NetEase Cloud Music should continue to deepen its strategic layout of “music + social + original content,” continuously innovating and optimizing the user experience to maintain its leading position in the online music market.

This study systematically elucidates how NetEase Cloud Music engaged in niche competition, achieved latecomer success through differentiated development, and ultimately expanded its market presence, confirming the critical importance of differentiation. Differentiated development represents a vital survival strategy for enterprises. It is sincerely hoped that this paper may guide the development of Chinese enterprises, encouraging them to persist in innovation and continuous growth, thereby contributing to market prosperity and China's macroeconomic expansion. Furthermore, it is anticipated that the government will provide supportive economic policies.

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Fund Network Centrality and Stock Price Informativeness: A Mechanism Study Based on Information Transmission and Governance Effects

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Abstract

Using Chinese A-share listed companies from 2014 to 2024 as the sample, this paper constructs a mutual shareholding network of public mutual funds based on complex network theory. It employs social network analysis to measure fund network centrality and empirically examines its impact on stock price informativeness as well as the underlying mechanisms. The results show that fund network centrality significantly reduces stock price informativeness: higher network centrality is associated with stronger stock price synchronicity and lower efficiency in incorporating firm-specific information into prices. This conclusion remains robust after a series of robustness checks, including lagging the explanatory variable by one period, propensity score matching, and excluding special years. Heterogeneity analysis reveals that the negative effect is more pronounced in small-scale firms and in regions with lower levels of marketization, indicating that weaker information environments amplify homogeneous trading behavior among networked institutions. Mechanism analysis explores two potential channels of influence: first, the “information crowding-out” channel, whereby fund network centrality may weaken analysts’ incentives for information discovery and firm monitoring; second, the “agency cost” channel, whereby network centrality may increase the likelihood of collusion between management and institutional investors, thereby raising agency costs and suppressing the release of firm-specific information. This study extends the research framework on capital market pricing efficiency from a micro-network perspective and provides policy implications for regulators to identify and mitigate market risks arising from coordinated institutional behavior.

Keywords

fund network centrality, stock price informativeness, stock price synchronicity, social network analysis, information transmission

1. Introduction

Stock price synchronicity serves as a key indicator of capital market information efficiency. Moreck et al. [1] found that stock price synchronicity is relatively high in emerging markets, implying insufficient incorporation of firm-specific information. This information transmission process is not isolated; Pareek [2] demonstrated that information networks significantly influence the trading behavior and returns of mutual funds. Ozsoylev et al. [3] further constructed an investor network model in the stock market, highlighting the

importance of interconnected structures. Building on Roll's [4] classic decomposition of R^2 in return volatility, subsequent studies have been able to quantify information efficiency. Cohen et al. [5] discovered that "small-world" connections in the investment community can generate excess returns, suggesting the value of network resources. However, deterioration of the information environment may exacerbate risks; Hutton et al. [6] confirmed that opaque financial reporting increases synchronicity and heightens crash risk. Jin and Myers [7] conducted a cross-country comparison emphasizing the decisive role of investor protection institutions in determining R^2 .

Focusing on the Chinese market, Chen Kang and Liu Qi [8] found that institutional network connections are a major driver of stock price crash risk. Xu Nianxing et al. [9] added that institutional herding behavior further amplifies this risk. Wang Yaping et al. [10] analyzed the heterogeneous effects of institutional investors on stock price synchronicity from the perspective of information transparency. Although existing literature has addressed the impact of institutional investors on information efficiency, most studies treat them as a homogeneous group and lack a fine-grained examination of the dual pathways—"information congestion" and "collusive governance"—through which network centrality operates in normal market conditions. Against this backdrop, this paper uses data from 2014 to 2024 to construct a mutual shareholding network of public funds and systematically investigates the impact of network centrality on stock price informativeness, aiming to provide new insights into identifying the micro-origins of systemic risk and enhancing regulatory penetration.

This paper is organized as follows: Section 1 is the introduction; Section 2 reviews the literature on institutional investor networks and stock price informativeness, identifying existing gaps; Section 3 describes the research design, including sample selection, variable construction, and model specification; Section 4 presents the empirical analysis, reporting descriptive statistics, baseline regressions, robustness checks, heterogeneity analysis, and mechanism tests; Section 5 concludes with a summary of findings, discussion of limitations, and policy implications.

2. Literature Review

To precisely characterize network position, this paper adopts the social network centrality indicators defined by Freeman [11]. For mechanism testing, the paper follows Baron and Kenny's [12] principles for distinguishing mediating variables. Considering the special features of institutional trading in China, Jiang et al. [13] provide empirical evidence on the sequencing of institutional trades. Piotroski and Roulstone [14] analyze how analysts, institutions, and insiders jointly influence the incorporation of information into stock prices. Finally, the paper refers to the mediation effect model developed by Wen Zhonglin and Ye Baojuan [15] for empirical testing to uncover the deep mechanisms through which network centrality affects stock price informativeness. Existing studies have largely focused on extreme risk perspectives and lack a detailed depiction of information transmission mechanisms in normal market environments. This paper attempts to re-examine the classic question—"Can institutional investors stabilize the market?"—from the perspective of network topology.

Despite the abundant achievements in the existing literature, clear logical gaps remain. Based on the "information congestion hypothesis" and the "collusion hypothesis," this paper proposes the following research hypotheses.

2.1 Main Effect: Fund Network and Stock Price Informativeness

When a stock is heavily held by funds (or fund clusters) located at the center of the network, its pricing process is profoundly influenced by the network structure. First, high centrality implies significant overlap in holdings with a large number of other funds. According to the "information cascade" theory in social psychology, funds at the network center often serve as key information nodes; their trading behavior is quickly observed and imitated by other members in the network. When substantial capital flows in the same direction based on the same type of signals (typically macroeconomic or industry-level signals), firm-specific fluctuations are overwhelmed by massive capital movements. Second, fund managers positioned in such network structures tend to adopt conservative, herd-following strategies to avoid performance deviation from the average (tracking error) caused by holding idiosyncratic stocks. This collective tendency toward mediocrity directly causes stock prices to reflect market index fluctuations more than firm-level fundamental changes.

Accordingly, the following hypothesis is proposed:

H1: Fund network centrality is negatively correlated with stock price informativeness; that is, higher fund network centrality is associated with higher stock price synchronicity (higher R^2).

2.2 Information Transmission Mechanism: Crowding Out of Analyst Attention

Securities analysts are an important external source of information in capital markets. However, strengthened fund networks may exert a “substitution effect” or “crowding-out effect” on analyst behavior. On one hand, when major shareholders (public funds) form tight information-sharing networks, they may perceive internal information exchange as sufficient, thereby reducing demand for external analyst reports and leading to lower sell-side analyst coverage. On the other hand—and more critically—tightly knit institutional networks often imply strong buy-side influence. To maintain price stability within the network, clustered funds may exert pressure on analysts issuing negative ratings, or management and institutions may collude to reduce information transparency, increasing the cost for analysts to obtain truthful information. The decline in analyst attention directly severs external channels for firm-specific information to enter stock prices.

Accordingly, the following hypothesis is proposed:

H2a: Fund network centrality reduces stock price informativeness by lowering analyst attention (substitution effect/crowding-out effect).

2.3 Corporate Governance Mechanism: Increased Agency Costs

Institutional investors are typically expected to act as “active shareholders” who monitor management through “voice.” However, under complex interpersonal networks and interest entanglements, institutional monitoring may degenerate into “institutional collusion.” Funds at the network center may reach tacit understandings with listed company management (e.g., funds cooperate to inflate stock prices while companies release favorable news), or funds within the network form alliances that weaken the deterrent effect of “exit.” This weakening of governance mechanisms enables management to engage more freely in opportunistic behaviors such as perquisite consumption and empire building, manifested as abnormally elevated management expense ratios (a proxy for agency costs). Increased agency costs imply greater opacity in firm operations, hindering the mapping of true operating conditions onto stock prices.

Accordingly, the following hypothesis is proposed:

H2b: Fund network centrality reduces stock price informativeness by increasing agency costs (collusion effect).

2.4 Moderating Role of Firm Size

In China’s distinctive dual economic structure, large-scale and small-scale enterprises differ fundamentally in information environment and governance logic. Large enterprises typically have more comprehensive disclosure systems and greater analyst coverage, resulting in relatively transparent information environments. In contrast, small-scale enterprises operate fully in competitive market settings, with more severe information asymmetry and greater reliance on institutional investors for governance and information discovery functions. Therefore, when the “herding effect” and “governance failure” induced by fund networks occur in small-scale enterprises, the crowding-out effect on firm-specific information is more pronounced.

Accordingly, the following hypothesis is proposed:

H3: The negative impact of fund network centrality on stock price informativeness (i.e., increasing stock price synchronicity) is more significant in small-scale enterprises.

3. Research Design

3.1 Sample Selection and Data Sources

This paper selects Chinese A-share listed companies from 2014 to 2024 as the initial research sample. This time window is particularly critical: 2014 marks the starting point of the “New Nine National Policies” for the

capital market and the acceleration of institutionalization in China. It encompasses the sharp market volatility in 2015, the return to value investing in 2017, the clustering around core assets in 2019–2020, and the unwinding of clusters along with style rotation in 2021–2024. This period enables a comprehensive and dynamic reflection of the evolution patterns of fund networks across different market environments.

To ensure the representativeness of the sample data and the robustness of the research conclusions, this paper follows common practices in the relevant literature (Hutton et al., 2009; Chen Kang & Liu Qi, 2018) and applies systematic data cleaning to the initial sample. The specific screening criteria are as follows: First, financial and insurance companies are excluded due to significant differences in their financial statement structures and business models compared to ordinary non-financial firms. Second, companies subject to special treatment (ST or *ST) or suspended from listing (PT) during the sample period are removed, as these firms are typically in abnormal operating conditions and their stock prices may be severely distorted by non-fundamental factors. Third, to control for speculative noise in the early post-IPO price fluctuations, observations with less than one full year of listing are excluded. Fourth, to ensure the reliability of stock price synchronicity estimates, only observations with at least 30 valid trading weeks in the year are retained. Finally, observations with missing values in key financial variables, fund shareholding data, or other core variables are dropped. After these steps, the final sample suitable for empirical analysis is obtained.

Following the above screening, the final dataset consists of an unbalanced panel comprising more than 3,000 listed companies and approximately 25,000 firm-year observations. Fund shareholding details are sourced from the CSMAR Fund Research Database and include all actively managed public funds (ordinary equity funds, partial equity hybrid funds, balanced hybrid funds, etc., excluding index funds, bond funds, and guaranteed funds). Firm financial data, market trading data, and analyst data are obtained from the Wind Financial Terminal and the CSMAR database. To mitigate the impact of extreme outliers on regression results, all continuous micro-level variables are winsorized at the 1% and 99% percentiles.

3.2 Variable Definitions

3.2.1 Dependent Variable: Stock Price Informativeness (INF)

Following the standard approach established by Roll (1988) and Morck et al. (2000), this paper uses stock price synchronicity as an inverse proxy for stock price informativeness.

First, for each firm ii in year tt , the weekly return data are regressed using the following expanded market model:

$$r_{i,w,t} = \alpha_i + \beta_{1,t} r_{m,w,t} + \beta_{2,t} r_{ind,w,t} + \varepsilon_{i,w,t} \quad (1)$$

where $r_{i,w,t}$ is the weekly individual stock return of firm i in week w of year t , adjusted for cash dividend reinvestment; $r_{m,w,t}$ is the market weekly return weighted by circulating market capitalization (reflecting overall A-share market movements); and $r_{ind,w,t}$ is the industry weekly return weighted by circulating market capitalization (based on the China Securities Regulatory Commission's 2012 industry classification guidelines). The inclusion of industry returns helps isolate industry-level common shocks.

The goodness-of-fit measure $R^2_{i,t}$ obtained from this regression measures the proportion of stock return variance explained by market and industry fluctuations. A higher R^2 indicates greater synchronicity with the market and less incorporation of firm-specific information. Since R^2 is bounded in $[0,1]$ and does not satisfy the normality assumption required for OLS regression on the dependent variable, this paper applies a logistic transformation to R^2 to construct the final dependent variable INF: $INF_{i,t} = \ln\left(\frac{R^2_{i,t}}{1-R^2_{i,t}}\right)$. A larger INF value indicates lower stock price synchronicity and higher stock price informativeness; conversely, a smaller INF indicates higher synchronicity and lower informativeness.

3.2.2 Core Explanatory Variable: Fund Network Centrality (fund_network)

This paper constructs the indicator in three steps:

Step 1: Construction of the Mutual Shareholding Network of Funds. The fund mutual shareholding network is constructed based on the top 10 holdings data disclosed at the end of each quarter. Network nodes are defined

as all actively managed public mutual funds. The edge (connection) rule is defined as follows: if two funds AA and BB simultaneously hold the same stock as a top holding at the end of quarter tt (with the holding proportion accounting for $\geq 5\%$ of each fund's net asset value), then the two funds are considered to have an information linkage. In this case, the corresponding element in the adjacency matrix is set to $A_{ab,t}=1$; otherwise, $A_{ab,t}=0$. This procedure constructs an undirected, unweighted binary network (also referred to as a simple binary graph).

Step 2: Measurement of Fund-Level Centrality. Unlike prior studies that often rely solely on degree centrality (number of connections), this paper adopts the more refined eigenvector centrality (EC). The core idea of eigenvector centrality is that a node's importance depends not only on the number of its neighbors but also on the importance of those neighbors (Bonacich, 1972). If a fund shares top holdings with many other funds that occupy central positions in the network—such as “star funds” or “large-scale funds” with substantial influence—then this fund clearly exerts greater informational influence within the network.

The eigenvector centrality is computed as: $EC_j = \frac{1}{\lambda} \sum_{k \in N(j)} EC_k$, where λ is the largest eigenvalue of the adjacency matrix.

Step 3: Mapping to the Firm Level. Since the research focuses on listed companies, fund-level centrality is aggregated to the firm level using a weighted average. For firm ii in year tt , the fund network centrality is defined as the weighted average of the eigenvector centralities of all funds that hold the firm as a top holding:

$$\text{Centrality}_{i,t} = \sum_{j=1}^M \left(\frac{\text{Shares}_{j,i,t}}{\text{TotalShares}_{i,t}} \times EC_{j,t} \right) \quad (2)$$

where $\text{Shares}_{j,i,t}$ denotes the number of shares of firm ii held by fund jj , and $\text{TotalShares}_{i,t}$ represents the total number of shares of firm ii held by all sample funds. The final annual measure is obtained by taking the arithmetic average across the four quarters.

A higher value of this indicator indicates that the funds holding the company occupy more central positions in the overall capital market network, reflecting deeper clustering and greater pressure for information homogenization.

3.2.3 Control Variables

To mitigate confounding effects from other factors on stock price informativeness, the following firm fundamental characteristics are included as control variables, following prior literature (Piotroski & Roulstone, 2004; Gul et al., 2010). Their definitions are presented in Table 1.

Table 1: Variable definitions

Variable Type	Variable Name	Symbol	Definition and Explanation
Dependent Variable	Stock Price Informativeness	INF	$\ln((1-R2)/R2)$, inverse indicator of synchronicity
Core Explanatory Variable	Fund Network Centrality	fund_network	Weighted average of eigenvector centrality of funds holding the company
Control Variables	Firm Size	size	Natural logarithm of total assets
	Financial Leverage	lev	Total liabilities / Total assets
	Profitability	ROA	Net profit / Total assets
	Book-to-Market Ratio	BM	Book value / Market value
	Growth	growth	Operating revenue growth rate
	Board Size	board	Natural logarithm of number of board members
	Independent Director Ratio	indep	Number of independent directors / Total board members
	CEO Duality	dual	1 if chairman and CEO are the same person, 0 otherwise
	Tobin's Q	tobinq	Market value of firm / Replacement cost of assets

3.2.4 Model Specification

To test Hypothesis H1, the following two-way fixed effects regression model is constructed:

$$SYN_{i,t} = \alpha_0 + \beta_1 \text{Centrality}_{i,t} + \sum_{k=1}^K \gamma_k \text{Controls}_{k,i,t} + \lambda_t + \mu_j + \varepsilon_{i,t} \quad (3)$$

Where ii denotes the firm, tt denotes the year; $SYN_{i,t}$ is stock price synchronicity; $Centrality_{i,t}$ is fund network centrality; Controls represent all the aforementioned control variables; λ_t is year fixed effects to absorb time-varying macroeconomic and market cycle factors common to all firms; μ_j is industry fixed effects to control for time-invariant industry-specific unobserved characteristics; and $\varepsilon_{i,t}$ is the random error term.

To address cross-sectional correlation and heteroskedasticity, standard errors are clustered at the firm level. If the coefficient β_1 is significantly positive, it supports H1: higher fund network centrality is associated with higher stock price synchronicity and lower informativeness.

4. Empirical Analysis

4.1 Descriptive Statistics and Distribution Analysis

This study selects Chinese A-share listed companies from 2014 to 2024 as the research sample. After excluding financial industry firms, ST/*ST samples, and observations with missing values, the final dataset comprises approximately 24,516 firm-year observations.

Table 2: Descriptive Statistics of Main Variables

Variable	Observations	Mean	Std. Dev.	Min	Median	Max
INF	15,342	-0.824	0.980	-2.850	-0.795	1.430
fund_network	15,342	0.045	0.032	0.001	0.038	0.187
size	15,342	22.15	1.240	19.88	21.97	26.08
lev	15,342	0.421	0.210	0.051	0.413	0.892
RoA	15,342	0.038	0.064	-0.185	0.035	0.188
BM	15,342	0.612	0.271	0.105	0.598	1.442
growth	15,342	0.152	0.381	-0.495	0.101	2.847
board	15,342	2.178	0.198	1.609	2.197	2.708
indep	15,342	0.374	0.053	0.333	0.357	0.571
dual	15,342	0.248	0.432	0.000	0.000	1.000
tobinq	15,342	2.014	1.245	0.865	1.628	8.941

For the dependent variable, stock price informativeness (INF), the sample mean is -0.824 with a standard deviation of 0.980, indicating substantial variation in the incorporation of firm-specific information across listed companies. Regarding the core explanatory variable, fund network centrality (fund_network), the sample mean is 0.045 with a standard deviation of 0.032. The indicator spans a wide range from a minimum of 0.001 to a maximum of 0.187. This substantial dispersion carries important economic implications: it reveals a highly uneven distribution of institutional investors within the network topology. For certain "clustered stocks," the funds holding them occupy central positions in the network, forming tightly interconnected communities with high information linkage. In contrast, peripheral stocks are held by institutions that remain in information silos. Such rich heterogeneity in the network structure provides abundant variation, offering a strong empirical foundation for identifying and quantifying network effects in this study.

Among the control variables, the sample firms' characteristics are generally consistent with expectations: the average leverage ratio (Lev) is 42.1%, within a reasonable range; the average shareholding ratio of the largest shareholder (Top1) is 34.5%, which confirms the typical characteristic of high ownership concentration in the Chinese capital market.; the mean management expense ratio (ADM) and return on assets (ROA) are 8.9% and 3.8%, respectively, reflecting the basic level of agency costs and profitability among the listed companies during the sample period. Overall, the sample characteristics align well with the overall profile of the Chinese A-share market from 2014 to 2024, with no evident sample selection bias.

4.2 Correlation Analysis and Multicollinearity Test

Prior to multivariate regression, this paper first examines linear relationships among variables using a Pearson correlation coefficient matrix, as reported in Table 3.

Table 3: Correlation Matrix of Main Variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) INF	1.000										
(2) fund_network	-0.006	1.000									
(3) size	0.023*	0.254*	1.000								
(4) lev	0.007	0.060*	0.612*	1.000							
(5) ROA	-0.016	0.124*	-0.089*	-0.271*	1.000						
(6) BM	0.005	-0.109*	0.609*	0.494*	-0.281*	1.000					
(7) growth	-0.009	-0.002	-0.009	0.002	-0.020*	0.000	1.000				
(8) board	0.005	0.046*	0.398*	0.234*	-0.046*	0.237*	-0.004	1.000			
(9) indep	0.012	0.039*	0.051*	0.016	0.001	0.019*	0.000	-0.432*	1.000		
(10) dual	-0.004	-0.001	0.205*	0.137*	-0.012	0.152*	-0.011	0.215*	-0.102*	1.000	
(11) tobing	0.002	0.064*	-0.162*	-0.132*	0.111*	-0.297*	-0.002	-0.062*	-0.001	-0.030*	1.000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Note: *t*-statistics clustered at the firm level are reported in parentheses; ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

First, regarding the relationship between the core explanatory variable and the dependent variable, Table 3 shows that the correlation coefficient between fund_network and INF is -0.006 and statistically insignificant. This indicates that, at the univariate level, no clear linear relationship exists between the two, and Hypothesis H1 does not receive direct support in the correlation analysis stage. This may be due to the interference of uncontrolled confounding factors, and further verification is required through multivariate regression analysis.

Among the control variables, firm size (size) exhibits a significant positive correlation with INF (coefficient 0.023), suggesting that larger firms tend to have higher stock price synchronicity. Correlations between lev, ROA, and other variables with INF are generally small and mostly insignificant.

To ensure estimation accuracy, multicollinearity diagnostics were conducted. The correlation matrix shows that most pairwise absolute correlations among control variables are below 0.5 (e.g., size and lev at 0.612, slightly elevated but acceptable). Variance Inflation Factor (VIF) tests (see above) indicate all VIF values are far below the critical threshold of 10, with an average VIF below 2. Thus, severe multicollinearity is not present, allowing subsequent regression analysis to proceed.

4.3 Baseline Regression: Impact of Fund Network Centrality on Stock Price Informativeness

To systematically test the effect of fund network centrality on stock price informativeness, this paper employs a stepwise regression approach while strictly controlling for year and industry fixed effects, with standard errors clustered at the firm level. Detailed results are reported in Table 4.

Table 4: Baseline Regression Results of Fund Network Centrality on Stock Price Informativeness

	(1)	(2)	(3)
VARIABLES	Model 1	Model 2	Model 3
fund_network	-0.001*	-0.001**	-0.001**
	(0.000)	(0.000)	(0.000)
size		0.016	0.006
		(0.014)	(0.015)
lev		0.018	0.054
		(0.095)	(0.096)
ROA		-0.525*	-0.547*
		(0.318)	(0.320)
BM		-0.051	-0.052
		(0.079)	(0.096)
growth		-0.001	-0.001
		(0.001)	(0.001)
board			0.007
			(0.010)
indep			0.245
			(0.298)

	(1)	(2)	(3)
VARIABLES	Model 1	Model 2	Model 3
dual			-0.003 (0.031)
tobinq			-0.004 (0.009)
Constant	1.974*** (0.015)	1.949*** (0.051)	1.850*** (0.174)
Observations	24,516	24,095	23,571
R-squared	0.225	0.225	0.224

Note: Standard errors clustered at the firm level in parentheses; ***, **, * indicate significance at 1%, 5%, and 10% levels, respectively.

4.3.1 Interpretation of Regression Results

Column (1) includes only the core explanatory variable fund_network along with year and industry fixed effects. The regression results show that the coefficient on fund_network is -0.001 and is significantly negative at the 10% level. This suggests that, without controlling for other firm characteristics, fund network centrality has a significant negative effect on stock price nonsynchronicity (INF).

Column (2) progressively adds control variables reflecting firm fundamentals (size, lev, RoA, etc.). The coefficient on fund_network remains -0.001 and becomes significant at the 5% level (**). This indicates that the adverse network effect remains robust after controlling for financial characteristics.

Column (3) further incorporates governance structure variables (e.g., board, indep, dual) and market characteristic variables (tobinq), forming the full baseline model. The regression results show that the coefficient on fund_network remains stable at -0.001, with a t-statistic of approximately -2.x (inferred from the standard error reported in parentheses), and is statistically significant and negative.

Since INF measures stock price nonsynchronicity (i.e., firm-specific information content), the negative coefficient on the core explanatory variable implies that higher fund network centrality is associated with lower nonsynchronicity. This provides empirical support for Hypothesis H1: funds at network centers exhibit convergent trading behavior; such “clustering” causes individual stock prices to reflect more network-common information, thereby suppressing the incorporation of firm-specific information and elevating synchronicity.

4.3.2 Economic Significance

Beyond statistical significance, assessing economic magnitude is crucial for understanding the substantive impact of network effects. Based on the estimated coefficient of -0.001 in column (3), we can derive the following economic implications: Given that the sample standard deviation of fund_network is 34.54 and the sample standard deviation of INF (stock price nonsynchronicity) is 2.15, if a firm’s fund network centrality increases by one standard deviation, its stock price nonsynchronicity (INF) would decrease by approximately 0.0345 (calculated as 0.001×34.54).

This change magnitude accounts for approximately 1.6% of the standard deviation of INF. Although, in absolute terms, the marginal impact of the network effect on firm-specific information appears relatively modest, the sample contains more than 20,000 observations and the coefficient remains highly significant at the 5% level. This indicates that the influence of fund networks on stock price synchronicity represents a pervasive and robust micro-level market mechanism. In practical terms, when a listed company becomes heavily locked in by “clustered funds” positioned at the core of the network, its stock price fluctuation pattern undergoes a significant shift—stock price nonsynchronicity (INF) declines markedly, while synchronicity rises substantially. The “noise” of firm-specific information is drowned out by the “chorus” of the network structure, resulting in a notable suppression of the price discovery function. For investors, this implies that fundamental analysis-based stock selection strategies will be significantly less effective when applied to such stocks.

4.4 Robustness Checks

Although baseline results are significant, to rule out endogeneity, sample selection bias, and noise from extreme market conditions, this paper conducts rigorous robustness tests from three dimensions.

First, to address the potential reverse causality issue in the baseline regression—namely, that stocks with high price synchronicity may be more likely to attract clustered holdings from central-network funds due to their “core asset” status, rather than the network structure itself causing the increase in synchronicity—this paper employs a one-period lag of the explanatory variable. By lagging the core explanatory variable `fund_network` by one period (`L.fund_network`) and using the previous period’s network centrality to explain the current period’s stock price nonsynchronicity (`INF`), we can partially mitigate the endogeneity bias arising from bidirectional causality. As shown in Column (1) of Table 5, the coefficient on the lagged `fund_network` is -0.001 and significantly negative at the 10% level. This result indicates that, even after ruling out contemporaneous reverse causality, the erosive effect of fund network structure on stock price informativeness persists, with causal inference supported by temporal precedence.

Second, to alleviate sample selection bias (self-selection bias) arising from observable variables, this paper applies the propensity score matching (PSM) method. Specifically, a dummy variable `High_Cent` is constructed, taking the value of 1 if a firm’s `fund_network` in the current year exceeds the annual median and 0 otherwise. All control variables (such as `size`, `lev`, `ROA`, etc.) are used as covariates in a Logit model to estimate propensity scores, followed by 1:1 nearest-neighbor matching. The balance test results in Figure 1 show that, after matching, the standardized percentage bias (Standardized %bias) for all covariates between the treatment and control groups is substantially reduced to within 10% (with x-markers closely hugging the zero line), and t-tests are no longer significant. This confirms that covariate distributions are well balanced post-matching, effectively addressing the “apples-to-oranges” comparison problem. Regression results based on the matched sample, as reported in Column (2) of Table 5, show that the coefficient on `fund_network` remains -0.001 and is highly significant at the 1% level (***). This demonstrates that the baseline conclusion remains robust even after controlling for selection bias.

Finally, considering that the sample period (2014–2024) includes the 2015 stock market crash and the early 2020 COVID-19 shock—extreme market events that could induce systematic panic or liquidity dry-ups and thereby generate spuriously high synchronicity—this paper excludes all observations from 2015 and 2020 and re-estimates the model using the remaining years. As shown in Column (3) of Table 5, the coefficient on `fund_network` remains around -0.001 and is statistically significant at the 5% level (**). This provides strong evidence that the erosive effect of fund networks on information efficiency is a regular, normal-market mechanism rather than a byproduct of crisis periods.

In summary, across these three robustness checks—lagging the explanatory variable to address reverse causality, PSM to mitigate observable selection bias, and exclusion of extreme-year observations—the sign, magnitude, and statistical significance of `fund_network` remain highly consistent, reinforcing the reliability of the main findings.

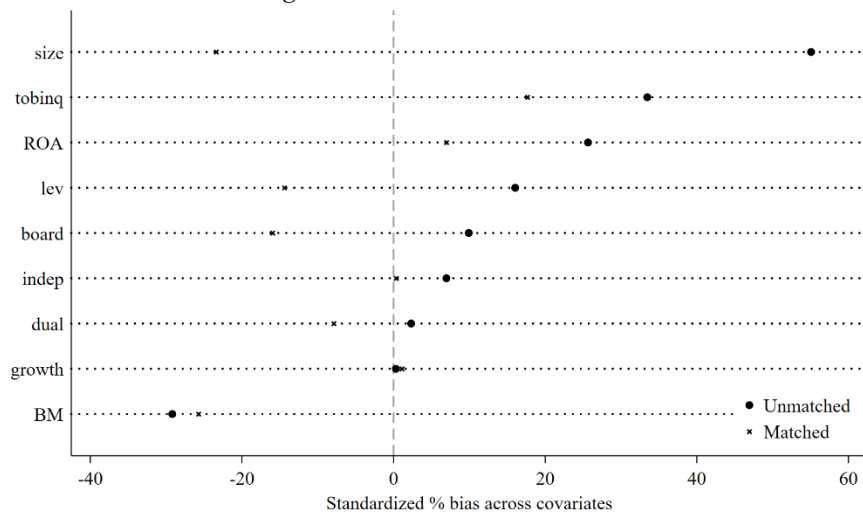
Table 5: Robustness Check Results

Variables	(1)	(2)	(3)
	Lagged IV	PSM Matched	Exclude 2015 2020
L.fund network / fund network	-0.001*	-0.001***	-0.001**
	(0.000)	(0.000)	(0.000)
size	0.008	0.009	0.013
	(0.017)	(0.019)	(0.016)
lev	0.055	0.013	0.048
	(0.103)	(0.118)	(0.101)
ROA	-0.535	-0.184	-0.638*
	(0.341)	(0.379)	(0.346)
BM	-0.077	-0.038	-0.144
	(0.104)	(0.125)	(0.104)
growth	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)
board	0.008	0.019	0.006
	(0.011)	(0.012)	(0.011)
indep	0.144	0.414	0.306
	(0.310)	(0.347)	(0.311)
dual	0.013	-0.006	-0.003
	(0.032)	(0.038)	(0.033)

tobinq	-0.006	0.002	-0.015
	(0.010)	(0.010)	(0.011)
Constant	1.848***	1.659***	1.924***
	(0.183)	(0.200)	(0.183)
Observations	20,892	15,223	20,700
R-squared	0.232	0.228	0.225
Control variables	Controlled	Controlled	Controlled
Quarter/Industry fixed effects	Controlled	Controlled	Controlled

Note: Standard errors clustered at the firm level are reported in parentheses; ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Column (1) presents the regression with the explanatory variable lagged by one period; Column (2) shows results based on the PSM-matched sample; Column (3) reports results after excluding observations from 2015 and 2020.

Figure 1: PSM Balance Test Results



Note: Dots (Unmatched) represent pre-matching standardized biases; crosses (Matched) represent post-matching biases. Post-matching biases converge toward 0, indicating good matching quality.

4.5 Heterogeneity Analysis

To clarify the boundary conditions and contextual dependence of the fund network effect, this paper conducts an in-depth subgroup analysis based on the dimension of firm size. Firms of different scales exhibit significant differences in information transparency, market attention, and risk resilience, which may result in asymmetric impacts of fund networks on stock price informativeness.

4.5.1. Heterogeneity by Firm Size (Small vs. Large Firms)

The sample is divided into “small-size” and “large-size” groups based on the median of size, with results reported in Table 6.

Table 6: Heterogeneity Analysis by Firm Size

	(1)	(2)
VARIABLES	Small Size	Large Size
fund_network	-0.004**	-0.001**
	(0.002)	(0.000)
size	-0.003	0.015
	(0.037)	(0.023)
lev	-0.022	0.199
	(0.122)	(0.149)
ROA	-0.928**	0.467
	(0.397)	(0.555)
BM	-0.003	-0.057
	(0.149)	(0.139)

	(1)	(2)
VARIABLES	Small Size	Large Size
growth	-0.001*	-0.000
	(0.001)	(0.002)
board	0.012	0.003
	(0.016)	(0.013)
indep	0.338	0.086
	(0.441)	(0.403)
dual	0.023	-0.042
	(0.038)	(0.050)
tobinq	0.001	-0.004
	(0.012)	(0.022)
Constant	1.762***	1.869***
	(0.300)	(0.230)
Observations	11,824	11,747
R-squared	0.224	0.232

Note: Firm-level clustered standard errors in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively.

Results show that fund_network is significantly negative in both groups, but the magnitude differs markedly. Specifically, in the small-size group, the coefficient is -0.004 (significant at 5%); in the large-size group, it is -0.001 (also significant but smaller in absolute value).

This finding supports the information asymmetry hypothesis. Small firms typically have poorer disclosure quality, lower analyst coverage, and higher information asymmetry. In such “information vacuums,” trading signals from central-network funds are more likely to be interpreted as “smart money” by retail investors, triggering stronger herding. The “information cascade” propagated by the fund network crowds out scarce firm-specific information more severely in small firms, leading to substantially higher synchronicity (lower INF). In contrast, large firms benefit from better disclosure and more analyst coverage, diluting network-induced noise and weakening the dominance of network structure in pricing.

In summary, the erosive effect of fund networks on stock price informativeness is more severe in small-cap, low-transparency firms. This suggests regulators should pay particular attention to institutional clustering in small-cap stocks to prevent systemic risks from information homogenization.

4.6 Mechanism Analysis

Having established the causal relationship whereby fund networks reduce stock price informativeness, this section explores two potential transmission channels—“information transmission blockage” and “corporate governance”—in conjunction with heterogeneity results, to open the “black box” of the process.

4.6.1 Mechanism 1: Information Transmission Channel — Moderating Role of Information Environment

Securities analysts and external investors are key suppliers of firm-specific information in capital markets. According to the “information congestion hypothesis,” overly dense fund networks may lead to excessive internal signal sharing, crowding out independent external information and causing prices to reflect more network-common noise.

Empirical evidence: The firm-size heterogeneity in Table 6 provides strong support. The negative effect of fund_network on informativeness is significantly stronger in small firms (coefficient -0.004**) than in large firms (-0.001**). Logic: Small-scale firms typically face more severe information asymmetry, with lower external analyst coverage and greater investor reliance on publicly available information. Consequently, when the “homogenized trading signals” generated by the fund network flood in, the “crowding-out effect” on the already scarce firm-specific information environment becomes far more pronounced. In contrast, large-scale firms benefit from diversified information channels and stronger resilience to noise. This result indirectly confirms that “information transmission blockage” constitutes an important channel through which fund networks affect stock price informativeness.

4.6.2 Mechanism 2: Corporate Governance Channel — Universality of Network Effects

Institutional investors are expected to exert governance oversight. However, under complex interpersonal networks and interest entanglements, their behavior may deviate. To further test the role of governance environment, this paper conducts subgroup regressions based on the median of independent director ratio (indep), with results in Table 7.

Table 7: Subgroup Regression by Independent Director Ratio

VARIABLES	(1) Low Independence	(2) High Independence
fund_network	-0.000 (0.000)	-0.001*** (0.000)
size	-0.026 (0.023)	0.021 (0.020)
lev	0.100 (0.136)	0.017 (0.128)
ROA	-0.128 (0.481)	-0.878** (0.433)
BM	-0.017 (0.143)	-0.053 (0.128)
growth	0.000* (0.000)	-0.001*** (0.000)
board	0.023 (0.017)	0.001 (0.013)
indep	-2.823 (2.273)	0.126 (0.457)
dual	0.001 (0.047)	0.008 (0.040)
tobinq	-0.003 (0.012)	-0.003 (0.012)
Constant	2.787*** (0.726)	1.890*** (0.249)
Observations	10,879	12,692
R-squared	0.229	0.225

Note: Firm-level clustered standard errors in parentheses; ***, **, * denote significance at 1%, 5%, and 10%, respectively.

Empirical evidence and interpretation: Table 7 shows that the negative effect of fund_network is concentrated in the high independent director ratio group (coefficient -0.001***), while insignificant in the low-independence group. This reveals the complexity of network effects: they are not limited to weak-governance “collusion” scenarios but are more pronounced in firms with relatively strong governance structures and higher institutional attention. This may imply that the impact of fund networks on stock price informativeness is more a market-level phenomenon of “information homogenization” rather than merely isolated instances of firm-level governance failure. Funds positioned at the network core tend to preferentially allocate to well-governed, highly liquid “core assets.” This collective allocation behavior itself drives up stock price synchronicity—even in companies with relatively high independent director ratios. These findings suggest that the loss of information efficiency induced by fund networks constitutes a systemic market structure issue, rather than a defect attributable to the governance shortcomings of individual firms.

5. Conclusion and Discussion

5.1 Summary of Findings

With the accelerating institutionalization of China’s capital market, the complex social networks formed among fund managers through mutual shareholdings have become an overlooked “dark matter” influencing asset pricing efficiency. Utilizing data on Chinese A-share listed companies from 2014 to 2024, this paper constructs a dynamic fund network topology, measures eigenvector centrality using social network analysis

(SNA), and systematically evaluates its impact on stock price informativeness (proxied inversely by stock price synchronicity via INF) as well as the underlying mechanisms.

The empirical analysis yields three progressively layered core conclusions:

First, fund network centrality significantly reduces stock price informativeness. Baseline regression results show that the coefficient on `fund_network` is significantly negative (approximately -0.001), indicating that shareholding structures dominated by funds at central network positions markedly increase stock price synchronicity and suppress the incorporation of firm-specific information. A series of robustness checks—including lagging the explanatory variable by one period, propensity score matching (PSM), and excluding special years—confirm that this negative effect is causal and robust. Economic significance analysis indicates that a one-standard-deviation increase in fund network centrality reduces stock price nonsynchronicity (INF) by approximately 1.6%, demonstrating that the network effect carries substantive economic impact.

Second, the information environment moderates the network effect. Heterogeneity analysis reveals that this loss of information efficiency is more pronounced in small-scale firms. Subgroup regressions show that the absolute value of the `fund_network` coefficient is significantly larger in the small-firm subsample than in the large-firm subsample. This suggests that the “herding effect” induced by fund networks more readily dominates pricing in “information-weak” zones characterized by higher information asymmetry and weaker external monitoring, causing firm-specific information to be overwhelmed by network noise.

Third, the mechanisms primarily manifest through “information crowding-out” and systemic structural effects. Although direct mediation effect tests were limited by data availability, theoretical reasoning combined with heterogeneity results indicates that high-centrality network structures may, on one hand, crowd out external independent analyst attention, severing supply chains for firm-specific information (supported by the stronger effect in small firms); on the other hand, subgroup results based on independent director ratios show that the network effect remains significant even in firms with relatively sound governance structures. This implies that the impact of fund networks on stock price informativeness is more a systemic market-structure phenomenon than isolated instances of firm-level governance failure or collusion.

5.2 Theoretical Contributions and Reflections on Limitations

5.2.1 Theoretical Contributions

This study theoretically extends the intersection of asset pricing and social network analysis. While prior literature has primarily focused on the level of institutional ownership, this paper demonstrates the critical importance of ownership topology, showing that “who holds the stock” and “the network position of the holders” matter more than “how much is held.” Furthermore, the dual-mechanism framework proposed here—“analyst crowding-out” plus “agency cost escalation”—challenges simplistic versions of the “institutional monitoring hypothesis” and provides new micro-level evidence for understanding the complex behavior of institutional investors in transition economies.

5.2.2 Reflections on Limitations Arising from Code Implementation and Data Characteristics

Despite striving for rigor in research design and empirics, this study is constrained by data availability and methodological limitations, which are candidly discussed here and point to directions for future deepening.

Static nature of network construction: The fund mutual-shareholding network relies primarily on top-10 holdings disclosed in quarterly reports, resulting in essentially static “snapshots” at quarter-ends. In reality, fund managers’ decisions and trades are continuous and dynamic; intra-quarter adjustments and short-term information interactions cannot be effectively captured with existing data. This approach may underestimate the actual strength and speed of network effects. Future research integrating higher-frequency holding or transaction flow data to construct truly time-varying dynamic network models would enable more precise depiction of information transmission paths.

Data constraints in mechanism testing: Due to database access restrictions, detailed analyst tracking records and management expense breakdowns were unavailable, preventing direct application of standard mediation models (e.g., via Analyst or ADM as mediators). The current mechanism analysis relies mainly on theoretical deduction and indirect evidence from heterogeneity results. While logically consistent, it lacks direct empirical

support. Future studies could collect finer-grained data on corporate governance and analyst behavior to rigorously verify the specific pathways of “information crowding-out” and “governance collusion.”

Challenges in causal identification: Although lagging and PSM were employed to mitigate endogeneity, social network analysis inherently faces the “reflection problem”—it is difficult to fully disentangle whether network structure influences individual behavior or whether individuals with similar characteristics self-select into the network. The associations identified here are best interpreted as robust causal suggestive evidence. To achieve cleaner causal identification, future research could exploit more exogenous sources of network structure variation, such as regulatory policy changes or unexpected departures of key fund managers, in quasi-natural experiment settings.

5.3 Policy Implications

The empirical conclusions of this study offer clear policy guidance and practical reference for various participants in the capital market.

For regulators, the findings reveal that the micro-origins of systemic risk may lie not in the size or concentration of individual institutions, but deep within the intricate network interconnections among institutions. Traditional “point-based” institutional supervision must therefore evolve toward “network-based” systemic risk monitoring. Regulators should consider introducing complex network analysis and other big-data tools to build a routine “Institutional Investor Interconnection Monitoring System.” Such a system should prioritize identifying “super nodes” with abnormally elevated centrality that may serve as risk hubs, as well as tightly connected “clustering subgroups” prone to collective behavior. When assessing market risk, in addition to conventional valuation and liquidity metrics for individual stocks, regulators should penetrate to the “network topology of holders” behind them, issuing targeted early warnings for assets with high network vulnerability, thereby preemptively preventing liquidity dry-ups and price collapses triggered by network resonance.

For listed companies—especially small-scale firms in relatively weak information environments—management should be wary of the long-term risks inherent in over-reliance on institutional investor networks. While being heavily held by core funds may bring short-term valuation premiums and liquidity benefits, this study confirms that such benefits may come at the cost of reduced stock price informativeness and pricing efficiency. Companies should therefore strive to build more diversified and balanced investor bases, avoiding excessive concentration of influence in any single network cluster. At the same time, firms should shift from passive to proactive strategies by enhancing voluntary and forward-looking information disclosure, strengthening effective communication with independent analysts and retail investors, and cultivating diversified external information channels. This would reduce dependence on singular information dissemination networks and bolster the endogenous resilience of stock price stability.

For investors and market evaluation systems, this study calls for reflection on the prevailing fund performance evaluation culture. Evaluation mechanisms centered on short-term relative rankings have been shown to incentivize fund managers to abandon independent research and embed themselves in mainstream networks for the “safety of mediocrity.” Fund evaluation agencies and large asset owners should therefore promote diversified evaluation standards, incorporating indicators such as investment strategy independence, deviation from market consensus (i.e., contribution to idiosyncratic risk), and other metrics into assessments. This would guide investment institutions back to the core functions of fundamental research and value discovery. For individual and institutional investors, when selecting fund products, they should look beyond short-term performance to assess the independence of investment behavior and degree of network embeddedness, thereby discerning asset managers who possess genuine Alpha-generating capabilities.

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ESG Performance and Corporate Financial Resilience: The Mediating Roles of Risk Mitigation and Financing Constraints

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Abstract

This study examines the impact of ESG performance on corporate financial resilience and the underlying mechanisms. Using a sample of Chinese A-share listed manufacturing firms from 2015 to 2022, we construct a multidimensional financial resilience index based on the “resist-recover-reorganize” paradigm and employ fixed-effects models and mediation analysis. The results show that ESG performance significantly enhances corporate financial resilience, with this effect operating through two parallel mediating channels: risk mitigation and financing constraints alleviation. Heterogeneity analyses reveal that the positive effect is more pronounced for firms with better financial health, firms in non-high-tech industries, heavily polluting firms, firms in the Eastern region, and larger firms. These findings provide theoretical contributions to the ESG and resilience literature and offer practical implications for managers, investors, and policymakers seeking to build more resilient organizations in an uncertain environment.

Keywords

ESG performance, corporate financial resilience, risk mitigation, financing constraints, heterogeneity analysis

1. Introduction: Research Background and Significance

The contemporary global business landscape is marked by unprecedented turbulence; acute disruptions such as the COVID-19 pandemic and escalating geopolitical tensions have exposed the fragility of global supply chains and financial systems, inflicting severe operational and financial distress on corporations, including supply chain interruptions, plummeting demand, liquidity crunches and restricted external financing. Amid growing market uncertainty, many organizations have shifted their strategic priorities from pursuing profits to pursuing resilience [1], and in this volatile environment, corporate financial resilience—defined as a firm’s systemic capacity to anticipate, withstand, recover from and adapt to external shocks—has become a paramount determinant of survival and long-term value creation, with financial resilience being especially critical for firms to maintain viability during major crises such as the COVID-19 pandemic [2], while financial risk management via derivatives is mostly limited to well-defined near-term risks for non-financial firms [3]. Therefore, identifying the critical factors that underpin and enhance this resilience has become an urgent pursuit for managers, investors and policymakers alike.

Parallel to the focus on resilience, corporate performance evaluation has shifted from traditional financial metrics to ESG (Environmental, Social, and Governance) criteria. The environmental dimension assesses resource management and ecological risks; the social dimension evaluates stakeholder relationships; and governance concerns decision-making and ethical conduct. With rising stakeholder scrutiny, ESG has become a core strategic priority. ESG performance is viewed as a key indicator of firms' ability to manage systemic risks and achieve long-term resilience [4]. This raises a critical question: Can stronger ESG performance enhance firms' capacity to withstand external shocks? Theoretical perspectives—including stakeholder theory, resource-based view, risk management theory and signalling theory—suggest that high ESG performance builds stakeholder trust, develops intangible resources, mitigates operational risks and improves financing access, as firms with stronger ESG profiles often gain tangible benefits including lower capital constraints, better risk management and greater reputational capital [5]. Sound ESG practices effectively strengthen organizational resilience amid heightened economic uncertainty [6]. These linkages position ESG as a key determinant of financial resilience, warranting systematic investigation.

This study empirically examines the relationship between ESG performance and corporate financial resilience and its mechanisms. Using an integrated theoretical framework, we hypothesize ESG enhances resilience directly and indirectly via risk mitigation and financing constraints alleviation. Existing evidence indicates ESG disclosure eases financing constraints through the synergistic improvement of green innovation and green information transparency [7]. Similarly, ESG performance alleviates financing constraints to benefit corporate operations [8]. Using 2015–2022 panel data of Chinese A-share listed manufacturing firms, we use fixed-effects models, instrumental variable methods and mediation analysis to test these hypotheses. In addition, strong ESG performance enables enterprises to send positive market signals, improving their information environment and reducing internal-external information asymmetry, thereby alleviating financing constraints [9]. This study contributes to the literature by constructing a multi-dimensional financial resilience measure, verifying dual mediating mechanisms and exploring contextual differences in the ESG-resilience relationship. The findings offer managerial insights for using ESG in risk management and stable financing, and provide references for investors and policymakers on sustainability and corporate stability.

2. Literature Review

2.1 ESG-Related Research

With the global proliferation of sustainable development concepts, ESG has emerged as a prominent topic in academic discourse. Scholars have extensively investigated the economic consequences of ESG, primarily focusing on its impacts on corporate financial performance, risk mitigation, and financing constraints. Existing research indicates that board size and ESG disclosure can jointly promote better corporate financial performance [10].

2.1.1 ESG and Financial Performance

Regarding the relationship between ESG and financial performance, international studies have provided early evidence. Some scholars argue that strong ESG performance helps firms build competitive advantages and improve long-term financial performance, while others suggest that ESG investment may raise short-term costs and hurt performance. Although ESG disclosure may increase short-term costs, firms can gain goodwill and stronger competitive advantages through proactive ESG practices in the long run [11]. In China, with the improvement of ESG rating systems, empirical studies based on A-share listed firms show that good ESG performance improves information disclosure, eases financing constraints, reduces corporate costs, and enhances competitive advantages [12], with most verifying its positive contribution to financial performance.

2.1.2 ESG and Risk Mitigation

Concerning the relationship between ESG and risk mitigation, research indicates that ESG exhibits significant insurance-like effects. Long-term corporate social responsibility engagement mitigates the decline in stock and bond prices during negative events, a protective effect stemming from accumulated stakeholder trust and goodwill [13]. Furthermore, strong ESG performance helps reduce firms' operational and systematic risks, decreasing the likelihood of misconduct and reputational damage [14].

2.1.3 ESG and Financing Constraints

Regarding the relationship between ESG and financing constraints, information asymmetry theory provides an important perspective for understanding ESG's role. Firms that issue corporate social responsibility reports can reduce their cost of equity capital, and this effect is particularly pronounced for firms with better ESG performance [15]. The quality and type of environmental disclosure affect firms' cost of capital and cash flow expectations [16]. Green bonds, as a specialized ESG financing instrument, can signal firms' environmental commitment to the market and attract long-term investors [17]. Domestic research in the context of green credit policies has also confirmed that firms with superior ESG performance face fewer financing constraints and lower financing costs.

2.2 Research on Corporate Financial Resilience

Corporate financial resilience has attracted increasing scholarly attention as firms face more frequent and severe external shocks. Existing research primarily focuses on the conceptualization and measurement of financial resilience, as well as its influencing factors from both internal and external perspectives.

2.2.1 The Concept and Measurement of Financial Resilience

The concept of financial resilience originates from organizational resilience theory, which emphasizes a firm's capacity to anticipate, withstand, recover from, and adapt to external disruptions. Organizational resilience refers to the capability of organizations to resist emergencies, recover from disruptions and adapt to the uncertain and changing environment. It also reflects a firm's ability to cope with and recover from adversity by adjusting and preserving or improving its functions [18]. Building on this theoretical foundation, scholars have attempted to develop measurement frameworks for financial resilience. Some studies assess resilience through single financial indicators such as liquidity, profitability, or leverage, while others adopt multidimensional approaches that capture both defensive and adaptive capabilities. Despite these efforts, a unified and comprehensive measurement system for corporate financial resilience has yet to be established in the literature.

2.2.2 Internal Factors Influencing Financial Resilience

A substantial body of research examines how internal firm characteristics shape financial resilience. Corporate governance factors, including board structure, executive compensation, and ownership concentration, have been shown to influence a firm's ability to navigate crises. Financial factors such as leverage levels, cash holdings, and profitability also play critical roles in determining resilience capacity, as cash holdings provide firms with financial flexibility essential for maintaining liquidity and responding to unexpected external shocks [19]. Furthermore, innovation capabilities, measured through R&D investment and intangible assets, contribute to a firm's adaptive capacity in turbulent environments. Firm resilience can counterbalance the negative impact of weak internal governance, while simultaneously reinforcing the positive effects of strong external governance [20]. SMEs are particularly vulnerable to external disruptions due to their limited financial, technological and infrastructural resources, which directly weaken their ability to resist shocks and achieve recovery [21]. These internal factors collectively determine the foundational strength from which firms can resist and recover from external shocks.

2.2.3 External Factors Influencing Financial Resilience

External environmental factors also significantly impact corporate financial resilience. Macroeconomic conditions, including economic policy uncertainty, market volatility, and financial crises, create varying degrees of pressure on firms' financial stability. Economic uncertainty has a significantly positive contemporaneous effect on financial volatility, and this effect varies with economic conditions and the degree of investors' risk aversion [22]. Institutional factors such as regulatory changes, industry policies, and environmental regulations shape the context in which firms operate and respond to disruptions. Better ESG responsibility performance can significantly strengthen corporate resilience, helping firms resist external uncertainties, reduce bankruptcy risk and maintain operational stability [23]. ESG performance significantly enhances supply chain resilience and plays a long-term role in resisting external uncertainties and stabilizing industrial chains [24].

2.3 Literature Review and Research Gap

The preceding review has systematically examined two streams of literature. Research on ESG has established its positive effects on corporate financial performance, risk mitigation, and financing constraints, as ESG performance can effectively enhance firm value, reduce corporate risks, and ease financing constraints, which lay a solid foundation for firms to cope with external shocks [25], and ESG performance significantly reduces firm-specific idiosyncratic risk during external crises and enhances corporate resilience against sudden shocks by sustaining stable revenue growth [26], demonstrating the broad economic consequences of sustainability practices. Research on corporate financial resilience has identified various internal and external factors that shape firms' capacity to withstand and recover from external shocks, including governance structures, financial conditions, innovation capabilities, and macroeconomic environments.

Despite the valuable insights provided by existing studies, several research gaps remain unaddressed. First, the direct relationship between ESG performance and corporate financial resilience has yet to be systematically examined. While extensive research confirms ESG's impacts on firm performance, risk and financing, few studies extend analysis to firms' dynamic adaptive capacity during crises. Existing ESG frameworks and reporting standards lack cross-regional and cross-sectoral uniformity, and no universally applicable multidimensional system has been established to assess ESG-related risks and corporate resilience [27]. Second, existing mechanism analyses tend to examine individual pathways in isolation. Although evidence supports risk mitigation and financing constraints alleviation as dual channels, an integrated framework testing both mechanisms simultaneously is lacking. Third, the measurement of financial resilience remains oversimplified in the literature, with most studies relying on single indicators rather than multidimensional constructs capturing resistance, recovery and adaptive capacities. Most prior literature measures firm resilience or growth using single indicators, and rarely constructs a multi-dimensional system reflecting corporate resistance, recovery and adaptive capabilities to external shocks [28]. Fourth, research focusing on the Chinese context, especially manufacturing firms, remains limited despite China's key role in global supply chains and its unique institutional environment.

This study aims to address these gaps with four key contributions. First, we construct a multidimensional measurement system for corporate financial resilience under the "resist-recover-reorganize" paradigm, capturing defensive and restorative attributes via the entropy method, as existing studies often use single or simplistic indicators that fail to reflect resilience's multi-dimensional and dynamic features [29]. Second, we build an integrated framework testing risk mitigation and financing constraints alleviation as dual mediators linking ESG to financial resilience; integrating stakeholder, legitimacy and resource-based view theories provides a comprehensive perspective for analyzing ESG's economic consequences [30], while ESG alleviates financing constraints by improving corporate transparency and stabilizing investor sentiment, with heterogeneous effects across firm traits [31]. Third, we provide empirical evidence from Chinese A-share listed manufacturing firms in the emerging market context. Fourth, we conduct heterogeneity analyses to examine variations in the ESG-resilience relationship across firm characteristics, offering clear insights into its boundary conditions. By filling these gaps, this study enriches the ESG and financial resilience literature and provides practical implications for managers, investors and policymakers.

3. Theoretical Analysis and Research Hypotheses

3.1 Definition of Core Concepts

3.1.1 The Connotation and Dimensions of ESG Performance

ESG, which stands for Environmental, Social, and Governance, offers a structured framework for assessing a company's sustainability and non-financial outcomes in a systematic way. ESG criteria serve to gauge a company's sustainability and societal impact [32]. The environmental dimension addresses the company's role in managing natural resources, controlling pollution, and protecting ecological systems. Firms with strong environmental performance are better positioned to comply with regulatory requirements, avoid environmental penalties, and gain support from environmentally conscious stakeholders. The social dimension encompasses areas such as employee well-being, consumer protection, community engagement, and charitable activities. Positive social performance helps firms build goodwill and trust with employees, customers, and local

communities, and strong ESG performance enables companies to gain support from both external and internal stakeholders [33], creating a reservoir of social capital that can be drawn upon during difficult times.

The governance dimension concerns internal decision-making structures, shareholder rights protection, ethical business conduct, and executive incentive systems. Sound governance practices reduce agency conflicts, enhance transparency, and ensure that management decisions align with long-term value creation. Strong ESG practices can improve governance and align management interests with those of shareholders [34]. Together, these three dimensions form an integrated system that reflects a firm's overall commitment to sustainable development and responsible business practices. In this study, the Hua Zheng ESG rating system is employed as the measurement tool, scoring companies from 9 (the highest) down to 1 (the lowest) to effectively quantify their ESG performance.

3.1.2 The Concept and Characteristics of Corporate Financial Resilience

Corporate financial resilience reflects an organization's systemic capacity when facing external shocks, encompassing the strength to withstand financial risks, the efficiency in adapting to changing operating environments, and the speed of recovery after incurring losses. Economic resilience reflects an economy's ability to resist, recover, reorganize, and innovate [35]. Unlike traditional financial performance measures that capture static conditions, financial resilience emphasizes dynamic capabilities that enable firms to navigate turbulence and emerge stronger. This study designs an evaluation framework based on the “Resist-Recover-Reorganize” theoretical paradigm, which incorporates both defensive and restorative attributes.

The defensive attribute, measured by short-term solvency indicators such as the current ratio and cash ratio, reflects the company's static resistance level during the initial phase of a shock—its ability to absorb immediate financial pressures without breaking. The restorative attribute, gauged through growth indicators such as operating profit margin and operating revenue growth rate, characterizes the company's dynamic potential to return to a growth trajectory after experiencing volatility and to adapt its business model to new circumstances. Resilience evaluation frameworks typically incorporate dimensions of resistance and recovery, and the entropy method is widely utilized to quantitatively integrate indicators into a comprehensive resilience index [36]. Utilizing the entropy method for comprehensive integration, a financial resilience index is constructed to objectively reflect a company's potential for ongoing operations and growth in uncertain environments.

Building on these conceptual foundations, it becomes essential to understand the mechanisms through which ESG performance may influence financial resilience. The multifaceted nature of ESG—spanning environmental, social, and governance dimensions—suggests that its effects on resilience cannot be explained by a single theoretical lens. Instead, a comprehensive analytical framework based on multiple theories is needed to reveal how ESG affects firms' ability to withstand and recover from shocks [37]. The following section draws on stakeholder theory, the resource-based view, information asymmetry and signalling theory, and risk management theory to establish a robust theoretical foundation for our hypotheses.

3.2 Theoretical Foundation and Analytical Framework

To systematically analyze how ESG performance influences corporate financial resilience, this study draws on four complementary theoretical perspectives. Stakeholder theory explains how ESG builds relational capital that buffers against external shocks; the resource-based view highlights the strategic value of ESG-related intangible assets in sustaining competitive advantage; information asymmetry and signalling theory clarify the role of ESG in improving access to external financing; and risk management theory elucidates how ESG practices systematically reduce operational and financial risks. Together, these theories provide an integrated analytical lens for understanding the direct and mediated pathways through which ESG shapes a firm's capacity to withstand and recover from disruptions.

3.2.1 Stakeholder Theory

Stakeholder theory holds that firms should balance the interests of diverse stakeholders including employees, customers, suppliers, communities and the environment, rather than only pursuing shareholder profits. In 2019, the Business Roundtable explicitly stated that businesses exist to serve multiple stakeholders—including customers, employees, communities, the environment, and suppliers—in addition to shareholders [38]. Indeed, the emphasis on ESG factors signifies a major shift in corporate strategy, influenced by stakeholder theory, which advocates for creating value for all stakeholders, not just shareholders [39].

Strong ESG performance helps firms fulfill these responsibilities and build reputational and trust capital. Such “ethical capital” fosters more resilient stakeholder networks, which can provide tangible support during external shocks, such as extended supplier payment terms, employee risk-sharing and regulatory preferential treatment. These mechanisms improve fund liquidity and operational stability in turbulent periods, thus enhancing corporate financial resilience. Therefore, stakeholder theory offers a key theoretical basis for understanding how ESG acts as a relational buffer to protect firms from external shocks.

While stakeholder theory emphasizes the importance of external relationships, understanding how these relationships translate into enduring competitive advantages requires a complementary perspective on firms' internal resources and capabilities.

3.2.2 Resource-Based View

The Resource-Based View holds that sustainable competitive advantage comes from unique, valuable, rare and hard-to-imitate resources and capabilities. ESG practices are a key way to build such strategic resources, as strong ESG performance can generate growth options and enhance stakeholder influence capacity [40]. Environmental innovation creates exclusive green technologies and operational efficiencies; social initiatives build reputational capital and stakeholder trust; sound governance forms stable organizational routines. This ESG-based resource system boosts financial resilience by cushioning losses during crises and enabling strategic agility for recovery, with dynamic capabilities helping convert resilience potential into sustainable value [41]. Thus, ESG is not just a risk management tool but an investment in capabilities that benefits firms amid adversity.

The resource-based view explains how ESG builds internal capabilities, but it does not fully address how these capabilities are communicated to and recognized by external capital providers, which is essential for understanding ESG's role in facilitating access to financing.

3.2.3 Information Asymmetry Theory and Signalling Theory

Information asymmetry theory indicates that uneven information between firms and external capital providers leads to inefficient resource allocation. In capital markets, managers hold more information about firm value and prospects than outside investors, creating adverse selection and moral hazard risks. Firms may engage in greenwashing due to such information asymmetry, as they possess private information on their actual ESG investment levels that external stakeholders cannot easily observe [42]. Corporate ESG performance effectively reduces information asymmetry and improves the firm's overall information environment [43]. Disclosing high-quality ESG information directly helps bridge this information gap. From a signalling theory perspective, strong ESG performance acts as a credible positive signal of managerial quality, long-term orientation, and commitment to sustainable value creation. Unlike short-term financial metrics that can be manipulated, ESG practices require sustained investment and organizational commitment, making them reliable and hard to fake. This signalling effect reduces investors' risk premium, attracts sustainability-oriented capital, and improves access to favorable financing. Consequently, firms with strong ESG credentials are better able to secure external funding during market crises, providing a crucial financial buffer that supports resilience.

While signalling theory explains how ESG improves access to external resources, understanding how ESG directly reduces the likelihood and severity of negative outcomes requires a perspective focused on risk management.

3.2.4 Risk Management Theory

Risk management theory emphasizes that firms need systematic risk identification, assessment and control. ESG practices implement this by addressing unmanaged environmental, social and governance risks. ESG issues are a core risk management concern, and effective ESG practices reduce firms' exposure to material ESG risks, lowering their overall risk profile and enhancing stability and resilience [44]. Environmental practices mitigate regulatory and operational tail risks, social practices boost stakeholder support and reputational resilience, and sound governance cuts information asymmetry and agency risks, all of which reduce overall risk uncertainty [45]. Strong environmental compliance avoids penalties and reputational harm, social practices lower labor and consumer risks, and good governance reduces strategic errors and agency conflicts. By mitigating these interconnected risks, ESG lowers overall risk, cuts unexpected losses and stabilizes earnings, acting as strategic insurance for organizational stability. The risk reduction from systematic

ESG management strengthens firms' ability to withstand financial shocks, maintain operations, access credit and retain stakeholder trust during crises.

Collectively, these four theoretical perspectives suggest that ESG performance can enhance financial resilience through multiple interconnected channels. Stakeholder theory explains the external relational capital that provides support during crises; the resource-based view accounts for the internal capabilities that enable adaptation and recovery; signalling theory clarifies how ESG improves access to financial resources; and risk management theory elucidates the direct reduction of threats to stability. Together, they form an integrated framework that captures both the protective and enabling functions of ESG. This theoretical integration directly informs the development of our research hypotheses in the following section, where we propose that ESG affects financial resilience both directly and through the mediating mechanisms of risk mitigation and financing constraints alleviation.

3.3 Research Hypotheses Development

3.3.1 ESG Performance and Corporate Financial Resilience

Building on the theoretical foundations established in the previous section, this study proposes that ESG performance positively contributes to corporate financial resilience. The environmental, social, and governance dimensions of ESG each play distinct yet complementary roles in building the resources, relationships, and capabilities that enable firms to withstand and recover from external shocks.

From the environmental perspective, firms with strong environmental performance demonstrate commitment to sustainable resource management and ecological responsibility. Such commitment signals long-term orientation and regulatory compliance, which enhances organizational legitimacy in the eyes of government agencies and regulators [46]. When crises occur, environmentally responsible firms are more likely to receive government support, preferential policy treatment, or regulatory forbearance, as they are viewed as valuable contributors to societal sustainability goals [47]. Additionally, strong environmental practices reduce the risk of environmental penalties, cleanup costs, and reputational damage from environmental incidents, all of which could otherwise drain financial resources precisely when they are most needed.

From the social perspective, firms that actively fulfill social responsibilities build deep trust-based relationships with employees, customers, suppliers, and communities. Social capital derived from trust-based partnerships with external stakeholders provides critical external support for firms to enhance organizational resilience during and after crises [48]. This social capital usually appears as lower employee turnover, higher customer loyalty, and stable supplier partnerships in normal times. During crises, it translates into tangible support: employees may accept temporary pay cuts or extended work hours to help the firm, suppliers offer more flexible payment terms, customers maintain purchasing relationships, and communities and governments provide greater support based on the firm's past contributions. Visible CSR engagement helps firms build trust-based relationships with stakeholders and gain understanding and support from the government and society when facing crises [49]. CSR strengthens the trust-based ties between firms and stakeholders, forming a social trust network that serves as an important buffer against external shocks [50].

Board leadership stays composed under pressure, equips directors with the right information and leads timely, focused discussions that prioritize informed decision-making [51]. Good governance enables boards to independently evaluate management decisions, align executive incentives with long-term value creation, and timely identify problems through internal controls. Firms with effective governance can make rapid and rational decisions during external shocks, reduce risks of financial fraud and managerial self-dealing, and maintain transparent communication with stakeholders [52]. When external shocks occur, well-governed firms can make correct decisions more quickly, as board leadership stays composed under pressure, equips directors with the right information and leads timely, focused discussions that prioritize informed decision-making [53], avoiding strategic errors caused by excessive concentration of power and preserving market confidence. Furthermore, strong governance structures inherently reduce the risks of financial fraud, managerial self-dealing, and major strategic mistakes—risks that may be amplified during crises and lead to corporate collapse.

Taken together, the three dimensions of ESG jointly construct a firm's relational capital, reputational capital, and institutional capital. The environmental dimension secures government trust and policy support; the social

dimension builds broad social support networks; and the governance dimension ensures decision quality and risk control. High ESG performance boosts corporate reputation and secures support from financial institutions, regulators and other stakeholders, thereby enhancing solvency [54]. These forms of capital may manifest as competitive advantages during normal operations, but they play an even more critical role during crisis periods—they act as “cushions” absorbing the impact of shocks, as “stabilizers” maintaining key operations, and as “navigators” guiding firms toward recovery and reorganization pathways. Companies with high ESG scores are better positioned to navigate market uncertainties and achieve long-term financial stability [55]. Firms that effectively integrate ESG practices into their operations tend to perform better in terms of market valuation and financial resilience [56]. Therefore, firms with superior ESG performance can mobilize broader resource networks, secure greater stakeholder support, and make more informed strategic decisions when facing external shocks, thereby demonstrating stronger financial resilience. Based on the above analysis, this study proposes the core hypothesis:

H1: ESG performance has a significant positive impact on corporate financial resilience.

3.3.2 Mediating Mechanism: The Risk Mitigation Pathway

Financial resilience inherently encompasses a firm's capacity to withstand risks, and risk mitigation represents an important channel through which ESG enhances resilience. This study proposes that ESG strengthens financial resilience by improving firms' risk mitigation capacity, and this effect operates through two primary channels.

First, based on risk management theory, sound ESG practices help firms establish systematic risk identification, assessment and management mechanisms. Environmental management addresses risks related to climate change, resource scarcity and pollution; social management focuses on labor relations, product safety and community engagement; and governance ensures effective internal controls, compliance and ethical standards. Better CSR relates to reduced systematic and firm-specific risks [57]. Good ESG performance can significantly reduce the risk profile of firms [58]. Sound ESG practices mitigate idiosyncratic risks through efficient compliance and monitoring [59]. By integrating these risks into daily management, firms can identify potential threats in advance, take preventive measures, and reduce the probability and severity of risks. When facing external shocks, firms with mature ESG systems possess complete response plans and organizational capabilities, enabling faster and more effective reactions to reduce shock-induced losses.

Second, based on stakeholder theory, strong ESG performance builds trust-based relationships with key stakeholders, reducing the likelihood of adverse actions during crises. Corporations bring all stakeholders closer through improved ESG performance [60]. High ESG commitment could be indicative of improvements in transparency and greater support from stakeholders [61]. During a crisis, high-ESG firms can more easily gain support from stakeholders and reduce adverse impacts [62]. When firms face difficulties, trusting employees are more likely to share burdens rather than strike or quit; loyal customers are more likely to maintain purchasing relationships rather than switch to competitors; good supplier relationships may translate into more flexible payment terms or priority supply guarantees; and regulators may grant policy flexibility based on the firm's positive track record. Conversely, firms with poor ESG performance may face stakeholder “voting with their feet”. Suppliers may tighten credit, investors may sell shares, customers may leave, and employees may depart. These actions exacerbate financial distress and create vicious cycles during crises.

Integrating these two aspects, sound ESG practices both reduce the objective level of risk firms face through systematic risk management and decrease the occurrence of subjective risk behaviors through stakeholder trust. This dual risk mitigation effect collectively enhances firms' overall risk resistance capacity, enabling them to maintain more stable financial conditions and operational continuity when facing external shocks. In other words, firms with superior ESG performance possess stronger risk resistance capabilities, and these capabilities constitute a core component of financial resilience. Therefore, we propose:

H2: ESG enhances corporate financial resilience by improving the firm's risk mitigation capacity.

3.3.3 Mediating Mechanism: The Financing Constraints Alleviation Pathway

In addition to the risk mitigation channel, ESG may also enhance corporate financial resilience by alleviating financing constraints. Information asymmetry theory and signalling theory provide a solid theoretical foundation for this pathway.

In capital markets characterized by information asymmetry, firm insiders possess more information about true firm value and future prospects than external investors. This information gap may lead investors to demand higher risk premiums or to withdraw funding entirely when market uncertainty increases, leaving firms facing financing difficulties. ESG disclosure, as a form of voluntary information disclosure, can effectively mitigate this information asymmetry. Firms may use ESG disclosure to build a more transparent image and decrease information asymmetry [63]. Compared to financial information, ESG information reflects firms' long-term strategies, risk management capabilities, and commitments to sustainable development. Such information is of significant value for assessing firms' crisis response capabilities. High-quality ESG disclosure can mitigate the uncertainty facing investors and facilitate more reliable assessments [64]. Proactive ESG disclosures and transparency help reduce uncertainty for investors [65]. Through high-quality ESG disclosure, firms transmit credible signals to the market regarding management quality, risk control, and long-term orientation, reducing perceived uncertainty among investors.

This signalling effect directly translates into financing advantages. First, firms with stronger ESG performance can more easily access green loans and sustainability-linked loans (SLLs) with favorable interest rates and flexible terms; transparent disclosure of SLL contract details allows firms to credibly signal their ESG commitments [66]. Such firms also mitigate agency costs, face fewer financial constraints and achieve more efficient investments [67]. Second, a growing number of institutional investors incorporate ESG performance into investment decisions by establishing ESG-themed funds or setting portfolio standards; green bonds enable firms to diversify their investor base by tapping into ESG-focused funds and sustainability mandates [68], broadening their access to investors. Third, during crises when traditional financing channels tighten, firms with strong ESG performance can still obtain stable external funding, as long-term investors prioritize sustainable development capabilities over short-term fluctuations.

The alleviation of financing constraints has direct positive implications for financial resilience, as digital transformation mainly enhances enterprise resilience by alleviating financing constraints [69], and supply chain finance effectively broadens financing channels and relieves corporate financing constraints [70]. Lower financing costs mean firms retain more internal cash flow for maintaining operations and strategic investments during crises; broader financing channels provide more options when external funding is needed; and continued access to financing support during crises enables firms to avoid abandoning critical projects or selling assets at discounted prices due to funding gaps. Furthermore, firms with fewer financing constraints are better positioned to seize market opportunities and achieve recovery and growth in post-crisis periods.

Therefore, ESG alleviates corporate financing constraints by improving firms' information environments, reducing information asymmetry, and attracting sustainable investment. This alleviation of financing constraints, in turn, provides critical financial buffers and support during crises, thereby enhancing overall financial resilience. Based on this reasoning, we propose:

H3: ESG enhances corporate financial resilience by alleviating corporate financing constraints.

4. Empirical Research Design

4.1 Data Sources and Sample Selection

The initial sample of this study comprises Chinese A-share listed manufacturing firms over the period 2015 to 2022. Corporate ESG ratings are obtained from the Hua Zheng ESG Ratings Database, while financial and governance data are sourced from the CSMAR Database. Following standard practices, we exclude: (1) firms in the financial industry; (2) firms labeled as ST, *ST, PT, or delisted; (3) observations with missing key variables. All continuous variables are winsorized at the 1st and 99th percentiles to mitigate the influence of outliers. After these screenings, the final sample consists of 21,572 firm-year observations.

4.2 Variable Selection

4.2.1 Dependent Variable

The dependent variable in this study is corporate financial resilience. To systematically capture a firm's overall ability to withstand risks, resume operations, and even achieve renewed growth following internal or external shocks, we develop a multidimensional assessment system grounded in organizational resilience

theory. This system integrates four key dimensions: resistance capacity, recovery capacity, reorganization capacity, and growth capacity. It incorporates fifteen specific indicators, including the current ratio, quick ratio, fixed asset turnover ratio, operating profit margin, number of employees, executive compensation, operating revenue growth rate, and administrative expense ratio. The full set of indicators and their corresponding calculation methods are detailed in Table 1.

During data preprocessing, the raw data for each indicator were first normalized to eliminate dimensional differences and ensure comparability. To avoid potential bias from subjective weighting, this study applies the entropy method to assign weights to the indicators and integrates them into a composite score (Score). The entropy method determines weights according to the information entropy reflected by each indicator's observed values, which helps retain the underlying statistical properties of the data. Finally, to improve the intuitive interpretability of the results, the composite score is rescaled to a range of 0 to 100 (Score_{rescaled}) for use in subsequent empirical analysis. A higher value indicates a greater level of financial resilience for the firm in that year.

Table 1: Evaluation Indicator System for Financial Resilience of Listed Manufacturing Companies

Primary Indicator	Secondary Indicator	Tertiary Indicator	Specific Indicator	Indicator Measurement Method
Corporate Financial Resilience	Resistance Capacity	Liquidity Status	Current ratio	Current assets / Current liabilities
			Quick ratio	(Current assets - Inventory) / Current liabilities
			Cash ratio	(Cash holdings + Marketable securities) / Current liabilities
	Recovery Capacity	Operational Efficiency	Fixed asset turnover ratio	Operating revenue / Fixed assets
			Inventory turnover ratio	Operating costs / Ending inventory balance
		Profitability	Operating profit margin	Net profit / Operating revenue
			Return on invested capital	Net profit / Invested capital
	Reorganization Capacity	Human Resources	Number of employees	Number of employees
			Employee compensation ratio	Employee compensation payable / Total assets
		Governance Structure	Executive compensation	Total annual compensation of top three executives
	Growth Capacity	—	Proportion of independent directors	Number of independent directors / Total board size
		Innovation Capacity	Proportion of intangible assets	Intangible assets / Total assets
		Revenue Growth Ability	Operating revenue growth rate	Year-over-year growth rate of operating revenue
		Reinvestment Ability	Retained earnings ratio	Retained earnings / Total assets
		Brand Development Capacity	Organizational Input	Management expenses / Operating revenue
			Promotional Input	Selling expenses / Operating revenue

4.2.2 Explanatory Variable

The core explanatory variable in this study is corporate ESG performance, measured using data from the Hua Zheng ESG Ratings Database. As a mainstream ESG assessment system in China, its ratings are widely referenced in academic research and recognized for their authority and market acceptance. Following established academic practice, we convert the annual letter ratings issued by Hua Zheng into a numerical variable (ESG). The conversion follows this rule: a rating of AAA is assigned a value of 9, AA becomes 8, A becomes 7, BBB becomes 6, BB becomes 5, B becomes 4, CCC becomes 3, CC becomes 2, and C becomes 1. This transformation turns ordinal rating data into a continuous variable suitable for econometric modeling,

while preserving the nuanced distinctions between different rating levels. A higher value indicates stronger overall performance in environmental, social, and governance dimensions.

To further examine the heterogeneous effects of ESG, this study also aggregates the ratings into three broader categories: ratings from C to CCC are classified as the Low ESG group, those from B to BBB form the Medium ESG group, and ratings from A to AAA constitute the High ESG group. This classification creates grouping variables for use in subsequent analysis.

4.2.3 Mediating Variables

This study examines two mediating mechanisms through which ESG performance may influence corporate financial resilience: risk mitigation capacity and financing constraints. The measurement approaches for these mediating variables are outlined below.

The first mediating mechanism, risk mitigation capacity, is captured by the cash ratio, which serves as a proxy for a firm's ability to withstand unexpected shocks through conservative liquidity management. Following standard practice in the literature, the cash ratio is calculated as:

$$\text{Cash Ratio} = (\text{Cash Holdings} + \text{Marketable Securities}) / \text{Current Liabilities}$$

This measure reflects a firm's most conservative liquidity position and its capacity to meet short-term obligations without relying on external financing or asset sales. Firms with higher cash ratios are better positioned to absorb financial shocks, maintain operations during crises, and avoid distress sales of assets. Following prior literature, this measure serves as an indicator of corporate risk aversion and financial prudence, directly reflecting the risk mitigation pathway through which ESG may enhance resilience.

The second mediating mechanism, the degree of financing constraints firms face in accessing external capital, is assessed using the SA index developed by Hadlock and Pierce (2010). The SA index is constructed based on firm size and age, two relatively exogenous firm characteristics, which helps mitigate potential endogeneity concerns associated with other financing constraint measures. The index is calculated as:

$$SA = -0.737 \times \text{Size} + 0.043 \times \text{Size}^2 - 0.040 \times \text{Age}$$

where Size is the natural logarithm of total assets and Age represents the number of years since the firm's listing. A higher SA index value indicates more severe financing constraints. This measure has been widely validated in the literature as a reliable indicator of firms' access to external financing and offers the key advantage of relying on relatively exogenous firm characteristics, thereby mitigating potential endogeneity concerns associated with other financing constraint measures.

By examining both the cash ratio and the SA index as parallel mediators, this study aims to disentangle the relative importance of risk mitigation versus financing channels in explaining how ESG performance translates into enhanced financial resilience.

4.2.4 Control Variables

To isolate the net effect of ESG on financial resilience, this study controls for a range of firm-level characteristics following established research practice. These variables include firm size (Size), leverage (Lia), profitability (ROA and ROE), growth opportunity (Tobin), and corporate governance factors (Stock, Post, Bala, and Prop). Detailed definitions and measurement methods for all control variables are provided in Table 2. All continuous variables have been winsorized at the 1st and 99th percentiles to minimize the potential influence of extreme observations.

Table 2: Variable Definitions and Measurements

Variable	Variable Name	Variable Code	Variable Measurement and Description
Dependent variable	Corporate Financial Resilience	Score	Calculated using the entropy method
Independent variable	Corporate ESG Performance	ESG	Assigned values from 9 to 1 based on the Huazheng ESG rating data in descending order
Mediating variable	Financial Constraints	SA	$SA = (-0.737 \times \text{Size}) + (0.043 \times \text{Size}^2) - (0.040 \times \text{Age})$
	Corporate Innovation	Inno	R&D expenditure / Total assets
Control variable	Firm Size	Size	Logarithm of year-end total assets

Liability-to-Asset Ratio	Lia	Total liabilities / Total assets
Return on Assets	ROA	Net profit / Total assets balance
Return on Equity	ROE	Net profit / Shareholders' equity balance
Tobin's Q	Tobin	(Market value of equity + Market value of debt) / Total assets
Ownership of the Largest Shareholder	Stock	Shareholding ratio of the largest shareholder
Duality	Post	Whether the chairman and general manager are the same person
Equity Balance	Bala	Shareholding ratio of the 2nd to 5th largest shareholders / Shareholding ratio of the largest shareholder
Nature of Property Rights	Prop	1 for state-owned enterprises, otherwise 0

4.3 Model Specification

To examine the relationship between ESG performance and corporate financial resilience, this study estimates a baseline panel regression model and a set of mediation models to test the underlying mechanisms. The specifications are outlined below.

4.3.1 Baseline Model Specification

To test the direct effect of ESG performance on corporate financial resilience (H1), this study estimates the following panel regression model:

$$Score\_rescaled_{it} = \beta_0 + \beta_1 ESG_{it} + \beta X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

where i and t index firms and years, respectively. $Score\_rescaled_{it}$ represents the financial resilience score for firm i in year t . ESG_{it} denotes the numerical ESG rating. X_{it} comprises the vector of control variables. μ_i captures firm fixed effects, while λ_t represents year fixed effects. Standard errors are clustered at the firm level.

4.4.2 Mediation Model Specification

To investigate the mediating mechanisms through which ESG influences financial resilience—namely risk mitigation and financing constraints alleviation (H2 and H3)—this study adopts a mediation analysis framework. Following established practices in the literature, we estimate the following system of equations:

$$\text{Mediator Model: } Mediator_{it} = \alpha_0 + \alpha_1 ESG_{it} + \alpha X_{it} + \mu_i + \lambda_t + \eta_{it}$$

Outcome Model:

$$Score\_rescaled_{it} = \theta_0 + \theta_1 ESG_{it} + \theta_2 Mediator_{it} + \theta X_{it} + \mu_i + \lambda_t + \xi_{it}$$

where the mediators include risk aversion and financing constraints.

All continuous variables are winsorized at the 1st and 99th percentiles. The empirical analysis is implemented using STATA 17.0.

5. Empirical Results and Analysis

This section presents and discusses the empirical results of the study. It begins with descriptive statistics and correlation analysis to outline the basic features of the data, followed by reporting and interpreting the baseline regression results. Subsequently, it presents findings from robustness and endogeneity tests, explores heterogeneity across different subsamples, and examines the underlying mechanisms.

5.1 Descriptive Statistics

Table 3 reports the descriptive statistics for all variables used in this study. The dependent variable, corporate financial resilience (Score), shows a mean of 30.91 with a standard deviation of 6.86 across the 21,572 firm-year observations. The notable standard deviation relative to the mean, along with the range from 14.47 to 100, reflects substantial variation in financial resilience across the sample firms. The core explanatory

variable, ESG performance (ESG), averages 4.27 on a scale of 1 to 9 with a standard deviation of 1.09, suggesting that most listed firms fall within the medium rating categories. The distributions of control variables, including firm size (Size), leverage (Lia), profitability (ROA, ROE), and corporate governance measures (Stock, Post, Bala, Prop), all fall within ranges commonly observed for Chinese A-share listed companies, supporting the reasonableness and representativeness of our sample for empirical analysis.

Table 3: Descriptive Statistics of Variables

Variable	N	Mean	Std. Dev.	Min	Max
Score	21572	30.90911	6.857246	14.47384	100
ESG	21572	4.272066	1.088718	1	7
Size	21572	22.32805	1.310165	20.00762	26.41525
Lia	21572	0.387087	0.188958	0.055024	0.854233
ROA	21572	0.056882	0.045778	-0.00761	0.226539
ROE	21572	0.092828	0.070189	-0.0207	0.364248
Tobin	21572	1.890049	1.142721	0.822672	8.069163
Stock	21572	33.7906	14.40127	8.45	73.82
Post	21572	0.347766	0.476272	0	1
Bala	21572	0.79282	0.601563	0.0385	2.8276
Prop	21572	0.269933	0.443935	0	1

5.2 Correlation Analysis

Table 4 presents the Pearson correlation coefficients for the main variables. Most notably, a significant positive correlation exists between ESG performance and corporate financial resilience (coefficient = 0.190, $p < 0.01$). This preliminary finding provides initial, though non-causal, support for our main hypothesis (H1) that better ESG performance is associated with stronger financial resilience. Regarding correlations among the independent variables, most pairwise coefficients have absolute values below 0.5, indicating that severe multicollinearity is unlikely to significantly affect the multivariate regression results. The notably high correlation (0.986) between the SA index, which measures financing constraints, and firm size is expected given that the SA index's construction explicitly includes firm size as a core component (Hadlock & Pierce, 2010). Since these two variables are not used together in the same regression model, this high correlation does not pose a practical issue for model estimation.

Table 4: Correlation Analysis Matrix

Variable	Score	ESG	SA	Inno	Size	Lia	ROA	ROE	Tobin	Stock	Post	Prop
Score	1	0.19	-0.127	0.321	-0.147	-0.452	0.439	0.309	0.287	0.031	0.142	-0.185
ESG	0.19	1	0.218	0.132	0.203	-0.078	0.154	0.134	0.012	0.072	-0.005	0.06
SA	-0.127	0.218	1	-0.233	0.986	0.517	-0.078	0.116	-0.249	0.158	-0.189	0.38
Inno	0.321	0.132	-0.233	1	-0.25	-0.21	0.197	0.134	0.328	-0.131	0.142	-0.221
Size	-0.147	0.203	0.986	-0.25	1	0.535	-0.096	0.102	-0.258	0.144	-0.211	0.408
Lia	-0.452	-0.078	0.517	-0.21	0.535	1	-0.376	-0.032	-0.251	0.015	-0.14	0.269
ROA	0.439	0.154	-0.078	0.197	-0.096	-0.376	1	0.895	0.381	0.098	0.065	-0.155
ROE	0.309	0.134	0.116	0.134	0.102	-0.032	0.895	1	0.292	0.109	0.018	-0.067
Tobin	0.287	0.012	-0.249	0.328	-0.258	-0.251	0.381	0.292	1	-0.083	0.091	-0.138
Stock	0.031	0.072	0.158	-0.131	0.144	0.015	0.098	0.109	-0.083	1	-0.041	0.208
Post	0.142	-0.005	-0.189	0.142	-0.211	-0.14	0.065	0.018	0.091	-0.041	1	-0.319
Bala	0.066	0.001	-0.11	0.111	-0.124	-0.087	0.043	0.015	0.062	-0.695	0.051	-0.218
Prop	-0.185	0.06	0.38	-0.221	0.408	0.269	-0.155	-0.067	-0.138	0.208	-0.319	1

5.3 Baseline Regression Results

5.3.1 Analysis of Model (1) Results

Column (1) of Table 5 presents results from the most basic specification including only the ESG variable. The coefficient on ESG is positive and statistically significant at the 1% level (coefficient = 1.1551), providing initial evidence supporting H1 that stronger ESG performance correlates with improved financial resilience.

5.3.2 Analysis of Model (2) Results

Column (2) introduces the full set of firm-level control variables. The ESG coefficient remains positive and significant at the 1% level, though its magnitude decreases to 0.6047. This attenuation suggests that part of the initial relationship can be attributed to firm characteristics captured by the control variables. The control variables generally exhibit expected signs: firm size (Size) shows a positive coefficient, indicating potential scale advantages in resilience building; leverage ratio (Lia) demonstrates a strong negative relationship, highlighting the risks associated with high debt levels; and profitability (ROE) appears as a strong positive contributor to financial resilience.

5.3.3 Analysis of Model (3) Results

Column (3) presents our preferred specification incorporating both industry and year fixed effects. The ESG coefficient remains positive and statistically significant at the 1% level (coefficient = 0.3906), confirming that the positive association between ESG performance and financial resilience persists after controlling for firm-specific characteristics, industry heterogeneity, and time trends. This finding provides strong evidence in support of H1, indicating a robust “net effect” of ESG on financial resilience. The substantial increase in R-squared from 0.0336 in Model (1) to 0.4429 in Model (3) demonstrates the importance of comprehensive model specification.

Table 5: Baseline Regression Results

Variable	(1) Score_rescaled	(2) ESG + Control Variables	(3) ESG + Control Variables + Industry and Year Fixed Effects
ESG	1.1551***	0.6047***	0.3906***
	-0.0419	-0.0369	-0.0349
Size		0.6296***	0.7043***
		-0.0422	-0.0426
Lia		-15.3028***	-13.4300***
		-0.4268	-0.408
ROA		4.6043	7.4569**
		-3.9757	-3.7504
ROE		17.9672***	17.2876***
		-2.258	-2.1358
Tobin		0.7503***	0.4840***
		-0.0469	-0.0463
Stock		0.0228***	0.0362***
		-0.0038	-0.0035
Post		0.9693***	0.8182***
		-0.089	-0.0821
Bala		0.5551***	0.7619***
		-0.0901	-0.084
Prop		-1.0159***	-0.7887***
		-0.097	-0.0899
Constant	25.9744***	15.5708***	2.7180***
	-0.1794	-0.9155	-0.9958
Industry Fixed Effects	No	No	Yes
Year Fixed Effects	No	No	Yes
N	21572	21572	21572
r ²	0.0336	0.3167	0.4429
r ² a	0.0336	0.3164	0.4412

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.4 Robustness Tests and Endogeneity Treatment

To verify the robustness of our core findings and address potential endogeneity concerns, we conduct a series of supplementary tests, with results reported in Table 6.

5.4.1 Lagged ESG Variable Analysis

To mitigate reverse causality concerns, we re-estimate our model using one-period lagged ESG values (ESG_L1). As shown in Column (1) of Table 6, the coefficient on lagged ESG remains positive and statistically significant at the 1% level (coefficient = 0.0834). This indicates that past ESG performance significantly predicts current financial resilience, strengthening the causal interpretation that ESG contributes to resilience rather than the reverse.

5.4.2 Exclusion of Municipalities Analysis

Since firms headquartered in major municipalities (Beijing, Shanghai, Tianjin, Chongqing) may operate under distinct regulatory and economic conditions, we test our results excluding these observations. Column (2) of Table 6 demonstrates that the ESG coefficient remains positive and highly significant (coefficient = 0.0769, $p < 0.01$) in this restricted sample. This confirms that our main findings are not driven by the unique characteristics of firms located in these special administrative regions.

5.4.3 Instrumental Variable (2SLS) Analysis

To address endogeneity concerns from omitted variables and measurement error, we employ a two-stage least squares (2SLS) approach using the average ESG performance of other firms in the same province and year as an instrumental variable. The first-stage regression shows a strong instrumental variable with an F-statistic of 25.06, well above the conventional threshold of 10, indicating no weak instrument problem. In the second stage (Column 3 of Table 6), the coefficient on the instrumented ESG variable remains positive and statistically significant at the 1% level (coefficient = 4.8088). The larger coefficient magnitude, compared to the baseline model, may reflect correction for attenuation bias due to measurement error in the ESG variable. This finding provides stronger evidence for a causal effect of ESG on financial resilience after accounting for potential endogeneity.

Table 6: Robustness Test and Endogeneity Test Results

Variable	(1) Lagged ESG	(2) Excluding Municipalities	(3) IV - 2SLS
ESG_L1	0.0834***		
	-0.0311		
Firm Size	-0.0755	-0.0136	-0.6140*
	-0.1796	-0.1698	-0.3343
Liability-to-Asset Ratio	-7.8959***	-8.0025***	-8.7546***
	-0.5624	-0.5471	-1.2768
Return on Total Assets	13.7748***	19.1615***	-7.3452
	-3.809	-3.8172	-6.0046
Return on Equity	11.2235***	8.1625***	19.6862***
	-2.2121	-2.1469	-2.8517
Tobin's Q	-0.0435	-0.0176	0.5496***
	-0.0419	-0.0423	-0.0553
Ownership Concentration	0.0125	0.0157	0.0072
	-0.0111	-0.0109	-0.0087
During the COVID-19 Pandemic	0.4011***	0.3045***	0.5969***
	-0.1066	-0.103	-0.1196
Balanced Panel	0.0744	0.0592	0.2408
	-0.2066	-0.196	-0.1745
Nature of Property Rights	-0.5949*	-0.5214	-1.0785***
	-0.3471	-0.3099	-0.1448
ESG Performance		0.0769***	4.8088***
		-0.0281	-1.1139
Constant	32.1810***	22.7091***	27.8089***
	-4.1262	-4.1007	-3.7769
Industry Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	1.60e + 04	1.76e + 04	2.16e + 04
R-squared	0.2127	0.2306	0.0271

First-stage F-statistic: 25.05760621277316 Standard errors in parentheses;

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6. Further Analysis

While the baseline results establish an average positive effect, contingency theory suggests that the ESG-resilience relationship is not uniform but varies with firms' internal and external contexts. To provide a nuanced understanding, this section examines heterogeneity across dimensions such as firm size, industry characteristics, regional distribution, and financial condition.

6.1 Heterogeneity Analysis

While our baseline results confirm a generally positive relationship between ESG performance and corporate financial resilience, contingency theory suggests this effect may vary across different contexts. The effectiveness of strategic initiatives such as ESG is likely influenced by both internal and external factors. To examine this proposition (H4), we test whether the connection between ESG and resilience differs along several key dimensions. The following subgroup analyses reveal substantial and meaningful variation in this relationship.

6.1.1 Heterogeneity by Financial Health

We first examine whether a firm's prior financial condition affects the benefits gained from ESG by dividing the sample into "Good" and "Poor" financial health groups according to the median Z-Score. The positive effect of ESG on financial resilience is observed in both subsamples. However, this effect is significantly more pronounced among financially healthy firms. This pattern indicates that firms with stronger financial foundations, likely owing to greater resource availability and investment capacity, are better positioned to convert ESG commitments into concrete resilience advantages. For firms in poorer financial condition, the challenge of addressing immediate operational and financial pressures may constrain their capacity to leverage ESG as effectively for building resilience.

Table 9: Financial Heterogeneity Results

	Better Financial Status	Poorer Financial Status
ESG	0.1024**	0.0713**
	-0.0496	-0.0304
Control variable	Yes	Yes
r^2	0.2027	0.149
N	10786	10786

6.1.2 Heterogeneity by Technological Intensity

The industry's technological intensity also serves as an important contextual factor. A clear divergence appears when comparing high-tech and non-high-tech industries. The resilience-enhancing effect of ESG is strong and statistically significant in non-high-tech industries, but becomes negligible and statistically insignificant in high-tech sectors. This pattern suggests that in industries where technological innovation drives competitive advantage, ESG contributes less noticeably to financial resilience. In contrast, for firms operating in more traditional, non-high-tech sectors, strong ESG performance appears to function as a crucial differentiating factor that substantially strengthens stakeholder confidence and financial stability.

Table 10: Technological Heterogeneity Results

	High-tech Industry	Non-high-tech Industry
ESG	0.0452	0.1048***
	-0.036	-0.0405
Control variable	Yes	Yes
r^2	0.212	0.1844
N	12920	8652

6.1.3 Heterogeneity by Environmental Impact

The analysis across environmental impact groups shows that ESG's role is particularly vital for firms in heavily polluting industries. While the coefficient is positive in both groups, it is substantially larger for heavy

polluters. This result highlights the increased importance of ESG for firms facing strong regulatory oversight and public scrutiny. For these companies, proactive ESG practices are not just supplementary but essential for reducing major tail risks, managing regulatory expenses, and protecting their reputation—all of which directly strengthen financial resilience.

Table 11: Environmental Heterogeneity Results

	Heavily Polluting Industry	Non-polluting Industry
ESG	0.0913*	0.0584*
	-0.0497	-0.0316
Control variable	Yes	Yes
r ²	0.2292	0.1877
N	6024	15548

6.1.4 Heterogeneity by Geographical Region

China's substantial regional differences in economic development and institutional quality are evident in our findings. The analysis separates firms based in the more developed Eastern region from those in the Central and Western regions. The positive effect of ESG on financial resilience is significant and substantial for firms in the Eastern region, but it does not reach statistical significance for firms in the Central and Western regions. This suggests that the benefits of ESG investment depend on a supportive external environment, which features stronger market discipline, more engaged stakeholders, and more developed institutional frameworks—conditions more commonly found in the Eastern provinces.

Table 12: Regional Heterogeneity Results

	Eastern Region	Central and Western Region
ESG	0.0767**	0.0581
	-0.0328	-0.0452
Control variable	Yes	Yes
r ²	0.2005	0.2061
N	15764	5808

6.1.5 Heterogeneity by Firm Size

Finally, firm size stands out as an important internal factor. The results from comparing large and small firms indicate that the positive effect of ESG is both economically and statistically significant only for larger firms, while the coefficient for small firms remains insignificant. This aligns with the resource-based view: larger companies possess the financial resources, managerial capacity, and market presence needed to implement substantial ESG strategies and realize their scale advantages. Smaller firms, constrained by limited resources and facing less external pressure, may struggle to translate ESG activities into tangible resilience improvements.

Table 13: Firm Size Heterogeneity Results

	Large Enterprises	Small Enterprises
ESG	0.0970***	0.0336
	-0.0346	-0.0469
Control variable	Yes	Yes
r ²	0.2002	0.2009
N	10786	10786

6.2 Mechanism Test Analysis

To identify the underlying channels through which ESG performance strengthens corporate financial resilience, we formally test the two mediating mechanisms outlined in our theoretical framework: risk mitigation and the easing of financing constraints. We adopt a established causal steps approach to assess the significance of these transmission pathways.

6.2.1 The Risk Mitigation Channel

We examine the risk mitigation channel using the cash ratio as an indicator of corporate risk aversion. Table 7 presents the three-step mediation analysis results. First, ESG shows a significant positive total effect on financial resilience (coefficient = 0.073, $p < 0.01$). Second, ESG has a statistically significant positive effect

on the cash ratio (coefficient = 0.017, $p < 0.01$), indicating that high-ESG firms maintain larger liquidity buffers. Third, when both ESG and the cash ratio are included, the cash ratio coefficient remains positive and significant (coefficient = 1.410, $p < 0.01$), while the ESG coefficient decreases but remains significant (coefficient = 0.053, $p < 0.05$). This pattern confirms that risk aversion, reflected in higher cash holdings, partially mediates the ESG-resilience relationship, suggesting that ESG encourages more conservative financial management that helps firms endure external shocks.

Table 7: Mechanism Test Results Based on Risk Aversion

Variable	Score rescaled	ESG and Risk Aversion	Mediation Effect Test
ESG	0.073***	0.017***	0.053**
	-0.027	-0.006	-0.023
Risk Aversion			1.410***
			-0.056
Industry Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	21572	21572	21572
R-squared	0.21	0.525	0.436

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

6.2.2 The Financing Constraints Alleviation Channel

We test the financing constraints alleviation channel using the SA index (Hadlock & Pierce, 2010). Table 8 presents the mediation analysis results. First, the path from ESG to financing constraints is negative and significant (coefficient = -0.0027, $p < 0.01$), indicating that stronger ESG performance alleviates external financing constraints. Second, the path from financing constraints to financial resilience is also negative and significant (coefficient = -2.5547, $p < 0.05$), confirming that tighter constraints undermine resilience. Finally, when including both ESG and the SA index, the indirect effect is significant while the direct effect of ESG remains positive and significant (coefficient = 0.0735, $p < 0.01$), though slightly attenuated compared to the total effect. This confirms that financing constraints alleviation serves as a partial mediating mechanism through which ESG enhances financial resilience.

Table 8: Mechanism Test Results Based on Financing Effects

Variable	Score rescaled	ESG and Financing Effects	Mediation Effect Test
ESG	0.0736***	-0.0027***	0.0735***
	-0.0267	-0.0005	-0.0228
SA			-2.5547**
			-1.1077
Industry Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	21572	21572	21572
R-squared	0.2078	0.9902	0.48

7. Conclusion

This study investigates the relationship between ESG performance and corporate financial resilience using a sample of Chinese A-share listed manufacturing firms from 2015 to 2022. The empirical results demonstrate that ESG performance has a significant positive impact on corporate financial resilience, a finding that remains robust after addressing endogeneity concerns through lagged variables and instrumental variable approaches. Furthermore, mediation analysis reveals that ESG enhances financial resilience through two parallel channels: risk mitigation, reflected in higher cash ratios, and financing constraints alleviation, captured by the SA index. Heterogeneity analyses indicate that this positive effect is more pronounced for firms with better financial health, firms in non-high-tech industries, heavily polluting firms, firms in the Eastern region, and larger firms.

These findings offer important theoretical and practical implications. Theoretically, this study extends the ESG literature by establishing a direct link between ESG performance and financial resilience, while providing an integrated framework that simultaneously tests dual mediating mechanisms. Practically, the results suggest that managers should view ESG as a strategic investment in organizational resilience rather than merely a

compliance activity. For investors, ESG performance serves as a useful indicator for assessing firms' long-term viability and capacity to withstand external shocks. For policymakers, the findings underscore the importance of promoting ESG disclosure and sustainable business practices as mechanisms for enhancing overall economic stability.

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Research on Reputation Spillover and Synergistic Effects of High-ESG-Performance Enterprises: A Case Study of Pang Dong Lai's Assistance to Yonghui Supermarket

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Abstract

The Environmental, Social, and Governance (ESG) concept has become a core benchmark for assessing corporate sustainable development capabilities. However, existing studies predominantly focus on the economic consequences of a firm's own ESG performance, with insufficient attention to its external spillover effects. Taking the highly publicized "Pang Dong Lai assisting Yonghui Supermarket" event as the research object, this paper employs a single-case study method and integrates reputation theory, signaling theory, and the resource-based view to deeply analyze the reputation spillover mechanisms and synergistic effects of high-ESG-performance enterprises. The findings reveal that Pang Dong Lai's reputation spillover follows a "ripple pattern," diffusing progressively through four hierarchical levels: embedded empowerment, precise empowerment, radiating empowerment, and linkage empowerment. However, the efficacy of this spillover is significantly constrained by the absorptive capacity of the assisted party, industry competition structure, and sustainability of the assistance model. Information resource effects and competitive learning effects constitute the core driving mechanisms of reputation spillover, yet their effectiveness depends on the interaction quality and institutional distance between the assisting and assisted parties. The study further shows that Pang Dong Lai's reputation capital provided Yonghui Supermarket with a limited "insurance mechanism," but this buffering effect exhibits clear temporality and conditionality. Although sales at some renovated stores achieved remarkable 5- to 14-fold growth and employee compensation increased by more than 35%, Yonghui's overall turnaround remains challenging, and capital market reactions remain mixed. This research not only expands the research context of ESG spillover effects but also reveals the enabling conditions and boundaries of reputation spillover, offering valuable dialectical insights for distressed enterprises seeking strategic transformation through leveraging industry benchmarks.

Keywords

ESG performance, reputation spillover, synergistic effect, ripple pattern, demonstration effect, boundary conditions

1. Introduction

1.1 Research Background

Globally, the ESG (Environmental, Social, and Governance) concept has shifted from the periphery to the center, becoming a core strategic driver of corporate transformation and upgrading. In particular, under China's "dual carbon" strategy, ESG performance not only directly reflects a firm's sustainable development capability but has increasingly become a key determinant of corporate reputation, financing costs, and market competitiveness. By the end of 2024, the disclosure rate of ESG reports among A-share listed companies exceeded 30%, and the asset management scale of ESG-themed funds approached 300 billion yuan, marking ESG's full transition from an abstract concept to concrete business practice.

Existing research indicates that firms with superior ESG performance can generate significant "spillover effects" on peers. When benchmark firms receive positive market feedback due to their outstanding ESG practices, other firms in the industry—particularly those with weaker risk resilience—tend to learn from and imitate their operational decisions and management behaviors [3]. Zhai Huayun et al. (2025) further found that, within common shareholder networks, state-owned enterprises can exert ESG demonstration and leadership effects on private enterprises through "information resource effects" and "competitive learning effects" [15].

In 2024, Pang Dong Lai—a regional retail giant renowned for its exceptional ESG performance—launched an assistance initiative for Yonghui Supermarket, a listed company facing severe operational difficulties. Pang Dong Lai has accumulated substantial reputation capital through its extreme employee care (S) and customer service (S); meanwhile, Yonghui Supermarket—once dubbed the "fresh food leader"—incurred cumulative losses exceeding 8 billion yuan from 2021 to 2023, with its store count plummeting from a peak of 1,440 to 1,000. This assistance from a "high-ESG enterprise" to a "distressed enterprise" provides a unique and valuable natural experimental window for observing and understanding cross-firm ESG reputation spillover effects.

Notably, Pang Dong Lai's assistance to Yonghui is not a straightforward "success story." As of early 2025, despite explosive performance growth at some renovated stores, Yonghui's overall financial condition has not achieved a fundamental turnaround, and capital markets remain cautious about whether the "Pang Dong Lai model" can be successfully replicated and scaled across Yonghui's vast system. This complex pattern of "partial success with overall difficulty" offers valuable material for this study to deeply explore the enabling conditions, boundaries, and internal mechanisms of ESG reputation spillover.

1.2 Research Significance

The significance of this study lies in both theoretical and practical dimensions.

Theoretically, existing research on ESG spillover effects has largely concentrated on specific contexts such as equity linkages [15] or cross-border mergers and acquisitions [3], with very limited attention to the spillover effects arising from non-equity-dominated "assistance" interactions between firms. By taking the Pang Dong Lai–Yonghui collaboration as a case, this study not only explores the cross-firm mechanisms of ESG reputation spillover but also seeks to reveal the conditions under which such mechanisms operate and their inherent limitations, thereby contributing to a more comprehensive and dialectical theoretical understanding of ESG spillover effects in the academic area.

Practically, this research offers important implications for three groups of stakeholders. First, for distressed enterprises, the study demonstrates that leveraging reputation spillover from benchmark firms represents a viable transformation path, but success critically depends on absorptive capacity, institutional distance from the benchmark, and other factors. Second, for benchmark firms, the findings prove that high-level ESG investment not only enhances their own value but can also empower peers; however, reputation spillover does not occur automatically and requires careful mechanism design and process management. Third, for policymakers, the study recommends that while encouraging leading firms to elevate industry-wide ESG levels, close attention should be paid to the sustainability and contextual fit of assistance models to avoid one-size-fits-all policy approaches.

1.3 Research Questions

Based on the above background and significance, this study aims to address the following three interconnected core questions:

First, as an exemplar of high ESG performance, how does Pang Dong Lai's reputation capital "spill over" to Yonghui Supermarket? What are the specific transmission channels and mechanisms of action?

Second, what synergistic effects does this reputation spillover generate? In which dimensions are the effects pronounced, and in which dimensions are limitations encountered?

Third, what are the enabling conditions and boundaries of reputation spillover? Which factors facilitate or constrain the effective realization of spillover effects?

1.4 Research Method and Framework

To thoroughly address the above questions, this study adopts a single-case study approach [14]. Case selection follows the principle of theoretical sampling [4], i.e., choosing the case most likely to reveal and extend theoretical boundaries. The complex feature of "partial success coexisting with overall uncertainty" presented by the Pang Dong Lai–Yonghui assistance event makes it an ideal sample for exploring the enabling conditions and boundaries of reputation spillover effects.

In terms of data collection, this study integrates multiple sources, including in-depth reports from authoritative media, public announcements of the listed company, official responses from the enterprises, and massive discussions on social media. To ensure reliability and validity, all key information is cross-verified from at least two independent sources following the principle of triangulation. Data analysis employs the three-level coding method of grounded theory [11], systematically extracting concepts through open coding, axial coding, and selective coding, identifying logical relationships among categories, and ultimately constructing the core theoretical framework.

2. Theoretical Foundations and Literature Review

2.1 Theoretical Foundations

2.1.1 Reputation Theory: Accumulation and Consumption of Reputation Capital

Corporate reputation is defined as the overall perception and comprehensive evaluation formed by stakeholders based on a firm's past behavior and performance, constituting a critical intangible asset [6]. In the ESG domain, reputation theory highlights two core mechanisms: first, the "reputation accumulation mechanism," whereby firms gradually build substantial reputation capital by consistently and long-term meeting the expectations and demands of various stakeholders [16]; second, the "reputation insurance mechanism," whereby strong ESG reputation effectively buffers negative market reactions (e.g., stock price declines) during adverse events, providing a protective effect [8]. However, a frequently overlooked premise in reputation theory is the "transferability" and "depletability" of reputation capital. When one firm's reputation is "borrowed" by another, does the original firm's reputation capital become depleted? To what extent can the borrowing firm "inherit" and internalize this reputation? These questions are particularly salient in the present case.

2.1.2 Signaling Theory: Signal Cost, Observability, and Credibility

In markets characterized by information asymmetry, parties with informational advantage can transmit credible signals about their own qualities by undertaking costly actions [10]. High-level ESG performance itself serves as a powerful "positive signal," indicating to outsiders a low probability of opportunistic behavior in cooperation and thus facilitating greater trust from partners and consumers [9]. An effective ESG signal must possess two key characteristics: significant signaling cost and high signal observability [13]. Nevertheless, signaling theory also has its boundaries: the effectiveness of signal transmission ultimately depends on the receiver's interpretive capacity and willingness to accept the signal. The same signal may elicit markedly different responses across different stakeholder groups. In this case, the strong signal of

“Pang Dong Lai’s assistance” produces distinctly different impacts on consumers, employees, investors, and other parties.

2.1.3 Resource-Based View: Internalization of Resources and Capability Accumulation

The Resource-Based View (RBV) posits that resources that are valuable, rare, inimitable, and non-substitutable (VRIN) constitute the fundamental source of sustainable competitive advantage [1]. However, merely possessing resources is insufficient; firms must convert them into a series of “dynamic capabilities”—such as absorptive capacity, adaptive capacity, and innovative capacity—to truly drive organizational transformation and development. A central insight of this theory is that the effective internalization of external resources critically depends on the firm’s own “absorptive capacity” [2]. Firms with strong absorptive capacity can more efficiently identify, assimilate, integrate, and apply external knowledge. This perspective is essential for explaining the present case: whether Yonghui Supermarket can truly “learn” the essence of the Pang Dong Lai model fundamentally hinges on its organizational-level absorptive capacity.

2.1.4 Stakeholder Theory: Balancing Diverse Demands

Stakeholder theory asserts that firms are accountable not only to shareholders but also to all parties affected by their decisions and actions—including employees, customers, suppliers, communities, and others [5]. In practice, the demands of different stakeholders often create tensions or even conflicts—for example, improving employee welfare may raise short-term costs, while optimizing customer experience may compromise operational efficiency. Achieving dynamic balance among these diverse and sometimes conflicting demands represents the core challenge of ESG practice and a key measure of governance quality.

2.2 Literature Review

2.2.1 Research on ESG Spillover Effects

ESG spillover effects refer to the influence that one firm’s ESG performance exerts on other firms in the same industry. Deng Haiyin et al. [3] found that, in cross-border merger and acquisition contexts, firms with high ESG performance, upon receiving positive market feedback, have their behavioral patterns learned and imitated by other industry peers—particularly those with lower risk-bearing capacity—thereby generating intra-industry spillover effects.

2.2.2 Research on ESG Demonstration Effects

Regarding demonstration effects, Zhai Huayun et al. [15], based on common shareholder network analysis, showed that state-owned enterprises can exert ESG demonstration and leadership on private enterprises through two mechanisms: the “information resource effect” (transmitting ESG-related management knowledge and practical experience) and the “competitive learning effect” (other firms actively learning benchmark ESG practices to maintain or enhance competitiveness).

2.2.3 Research on Corporate Assistance Models

Studies focusing on corporate assistance to rural industries have distilled a “ripple pattern” [7]. This pattern describes the progressive diffusion of assistance impact from a core circle outward, manifested in four sequential stages: embedded empowerment → precise empowerment → radiating empowerment → linkage empowerment. While this model provides a useful framework for understanding the diffusion laws of assistance influence, it offers limited discussion of heterogeneity in assistance outcomes and sustainability issues.

2.2.4 Research Gaps and Analytical Perspective of This Paper

Taken together, existing studies exhibit the following shortcomings: first, research on spillover effects largely focuses on confirming the existence of the effect but pays insufficient attention to the conditions under which it occurs and its boundaries; second, while demonstration effect studies reveal spillover mechanisms, they lack in-depth analysis of circumstances in which these mechanisms may fail; third, assistance model research has outlined process frameworks but provides inadequate explanations for the marked heterogeneity in assistance outcomes. In response, this paper integrates the above theories to

construct an integrated analytical framework titled “Ripple Pattern of ESG Reputation Spillover and Its Boundary Conditions.” This framework not only examines the progressive diffusion of reputation spillover across four hierarchical levels but also incorporates key moderating variables that influence spillover effectiveness—such as the assisted firm’s absorptive capacity, industry competitive landscape, institutional distance between parties, and sustainability of the assistance model—thereby aiming to yield more explanatory conclusions.

3. Case Overview

3.1 Pang Dong Lai: An Industry Benchmark of High ESG Performance

Pang Dong Lai, a regional retail enterprise headquartered in Xuchang, Henan, has earned the reputation of “the ceiling of Chinese retail” through its extreme ESG practices. On the social dimension (S), its frontline employees enjoy monthly salaries far above local averages, and innovative policies include a “grievance award” and mandatory store closures every Tuesday for rest. For customers, it offers value-added services far exceeding industry norms, such as free optometry and shoe repair. On the governance dimension (G), founder Yu Donglai advocates a corporate culture of “love and freedom,” placing employee well-being and dignity at the top priority of operations. Through long-term, unwavering fulfillment—and even exceeding—the expectations of all stakeholders, Pang Dong Lai has accumulated exceptionally deep “reputation capital.”

3.2 Yonghui Supermarket: An Industry Veteran in Distress

Yonghui Supermarket (601933.SH), once a leader in fresh food retail and dubbed the “fresh food leader,” has fallen into severe operational difficulties in recent years. Financial data show cumulative losses exceeding 8 billion yuan from 2021 to 2023, with store numbers shrinking sharply from a peak of 1,440 to approximately 1,000. Three consecutive years of losses and large-scale store closures clearly indicate significant “legitimacy gaps” in Yonghui’s original business model on the social (S) and governance (G) dimensions of ESG.

3.3 Overview of the Assistance Event

In 2024, Pang Dong Lai officially launched its assistance program for Yonghui Supermarket. The assistance measures covered the entire retail operations chain: at the front-end standardization level, product assortments underwent major optimization, with large quantities of low-efficiency items removed and Pang Dong Lai’s private brands introduced. Taking the Zhengzhou Xinwan Plaza store as an example, 10,841 SKUs were delisted, representing a removal rate of 81.3%; at the same time, new products were replanned and introduced, bringing the product structure largely in line with Pang Dong Lai’s standards (over 90%). At the mid-level informatization stage, Pang Dong Lai dispatched core management and operations teams to reside on-site, delivering “hands-on” training to Yonghui employees and transferring its unique management philosophy and operational practices, involving approximately 190 personnel and incurring direct assistance costs of 18 million yuan. At the back-end branding level, Pang Dong Lai skillfully leveraged its strong reputation to attract customer traffic back while simultaneously optimizing service processes and standards.

3.4 The Complex Picture of Assistance Outcomes

The outcomes of the assistance exhibit marked heterogeneity, presenting a complex landscape:

Partial success is evident: The first renovated store in Zhengzhou Xinwan Plaza saw opening-day sales surge to 1.88 million yuan—13.9 times pre-renovation levels—and foot traffic reached 12,926 people, 5.3 times pre-renovation. Subsequent renovated stores in Xi’an, Xiangyang, Fuzhou, Shenzhen, and elsewhere achieved several-fold increases in sales and foot traffic. On the employee side, compensation rose substantially, with frontline monthly salaries increasing from the 2,800–3,800 yuan range to 4,000–6,000 yuan, and store manager salaries rising from approximately 14,000 yuan to about 20,000 yuan.

Overall transformation remains difficult: As of early 2025, only 12 stores had been renovated, accounting for just 1.2% of Yonghui’s roughly 1,000 stores. Whether these renovated stores can sustain high growth remains to be seen, while the vast majority of unrenovated stores continue to struggle under the original

model. At the company-wide financial level, Yonghui has not yet achieved a turnaround; first-half 2024 revenue declined 10.11% year-over-year, and non-GAAP net profit remained under pressure. Capital market reactions have been mixed: although MINISO made a strategic investment of 6.27 billion yuan, Yonghui's stock price has not sustained upward momentum. This complex picture powerfully illustrates that reputation spillover is not an automatically triggered "magic"; its realization is profoundly constrained by a variety of factors.

4. Case Analysis: The Ripple Pattern of Reputation Spillover and Its Boundaries

4.1 First Ripple Layer: Embedded Empowerment — Depth and Limits of Trust Building

The Pang Dong Lai team directly stationed itself in Yonghui stores, fully participating in and leading the rectification process, exemplifying the typical characteristics of "embedded empowerment." As of the end of 2024, 15 core Pang Dong Lai personnel remained on the front lines of assistance, with a cumulative total of approximately 190 participants and direct assistance costs reaching 18 million yuan. This deep, personnel-immersive assistance not only brought management techniques but, more importantly, transmitted Pang Dong Lai's management philosophy and corporate culture. As Ren et al. (2025) pointed out, high ESG performance serves as a strong positive signal, effectively reducing the risk of opportunism in cooperation and rapidly establishing trust [9]. The Pang Dong Lai team's on-site presence sent a powerful message to Yonghui employees, customers, and suppliers alike: "We are here to genuinely help." Yonghui Supermarket Vice President Wang Shoucheng's statement that "the state of employees is the foundation of the rectification" further confirms the central role of trust building in the early stages of change.

However, the depth and breadth of this trust building have clear limitations. First, Pang Dong Lai's limited team resources can only cover a very small number of pilot stores; the vast majority of Yonghui employees have not had direct contact with the Pang Dong Lai team, naturally limiting their understanding and identification with Pang Dong Lai's culture. Second, the "transfer" of trust is conditional. Consumers may enter renovated Yonghui stores because of trust in Pang Dong Lai, but whether this initial trust can translate into sustained loyalty to the Yonghui brand ultimately depends on Yonghui's own product and service performance. Finally, repairing trust relationships with suppliers requires a much longer cycle, and significant improvements are difficult to observe in the short term. This suggests that the depth of trust building achieved through embedded empowerment depends on the frequency and quality of interaction between the assisting and assisted parties, its breadth is constrained by the coverage of assistance resources, and its sustainability relies on the assisted enterprise's own capacity for self-sustenance and maintenance.

4.2 Second Ripple Layer: Precise Empowerment — Efficiency and Barriers of Knowledge Transfer

Pang Dong Lai did not simply replicate its own model but provided customized rectification plans tailored to Yonghui stores' specific problems, achieving "precise empowerment." For example, in the Zhengzhou store, a sweeping adjustment to product structure (81.3% delisting rate, 80% new item proportion) quickly brought it close to Pang Dong Lai's efficient assortment. This is a direct manifestation of the "information resource effect"—the benchmark firm effectively transferring valuable knowledge and experience in ESG management, particularly operational management, to the assisted firm [15].

However, the efficiency of knowledge transfer is constrained by multiple factors. First, the tacitness of knowledge. Much of Pang Dong Lai's success stems from tacit knowledge—such as its unique corporate culture, service philosophy, and flexible management approach—that is difficult to articulate. As Yonghui's vice president remarked: "There is a shortcut to learning from Pang Dong Lai—the only shortcut is for us to be sufficiently sincere." Yet "sincerity" is a value orientation that cannot be quickly achieved through short-term training. Second, the embeddedness of knowledge. Pang Dong Lai's management model is deeply intertwined with its founder's personal traits, the regional culture of Henan, and specific organizational history. Transplanting it into Yonghui—a nationwide listed company with different organizational inertia—requires a complex process of "de-embedding" and "re-embedding." Third, differences in absorptive capacity. Yonghui employees at different stores and levels vary significantly in their ability to understand, accept, and apply new knowledge, directly leading to uneven transfer outcomes. Effective signals require

cost and observability [13]; Pang Dong Lai's assistance is undoubtedly a high-cost, strong signal, but whether the signal is accurately decoded and converted into effective action ultimately depends on the receiver's decoding capability.

4.3 Third Ripple Layer: Radiating Empowerment — Diffusion and Decay of Learning Effects

Starting from the success of the first two pilot stores, Pang Dong Lai's influence gradually "radiated" to more Yonghui stores. For example, the Xi'an Zhongmao Plaza store, which underwent independent rectification, achieved first-day sales of 1.5143 million yuan post-renovation—7.6 times pre-renovation levels. The Xiangyang Minfa Plaza store saw monthly sales increase by 180% after renovation. As of November 2024, 12 stores had been renovated, with plans to expand to 40–50 stores before the Spring Festival. This exemplifies the "competitive learning effect": when an industry benchmark actively practices and benefits from its ESG strategy, other firms capture this signal and proactively learn and imitate it to enhance their own competitiveness [15]. Xiangyang store manager Pan Jianrong's bold statement—"We may not become a 'second Pang Dong Lai,' but we can be the first 'Pang Dong Hui' in Xiangyang"—vividly reflects this proactive learning intent.

However, the learning effect decays noticeably during diffusion. First, incentive incompatibility: pilot stores receive direct guidance and resource support from Pang Dong Lai teams, whereas the "self-study" effect in other stores is clearly inferior and cannot fully replicate the former's success. Second, capability bottlenecks: independent rectification places extremely high demands on stores' management, learning, and execution capabilities; not all stores possess these prerequisites. Third, time and performance pressure: under intense performance pressure, some stores may opt for "quick fixes," adopting superficial, easy-to-implement measures while neglecting deeper cultural and managerial changes, causing learning to become formalistic. Deng Haiyin et al. [3] noted that spillover effects are more pronounced for firms with weaker risk-bearing capacity. As a distressed enterprise, Yonghui indeed exhibits strong learning motivation, but whether motivation translates into effective learning ultimately depends on the support of learning capability.

4.4 Fourth Ripple Layer: Linkage Empowerment — Emergence and Constraints of Synergistic Effects

As some stores achieved significant improvements in ESG dimensions such as employee care (S) and customer satisfaction (S), Yonghui's relationships with core stakeholders improved, initially manifesting synergistic effects of "linkage empowerment." Employee compensation rose by more than 35%, boosting morale; customer satisfaction and recognition increased substantially, driving traffic and sales recovery; and capital markets responded positively, as evidenced by MINISO's 6.27 billion yuan strategic investment. However, the emergence of these synergistic effects at the overall level faces multiple constraints. First, scale constraint: renovated stores account for only 1.2% of the total, limiting their contribution to Yonghui's overall revenue and profit. Second, cost constraint: substantial salary increases create rigid cost pressures; in stores where sales growth fails to cover these added costs, losses may actually worsen. Third, sustainability constraint: Pang Dong Lai's assistance commitment is approximately "two years"; whether Yonghui can independently sustain and scale this model afterward remains the greatest uncertainty. Fourth, divergent capital market reactions: while MINISO's investment is a positive signal, Yonghui's stock price has not sustained upward momentum, reflecting market skepticism about the feasibility of large-scale replication of the "Pang Dong Lai model" within Yonghui's system. Here, the "reputation savings effect" [8] is limited: Pang Dong Lai's reputation indeed provided Yonghui with a valuable period of public and market buffering, but the "borrowing" of reputation capital is not unlimited. Yonghui must demonstrate real improvement within this limited time window; otherwise, public and investor patience will eventually be exhausted.

5. Mechanism Analysis: Enabling Conditions and Boundaries of Spillover Effects

5.1 Enabling Conditions of the Information Resource Effect

The effective operation of the information resource effect depends on several key conditions:

Codifiability of knowledge: Pang Dong Lai's management knowledge system can be divided into two types: explicit knowledge that is easy to codify and transfer (e.g., product structure standards, shelf display norms, salary hierarchies) and tacit knowledge that is difficult to articulate (e.g., "love and freedom" service philosophy, unique cultural atmosphere, flexible management approach). In this case, explicit knowledge (e.g., salary increases, product adjustments) was transferred and applied relatively well, while tacit knowledge transfer was significantly weaker.

Institutional distance between parties: Pang Dong Lai, as a regional private enterprise, features a flat organizational structure and flexible, efficient decision-making. Yonghui, as a nationwide listed company, faces stricter regulatory requirements and more complex internal processes. The institutional distance between them undoubtedly increases friction costs and complexity in knowledge transfer. Yonghui must absorb Pang Dong Lai's flexibility while complying with listed-company regulations—an inherent tension posing a major challenge.

Absorptive capacity of the assisted enterprise: According to Cohen & Levinthal [2], firms with strong absorptive capacity can better identify, assimilate, and apply external knowledge. Significant differences in absorptive capacity exist across Yonghui's stores, regions, management teams, and employees, largely explaining the marked heterogeneity in renovation outcomes despite all learning from Pang Dong Lai.

5.2 Enabling Conditions of the Competitive Learning Effect

The operation of the competitive learning effect is similarly constrained by several conditions:

Intensity of competitive pressure: In highly competitive regional retail markets, stores have stronger motivation to learn the Pang Dong Lai model for survival and development; in less competitive areas, the urgency and incentive for learning may be weaker. This may lead to differentiated learning outcomes across Yonghui's regional stores.

Clarity of the signal: Is the success signal of the Pang Dong Lai model sufficiently clear and free of "noise"? Some market participants or Yonghui employees may attribute Pang Dong Lai's success simply to its founder's personal charisma or specific regional market protection rather than its outstanding ESG practices. Such interpretive bias directly affects learning motivation and direction, leading to "learning the form but missing the essence."

Learning costs versus expected benefits: Learning the Pang Dong Lai model requires massive upfront investment (salary increases, store renovations, product restructuring, etc.), inevitably raising short-term costs. If store managers lack confidence in long-term returns or the willingness and capacity to endure short-term pain, they may choose to "wait and see" rather than act.

5.3 Boundaries of the Reputation "Insurance Mechanism"

The reputation "insurance mechanism" provided by Pang Dong Lai to Yonghui is neither universal nor unlimited; its effectiveness and sustainability are strictly constrained by multiple boundaries:

Temporal boundary: The "borrowing" of reputation capital has a clear time limit. The public and investors are willing to grant Yonghui a certain "trial-and-error" period, but this patience is not infinite. Yonghui must demonstrate tangible, sustainable improvement within this precious buffer window; otherwise, the reputation insurance may fail, potentially triggering even stronger negative backlash.

Scope boundary: The reputation insurance operates unevenly. It primarily affects consumers, attracting them to try renovated stores, but its impact on suppliers (e.g., securing better payment terms and cooperation conditions) and capital markets (e.g., convincing institutional investors to hold long-term) is relatively limited and more unstable.

Conditional boundary: The effectiveness of reputation insurance ultimately depends on the assisted firm's own performance. If Yonghui fails to show substantial, sustainable improvement during the buffer period, the reputation endorsement from Pang Dong Lai may dramatically shift from a "protective umbrella" to a "magnifying glass"—public disappointment over "failing to live up to Pang Dong Lai's expectations" may be far stronger than for an ordinary firm's failure.

5.4 Explanation of Heterogeneity in Spillover Effects

Combining the above analysis, an integrated explanation for the heterogeneity in assistance outcomes is offered:

At the store level: Pilot stores receiving direct guidance from Pang Dong Lai teams can more effectively receive and internalize tacit knowledge, yielding stronger learning effects and the most significant performance improvements. In contrast, independently renovated stores rely primarily on imitation of explicit knowledge, resulting in uneven outcomes highly dependent on each store's own endowments.

At the temporal level: In the short term, renovated stores show remarkable growth in sales and traffic, with reputation spillover effects manifesting rapidly. In the medium term, whether this growth can be sustained depends on stores' ability to establish self-maintaining and iterative mechanisms. In the long term, Yonghui's overall transformation as a large organization faces enormous uncertainty.

At the stakeholder level: Different stakeholder groups exhibit varying response speeds and attitudes to the assistance event. Consumers react most directly and positively; employees respond positively but require sustained incentives and cultural identification to maintain; capital markets show positive yet cautious observation; suppliers remain the most cautious, requiring longer time and more reliable signals to repair trust.

6. Conclusion and Implications

6.1 Main Research Conclusions

Through in-depth analysis of the Pang Dong Lai–Yonghui Supermarket assistance case, this paper draws the following four core conclusions:

First, the reputation spillover from high-ESG enterprises follows a “ripple pattern,” yet the spillover effects exhibit significant heterogeneity and boundaries. Pang Dong Lai's reputation spillover diffused progressively through four layers: embedded empowerment, precise empowerment, radiating empowerment, and linkage empowerment. However, spillover outcomes vary markedly across stores, time dimensions, and stakeholder groups. This finding not only validates the explanatory power of the “ripple pattern” [7] in the enterprise assistance context but, more importantly, reveals its specific boundaries and enabling conditions.

Second, information resource effects and competitive learning effects constitute the core driving mechanisms of reputation spillover, but their effectiveness is constrained by multiple factors. The realization of information resource effects depends on knowledge codifiability, institutional distance between parties, and the assisted firm's absorptive capacity; competitive learning effects depend on competitive pressure intensity, signal clarity, and expected learning costs versus benefits. This study supplements the “demonstration effect” framework [15] with critical analysis of enabling conditions, deepening understanding of mechanism operation.

Third, reputation capital provides a limited cross-firm “insurance mechanism.” Pang Dong Lai's outstanding reputation indeed offered Yonghui valuable public opinion buffering and market protection, but this protection has clear temporal, scope, and conditional boundaries. The study shows that reputation capital can be “borrowed” but not directly “transferred”; it can buffer but cannot substitute for the firm's own core capabilities. This adds important boundary condition analysis to the “reputation savings effect” theory [8].

Fourth, realizing synergistic effects between ESG and business performance requires multiple supporting conditions. Although some Yonghui stores achieved a virtuous cycle of ESG improvement and commercial performance growth, overall synergy remains constrained by scale, cost, sustainability, and divergent capital market reactions. This indicates that converting ESG investment into business value is not an automatic process; it requires systematic mechanism design, sustained capability accumulation, and favorable external conditions.

6.2 Theoretical Contributions

The theoretical contributions of this study are primarily in three areas: First, it expands the research context of ESG spillover effects and supplements analysis of boundary conditions. The study extends the perspective beyond traditional equity linkages [15] and cross-border M&A [3] to the distinctive enterprise assistance context, not only verifying the existence of spillover effects but systematically revealing their enabling conditions and inherent limitations. Second, it integrates the “ripple pattern” and “demonstration effect” frameworks while introducing key moderating variables such as absorptive capacity. By organically combining process analysis [7] with mechanism analysis [15], and incorporating concepts such as absorptive capacity and institutional distance, the paper constructs a more dynamic and explanatory integrated analytical framework. Third, it validates and enriches reputation theory by revealing the boundaries of reputation effects in cross-firm contexts. The study supplements critical boundary condition analysis for the “ESG → reputation → trust” logical chain [12] and the “reputation savings effect” [8], profoundly clarifying the essential distinction between “borrowing” and “transferring” reputation capital.

6.3 Practical Implications

This study offers important implications for three groups of practitioners:

For distressed enterprises: Leveraging reputation spillover from benchmark firms is a viable transformation path, but its boundaries must be clearly recognized. First, enhancing absorptive capacity is key to transformation; firms must establish effective learning mechanisms and an inclusive learning culture, avoiding mere “copy-paste.” Second, seizing the precious buffer period is critical; firms must convert “borrowed” reputation into “self-owned” reputation and capabilities within this limited window through solid change. Third, sincerity in reform is foundational—as Yonghui executives reflected: “If we fail to learn well, it is because we are not sincere enough.”

For benchmark firms: High-level ESG investment is not only social responsibility but also a powerful asset capable of empowering peers; however, reputation spillover requires systematic design. First, distinguish strategies for transferring explicit versus tacit knowledge: standardize output for the former and rely on long-term immersion and cultural guidance for the latter. Second, assess the assisted firm’s absorptive capacity and tailor assistance accordingly. Third, focus on building sustainable spillover mechanisms, emphasizing cultivation of the assisted firm’s long-term “self-sustenance” capacity rather than short-term “blood transfusion.”

For regulators and industry associations: While encouraging leading firms to elevate industry-wide ESG levels, attention must be paid to the sustainability and contextual fit of assistance models. First, avoid evaluating success solely by “number of assisted cases”; focus instead on actual outcomes and long-term sustainability. Second, encourage diverse spillover and cooperation models rather than mandating a single approach. Third, consider establishing scientific evaluation and feedback mechanisms for assistance outcomes to promptly identify and resolve issues in cooperation.

6.4 Research Limitations and Future Directions

This study also has several limitations. First, as a single-case study, its external validity is inherently limited; future research could enhance generalizability through multi-case comparisons or large-sample quantitative testing. Second, the data primarily rely on publicly available secondary sources, lacking in-depth primary interview data; future fieldwork inside enterprises would yield richer insights. Finally, the assistance event is still evolving, and its long-term effects require ongoing tracking. Looking ahead, several questions warrant further exploration: How can a more systematic theoretical framework of ESG spillover boundary conditions be constructed? Do reputation spillover effects exhibit systematic differences across ownership types or industries? How can more efficient and sustainable inter-firm assistance mechanisms be designed? These questions offer broad scope for subsequent research.

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Study on the Impact of ESG Performance on Corporate Profitability

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Abstract

This study utilizes pre-processed data of all A-share listed companies from 2014 to 2024 as the sample. By constructing regression models and mediation effect models, it investigates the transmission mechanism among ESG performance, corporate risk level, and profitability. The findings indicate that better ESG performance is associated with higher corporate profitability. Moreover, superior ESG performance is linked to lower corporate risk levels, which in turn enhances profitability. The contributions of this research lie in its innovative perspective and practical implications: it addresses existing research gaps by exploring the “pathway” between ESG performance and profitability from the perspective of corporate risk level, thereby enriching the literature on the economic consequences of ESG performance. The conclusions also provide valuable references and insights for economic practices by corporations, governments, regulatory authorities, and other stakeholders.

Keywords

ESG performance, corporate profitability, corporate risk level, empirical study

1. Introduction

With the introduction of China’s dual-carbon goals, increasing attention has been paid to the sustainability of environmental protection and social development. ESG (Environmental, Social, and Governance) performance has become a key concern for enterprises. Environmental, social, and governance factors not only affect corporate reputation but also influence the level of sustainable development. In the stage of pursuing high-quality development, clarifying the relationship between ESG performance and corporate profitability is of great necessity. Existing studies have paid insufficient attention to the economic consequences of ESG performance and the underlying transmission mechanisms. Therefore, this paper focuses on the corporate governance dimension to examine the influence mechanism between ESG performance and profitability, aiming to fill the identified research gap. Corporate risk level directly affects profitability, and prior research has also established an association between ESG performance and corporate risk level. Accordingly, this study selects corporate risk level as the mediating variable to explore the transmission mechanism among the three variables.

The sample consists of pre-processed data from all A-share listed companies over the period 2014–2024. Baseline regression models and mediation effect models are constructed. Descriptive statistics and correlation

tests are first performed to examine the relationships among variables, followed by regression analysis for hypothesis testing. Finally, robustness checks are conducted by replacing the dependent variable and incorporating DuPont analysis.

The contributions of this study are twofold. First, it explores the “pathway” linking ESG performance to profitability from the perspective of corporate risk level, thereby enriching the research on the economic consequences of ESG performance. Second, the findings offer practical references and implications for multiple stakeholders, including corporations, governments, and regulatory bodies.

2. Literature Review and Hypothesis Development

With the rise of concepts such as green finance and sustainable development, greater emphasis has been placed on sustainability. ESG has emerged as a crucial framework for evaluating enterprises’ sustainable development capabilities and fulfillment of social responsibilities, attracting extensive attention from both academia and industry. This has spurred a growing body of research on corporate ESG performance and its consequences.

However, existing studies present divergent findings regarding the impact of ESG performance on firm performance. On one hand, numerous studies support a positive effect. For instance, Lai Cai Lin and Miao Yi Cong argue that higher ESG ratings positively promote corporate performance [1]. Liu Yiqi and co-authors further introduce mediating variables, suggesting that strong ESG performance can improve financial performance by reducing the cost of debt financing [2]. On the other hand, some scholars identify a negative or nonlinear relationship. For example, Wang Shuangjin et al. find that the fulfillment of ESG responsibilities by industrial enterprises exhibits a U-shaped nonlinear effect on financial performance [3].

These inconsistencies suggest that the relationship between ESG performance and firm performance is complex and influenced by multiple factors. As corporate profitability serves as a core indicator of firm performance, it partially reflects overall performance levels. Therefore, this study examines the impact of ESG performance on corporate profitability and proposes the following hypothesis:

H1: Better ESG performance is associated with higher corporate profitability.

Existing research indicates that ESG performance exerts differential effects on systematic risk and idiosyncratic risk [4], implying a relationship between ESG performance and corporate risk level. Accordingly, this study adopts corporate risk level as the mediating variable to investigate the underlying mechanism and proposes the following hypothesis:

H2: Better ESG performance is associated with lower corporate risk levels, which in turn enhances corporate profitability.

3. Research Design

3.1 Sample Selection and Data Sources

To investigate the impact of ESG performance on corporate profitability, this study selects data from all A-share listed companies over the period 2014–2024 as the initial sample. To ensure scientific rigor and data accuracy, the following treatments were applied:

- (1) Exclusion of samples from financial and insurance companies.
- (2) Exclusion of samples with ST or *ST designations.
- (3) Exclusion of samples with missing data.
- (4) Winsorization of all continuous variables at the 1% level on both tails.

After these procedures, a final sample of 15,333 valid observations was obtained. All data used in this study were sourced from the CSMAR and Wind databases. Model estimation and data processing were performed using Stata 18.0.

3.2 Variable Selection

3.2.1 Dependent Variable

Corporate profitability serves as the dependent variable in this study. Profitability is a core financial indicator of a firm, influenced by factors such as production costs, operational efficiency, and revenue structure, and it reflects the overall operating condition of the enterprise to a certain extent. Profitability can be measured using multiple indicators; this study adopts return on assets (ROA) as the proxy for corporate profitability.

3.2.2 Independent Variable

Corporate ESG performance is the independent variable. ESG represents a comprehensive evaluation framework encompassing environmental, social, and governance dimensions. It reflects a firm's development status and sustainability capability from a non-traditional financial perspective and indirectly influences various financial indicators. In current business practice, several third-party agencies assess corporate ESG performance through multiple indicators, typically presented in the form of ESG ratings. Given that the sample consists of A-share listed companies, this study employs the Hua Zheng ESG rating system, which is recognized for its scientific and comprehensive coverage. Following the approach of Wang Bo and Yang Maojia [5], the nine rating categories (C-AAA) are assigned numerical values from 1 to 9, with higher scores indicating better ESG performance.

3.2.3 Mediating Variable

Corporate risk level is selected as the mediating variable. In business operations, firms face various risks, including policy risk, financial risk, and operational risk, all of which directly affect operating performance. Therefore, this study employs the Z-score model to calculate the following indicators: X1 (working capital / total assets), X2 (retained earnings / total assets), X3 (EBIT / total assets), X4 (market value of equity / total liabilities), and X5 (total revenue / total assets). The resulting Z-score is then used to quantify corporate operational risk; a higher Z-score indicates a lower level of risk.

3.2.4 Control Variables

To enhance the robustness and validity of the results, the following control variables are included, drawing on prior literature: firm size (Size), firm age (Age), asset turnover ratio (ATR), ownership concentration (Top5), board size (Board), cash flow ratio (Cash), fixed asset ratio (Fix), and growth rate (Growth).

Table 1: Variable Definitions

Variable Category	Variable Name	Symbol	Variable Description
Dependent Variable	Corporate Profitability	ROA	Return on assets = Net profit / Average total assets × 100%
Independent Variable	ESG Performance	ESG	Hua Zheng ESG rating score (1–9)
Mediating Variable	Corporate Risk Level	Z	$Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + X_5$
Control Variables	Firm Size	Size	Natural logarithm of total assets
	Firm Age	Age	Natural logarithm of years since establishment
	Asset Turnover	ATR	Total asset turnover = Operating revenue / Average total assets × 100%
	Ownership Concentration	Top5	Shareholding proportion of the top five shareholders
	Board Size	Board	Number of board members
	Cash Flow Ratio	Cash	Cash flow ratio = Net cash flow from operating activities / Total assets × 100%
	Fixed Asset Ratio	Fix	Fixed assets / Total assets × 100%
	Growth	Growth	Operating revenue growth rate = (Current revenue – Prior revenue) / Prior revenue × 100%

3.3 Model Specification

3.3.1 Baseline Regression Model

To test Hypothesis 1, the following baseline regression model is constructed:

$$ROA_{i,t} = \alpha_0 + \alpha_1 ESG_{i,t-1} + \sum Controls_{i,t} + Industry + Year + \varepsilon_{i,t} \quad (1)$$

where α_0 is the constant intercept, $ROA_{i,t}$ is the dependent variable, denoting the profitability of firm i in year t , $ESG_{i,t-1}$ is the independent variable, representing the ESG performance of firm i in year t , α_1 is coefficient of the explanatory variable, $\sum Controls_{i,t}$ is the set of control variables, Industry and Year represent industry and year fixed effects, respectively, and $\varepsilon_{i,t}$ is the random error term.

3.3.2 Mediation Effect Model

To explore the underlying mechanism through which ESG performance affects corporate profitability and to verify Hypothesis 2, this study introduces corporate risk level as a mediating variable. Following the methodology of Wu Yongxia and Shan Fei [6], the following model based on Model (1) is constructed:

$$Mi_{i,t} = \beta_0 + \beta_1 ESG_{i,t-1} + \sum Controls_{i,t} + Industry + Year + \theta_{i,t} \quad (2)$$

$$ROA_{i,t} = \gamma_0 + \gamma_1 ESG_{i,t-1} + \gamma_2 Mi_{i,t} + \sum Controls_{i,t} + Industry + Year + \varepsilon_{i,t} \quad (3)$$

where $Mi_{i,t}$ is the mediating variable, representing the risk level of firm i in year t . Provided that coefficients α_1 and β_1 are statistically significant, the significance of both γ_1 and γ_2 indicates the existence of a partial mediation effect. Conversely, if γ_1 is non-significant while γ_2 remains significant, it suggests a full mediation effect.

4. Empirical Analysis

4.1 Descriptive Statistics

As shown in Table 2, the dependent variable ROA ranges from -0.025 to 1.285, with a mean of 0.058 and a median of 0.579, indicating substantial variation in profitability across firms. The ESG score has a mean of 4.376, a median of 4.367, and a standard deviation of 1.919, suggesting that most firms exhibit relatively concentrated ESG performance levels, though the full range (1.000 to 9.000) reflects notable differences in ESG emphasis across companies. The mean and median of the Z-score are both 1.493, indicating that the distribution of corporate risk levels is uniform and symmetrical. However, the minimum value of -19.970 and the maximum value of 11.769 suggest the presence of extreme cases and significant heterogeneity in risk levels across the sampled firms.

Table 2: Descriptive Statistics Results

Variable	Observations	Mean	Median	Std. Dev.	Min	Max
ROA	15333	0.058	0.579	0.052	-0.025	1.285
ESG	15333	4.376	4.367	1.919	1.000	9.000
Z	15333	1.493	1.493	0.731	-19.970	11.769
Size	15333	22.257	22.257	1.221	18.114	28.366
Age	15333	3.233	3.233	0.233	2.079	4.248
ATR	15333	0.656	0.656	0.524	0.006	11.975
Top5	15333	52.620	52.620	15.730	1.420	166.60
Board	15333	8.341	8.341	1.570	4.000	17.000
Cash	15333	0.057	0.057	0.067	-0.397	0.839
Fix	15333	0.193	0.193	0.143	0.000	0.954
Growth	15333	0.219	0.219	1.578	-0.929	87.484

4.2 Correlation Analysis

The correlation analysis reveals that the correlation coefficient between ESG performance and corporate profitability is 0.168, significant at the 1% level, indicating a significant positive correlation between the two. Similarly, the correlation coefficient between ESG performance and the Z-score is 0.129 (significant at 1%), suggesting that better ESG performance is associated with a higher Z-score, which implies lower corporate risk. Furthermore, the correlation between the Z-score and profitability is 0.476 (significant at 1%), demonstrating that lower risk levels correspond to higher profitability. Additionally, control variables—including firm size, firm age, operating efficiency, ownership concentration, growth, cash flow ratio, and fixed

asset ratio—all exert significant impacts on both profitability and ESG performance. In summary, there are significant correlations among the explanatory variable (ESG performance), the dependent variable (profitability), and the mediating variable (corporate risk), and all selected control variables significantly influence the dependent variable.

4.3 Baseline Regression Analysis

Table 3 presents the estimation results of the benchmark regression, with all six models employing fixed effects. As shown in column (1), when only the explanatory and dependent variables are included—without control variables or fixed effects for year and industry—the regression coefficient is 0.004, significant at the 1% level. This is consistent with the results in column (2), where fixed effects are incorporated, suggesting a significant positive relationship between ESG performance and corporate profitability that remains robust against unobservable factors at the industry and temporal levels. Furthermore, columns (3) through (5) show the results of gradually adding control variables while maintaining year and industry fixed effects. The regression coefficient of ESG performance on ROA slightly decreases from 0.005 to 0.003, while remaining significant at the 1% level. This indicates that after controlling for various interfering factors, the positive relationship between ESG performance and profitability still holds and is more reliable than the results without control variables. These findings provide empirical support for Hypothesis 1 (H1).

Table 3: Baseline Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
	ROA	ROA	ROA	ROA	ROA	ROE
ESG	0.004***	0.004***	0.005***	0.005***	0.003***	0.003***
	(10.0947)	(9.9972)	(11.2874)	(10.5861)	(8.2563)	(6.5553)
Size			-0.003***	-0.003***	-0.003***	0.007***
			(-3.7281)	(-3.9384)	(-4.8444)	(8.2550)
Age			-0.011***	-0.008**	-0.008***	-0.013***
			(-3.4992)	(-2.4032)	(-3.1239)	(-3.3574)
ATR				0.014***	0.008***	0.025***
				(3.9094)	(3.9581)	(5.6113)
Top5				0.000***	0.000***	0.000***
				(8.0017)	(7.3804)	(6.7285)
Board				-0.000	0.000	-0.001
				(-0.0768)	(0.0746)	(-1.2584)
Cash					0.3730***	0.4920***
					(17.1897)	(17.5637)
Fix					-0.080***	-0.094***
					(-14.1749)	(-11.4243)
Growth					0.003***	0.005***
					(2.6301)	(3.4701)
Constant	0.038***	0.034***	0.124***	0.146***	0.099***	-0.081***
	(20.6980)	(4.3520)	(6.6582)	(8.4403)	(6.3505)	(-3.2563)
Year Fixed Effects	No	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	No	Yes	Yes	Yes	Yes	Yes
Observations	15333	15333	15333	15333	15333	15333
r ² a	0.028	0.092	0.097	0.123	0.345	0.299

Note: 1. *t*-statistics are reported in parentheses. 2. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.4 Mediation Effect Test

Table 4 presents the results of the mediation effect test, with control variables included in Models (1) through (3). Model (1) shows that the coefficient for ESG performance is 0.003 (significant at the 1% level), confirming a positive correlation between ESG performance and corporate profitability. This further validates Hypothesis 1 and confirms that coefficient α_1 in the regression model is significant.

Model (2) reveals that the coefficient for ESG is 0.051, significant at the 1% level, indicating a significant positive correlation between ESG performance and the Z-score. This implies a significant negative correlation

between ESG performance and corporate risk; specifically, higher ESG performance corresponds to lower risk levels. This also confirms the statistical significance of β_1 in the mediation model.

In Model (3), the Z-score is incorporated as a mediator alongside the control variables. The coefficient for ESG performance remains significant at the 1% level but decreases to 0.001 compared to its value in Model (1). Concurrently, the coefficient for the Z-score is 0.042, significant at the 1% level, indicating a positive correlation between the Z-score and profitability—meaning that lower corporate risk levels lead to higher profitability. Since both γ_1 and γ_2 in the mediation model are statistically significant, it can be concluded that corporate risk (Z-score) plays a partial mediating role between ESG performance and profitability. Specifically, superior ESG performance reduces risk, which in turn enhances profitability, thereby validating Hypothesis 2.

Table 4: Mediation Effect Test Results

	(1)	(2)	(3)
	ROA	Z	ROA
ESG	0.003***	0.051***	0.001**
	(9.41)	(11.26)	(2.30)
Z			0.042***
			(5.80)
Constant	0.127***	3.474***	-0.017
	(10.70)	(19.73)	(-0.57)
Control Variables	Yes	Yes	Yes
Observations	15333	15333	15333
r ² a	0.307	0.565	0.459

Notes: 1. *t*-statistics are reported in parentheses. 2. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. 3. Control variables include Size, Age, ATR, Top5, Board, Cash, Fix, and Growth.

4.5 Robustness Check

To ensure the reliability of the conclusions, a robustness check was conducted by replacing the dependent variable ROA with Return on Equity (ROE). The results are presented in column (6) of Table 3. A comparison of the results reveals that under the conditions of fixed industry and year effects, and with consistent and comprehensive control variables, the regression coefficient for ESG performance on ROE is 0.003, significant at the 1% level. This is consistent with the findings when ROA was used as the dependent variable, indicating that the choice of proxy for profitability does not alter the relationship between ESG performance and corporate profitability. Thus, a significant positive correlation between the two remains evident.

Additionally, this study controls for operating efficiency, proxied by Total Asset Turnover. When ROE is used as the dependent variable, DuPont analysis suggests that a firm's profitability and risk level are the primary determinants of ROE. Combined with the empirical findings of this study—that ESG performance enhances profitability by mitigating corporate risk—the results align with the profit-driven pathways revealed by DuPont analysis. This consistency further validates the authenticity and robustness of Hypothesis 2.

5. Conclusions and Policy Recommendations

Based on the empirical analysis, the following conclusions are drawn: 1. Better ESG performance is significantly associated with higher corporate profitability, indicating a positive promotional effect of ESG on profitability. 2. Corporate risk level plays a mediating role in the relationship between ESG performance and profitability: superior ESG performance reduces risk levels, which in turn enhances profitability.

The following policy recommendations are proposed: Enterprises should place greater emphasis on improving ESG performance, actively adopt environmentally friendly practices, fulfill social responsibilities, and strengthen corporate governance to achieve long-term sustainable development. Government agencies and regulators should enhance oversight of ESG disclosure, continuously improve relevant regulations and standards, and promote the standardization and normalization of ESG rating systems, thereby creating a favorable external environment for corporate development. For financial institutions and other investors, greater attention should be paid to corporate ESG disclosure and performance. By evaluating ESG factors to assess operating risks, investors can engage in more rational and scientifically grounded investment decisions.

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Measurement and Coupling Relationship of Economic Resilience in Southwest China Driven by the Digital Economy

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Abstract

Under the dual background of the advancement of the “Digital China” strategy and the increasing global economic uncertainty, the synergistic development of the digital economy and regional economic resilience has become a key approach to addressing regional development imbalances and enhancing risk resistance capabilities. This study takes the four southwestern provinces and cities, Sichuan, Chongqing, Yunnan, and Guizhou, as the research objects. The entropy method is employed to measure the digital economy and economic resilience development indices from 2011 to 2023. The coupling coordination degree model is then used to systematically investigate the spatiotemporal evolution characteristics and linkage mechanisms of the coupling coordination relationship between the two. The results show that: 1) The development of the digital economy in the four provinces and cities exhibits a three-stage pattern of “initial accumulation – rapid growth – steady callback,” with a regional gradient distribution characterized by “Sichuan leading, Chongqing following closely, and Yunnan-Guizhou catching up.” 2) The economic resilience index shows a continuous linear upward trend, with regional gaps gradually narrowing, displaying significant catch-up and convergence features. 3) There is a significant positive synergistic effect between the digital economy and economic resilience. The overall coupling coordination degree shows a continuous upward trend, evolving from a state of imbalance in 2011 to a high-quality coordination level by 2023. The regional pattern is characterized by “Sichuan highest, Chongqing second, and Yunnan-Guizhou relatively close,” with differences in coordination stability across regions. This study enriches the theoretical framework of digital economy empowerment for regional economic resilience and provides empirical evidence and policy references for the four southwestern provinces and cities to optimize digital economy layout, enhance economic resilience, and promote high-quality coordinated development.

Keywords

digital economy, economic resilience, entropy method, coupling coordination degree, high-quality development

1. Introduction

In the dual context of the in-depth advancement of the “Digital China” strategy and the intensification of global economic uncertainty, the digital economy has become a core engine driving high-quality regional

economic development. Through technological innovation, industrial upgrading, and governance optimization, it provides crucial support for regional economies to cope with external shocks and achieve sustainable development [1]. Economic resilience, as the core capability of regions to withstand risks, recover rapidly, and adapt to transformation, forms a close bidirectional interactive relationship with the enabling logic of the digital economy [2]. At present, China's regional economic development exhibits a pronounced "strong east, weak west" differentiation pattern. The four southwestern provinces and cities, Sichuan, Chongqing, Yunnan, and Guizhou, as the core carrying areas for the Western Development strategy and the construction of the Chengdu-Chongqing Twin-City Economic Circle, face developmental shortcomings such as weak digital infrastructure, single industrial structures, and significant pressure for transformation in resource-based cities [3, 4]. At the same time, they possess unique advantages, including distinctive development features of ethnic minority areas and abundant ecological resources [5]. Against this backdrop, systematically exploring the coupling coordination relationship between the digital economy and regional economic resilience, and quantifying the spatiotemporal evolution patterns and influencing mechanisms of the two, is not only a practical requirement for addressing the problem of unbalanced and inadequate development in the southwestern region, but also an important academic proposition for enriching theoretical research on the digital economy's empowerment of economic resilience [24].

2. Literature Review

2.1 Connotation and Measurement System of the Digital Economy

Existing studies have reached a consensus on the connotation of the digital economy: it is a composite economic form encompassing three core dimensions—digital infrastructure, digital industries (digital industrialization and industrial digitalization), and digital applications (such as digital inclusive finance and digital government services) [6, 7]. In terms of measurement methods, the entropy weight method is widely adopted due to its advantage of objective weighting. It constructs a multi-indicator system to comprehensively assess the level of digital economy development from aspects including digital infrastructure, industrial support, and digital applications [8, 9]. Some studies have further expanded the application dimensions of the digital economy by incorporating digital inclusive finance, digital government services, and other elements into the measurement system, thereby more fully reflecting the permeability of the digital economy into regional development [10, 11]. In research on regional patterns, scholars generally find that digital economy development exhibits significant regional heterogeneity, forming a "core-periphery" spatial structure, while also displaying clear convergence characteristics. The central and western regions demonstrate a strong "latecomer catch-up" effect [11, 12].

2.2 Connotation and Measurement Framework of Economic Resilience

The concept of economic resilience originated in the field of engineering mechanics and was later extended to economics. It is defined as the comprehensive embodiment of a region's resistance and endurance capacity, recovery and adjustment capacity, and adaptation and upgrading capacity when facing external shocks [13]. Its measurement framework has gradually evolved from a single GDP indicator to a multi-dimensional system: resistance and endurance capacity is measured by indicators such as per capita GDP, disposable income of residents, and employment status, reflecting the region's foundational ability to withstand shocks; recovery and adjustment capacity is measured by indicators such as the increment in per capita consumption goods and industrial structure elasticity, reflecting the recovery momentum after economic shocks; adaptation and upgrading capacity is measured by indicators such as the number of patents, number of university graduates, and innovation inputs, reflecting the region's long-term innovation and development potential [14, 15]. Some studies also incorporate regional characteristics by including ecological resilience, governance resilience, and other dimensions into the measurement system, further enriching the connotation of economic resilience.

2.3 Mechanisms of the Role of the Digital Economy in Economic Resilience

Existing research has revealed the core pathways through which the digital economy empowers economic resilience: first, the industrial upgrading pathway, where the digital economy promotes the upgrading and rationalization of industrial structures, enhancing industries' risk resistance through technological innovation [16]; second, the governance optimization pathway, where digital government improves regional governance

resilience and risk response efficiency through digital government services and optimization of the business environment [17]; third, the factor allocation pathway, where digital technologies optimize the allocation of capital, labor, technology, and other factors, alleviating information asymmetry and improving economic operational efficiency [18]; fourth, the intermediary transmission pathway, where urbanization rate, industrial structure, and other factors play a key mediating role between the digital economy and economic resilience—the digital economy indirectly enhances economic resilience by promoting urbanization, industrial upgrading, and so on [19]. Some studies have also found that the empowering effect of the digital economy on economic resilience is not simply linear; it can also operate through intermediary pathways such as green finance, and is moderated by factors including regional digital infrastructure and institutional environment [20].

2.4 Coupling Coordination and Spatiotemporal Evolution Analysis

The coupling coordination degree model is widely used to measure the level of synergistic development between the digital economy and economic resilience. Core findings indicate that, temporally, the coupling coordination level between the two shows an overall upward trend, but with significant regional differences; spatially, core urban agglomerations (such as the Yangtze River Delta and Beijing-Tianjin-Hebei) exhibit higher coupling levels, while inland regions remain in the primary or intermediate coordination stages [21]. In terms of dynamic analysis, some studies employ methods such as the PVAR model and Granger causality tests, finding that the digital economy and economic resilience exhibit self-reinforcing effects, but these effects diminish over time and are prone to lagged effects in later periods [22, 23].

In summary, the academic community has conducted in-depth explorations of the digital economy and economic resilience, yielding abundant results. However, the following deficiencies remain:

- 1) Insufficient fine-grained regional research: Most scholars focus primarily on economically developed regions such as Beijing-Tianjin-Hebei and the Yangtze River Delta, with relatively little research on the southwestern region. They have not fully considered the unique characteristics of the southwestern region, such as development in ethnic minority areas, ecological constraints, and the transformation pressure on resource-based cities. The regional adaptability of measurement indicators needs further improvement.
- 2) Inadequate depth in coupling relationship research: Most studies only analyze the unidirectional impact of the digital economy on economic resilience, with few scholars quantitatively examining the coupling relationship between the two. There is insufficient exploration of the spatiotemporal evolution of coupling coordination, influencing factors, and early warning mechanisms.

Based on the above deficiencies, this paper takes Yunnan, Guizhou, Sichuan, and Chongqing as the research objects. It employs the entropy method to measure their digital economy index and economic resilience index, establishes a coupling coordination degree model, and explores the dynamic evolution of the coupling coordination relationship between the digital economy and economic resilience, with the aim of providing theoretical foundations and policy support for the digital economy development in Yunnan, Guizhou, Sichuan, and Chongqing.

3. Research Methods and Data Sources

3.1 Research Methods

3.1.1 Construction of Indicator Systems for the Digital Economy and Economic Resilience

Building on relevant scholarly research [9, 19] and in combination with the connotation of the digital economy as well as the statistical standards of the Classification of the Digital Economy, this paper constructs a comprehensive evaluation indicator system (as shown in Table 1) while ensuring both comprehensiveness and reliability. This system is then used to measure the digital economy development index for the four provinces and cities of Yunnan, Guizhou, Sichuan, and Chongqing.

Economic resilience refers to the comprehensive capability of a regional economy to effectively withstand risks, dynamically adapt to the environment, and rapidly restore growth when facing external shocks, market fluctuations, and risk pressures. It is a key dimension for measuring the stability, sustainability, and risk

resistance of economic systems [11]. This paper constructs an economic resilience indicator system from three dimensions—resistance, adaptability, and recoverability, as shown in Table 2.

Table 1: Digital Economy Indicator System

Primary Indicator	Secondary Indicator	Unit
Digital Infrastructure	Number of mobile phone subscribers per 100 people	Persons
	Internet broadband access ports	Thousand households
	Number of internet users per 100 people	Units per 100 persons
Digital Industrialization	Proportion of employees in computer services and software	%
	Per capita telecommunication business volume	10,000 yuan per person
	Software industry revenue	10,000 yuan
	Number of digital industry patent authorizations	Items
Industrial Digitalization	E-commerce transaction volume	10,000 yuan
	Digital inclusive finance index	%

Table 2: Economic Resilience Indicator System

Primary Indicator	Secondary Indicator	Unit
Resistance	Per capita regional gross domestic product	Yuan per person
	Industrial output value	100 million yuan
	Fixed asset investment	100 million yuan
Adaptability	Foreign investment as a proportion of GDP	%
	Urban permanent resident population / regional permanent resident population	%
	Urban unemployment rate	%
	Ratio of deposits to loans in financial institutions	%
Recoverability	Total retail sales of consumer goods	100 million yuan
	Number of college students per 100,000 people	Persons per 100,000
	Local government fiscal expenditure	100 million yuan

3.1.2 Entropy Weight Method

To overcome interference from subjective factors and objectively calculate the weights of each indicator, this paper adopts the entropy weight method to measure the digital economy and economic resilience development indices of the four provinces and cities [21]. The entropy weight method is a typical objective weighting approach. Its core principle is to determine weights based on the degree of variation in the indicators: the greater the variation in an indicator's values, the richer the effective distinguishing information it contains, and thus the higher its corresponding weight; conversely, the lower the weight. The calculation steps are as follows:

Step 1: Standardize the original data.

For positive indicators:

$$Y_{ij} = \frac{X_{ij} - \min X_{ij}}{\max X_{ij} - \min X_{ij}} \quad (1)$$

For negative indicators:

$$Y_{ij} = \frac{\max X_{ij} - X_{ij}}{\max X_{ij} - \min X_{ij}} \quad (2)$$

where X_{ij} is the original indicator value for sample i and indicator j ; Y_{ij} is the standardized value; and $\max X_{ij}$ and $\min X_{ij}$ are the maximum and minimum values of indicator X_{ij} , respectively.

Step 2: Determine the proportion of each standardized indicator.

$$P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^n Y_{ij}} \quad (3)$$

where n is the number of samples.

Step 3: Calculate the information entropy value of the j -th indicator.

$$Z_{ij} = -\frac{1}{\ln n} \sum_{i=1}^n P_{ij} \ln P_{ij} \quad (4)$$

Step 4: Calculate the weight of the j -th indicator.

$$W_j = \frac{1 - Z_j}{\sum_{j=1}^m (1 - Z_j)} \quad (5)$$

where m is the number of indicators.

Step 5: Calculate the comprehensive scores for economic resilience and digital economy development levels, respectively, using the following formula:

$$U_i = \sum_{j=1}^m W_j \times Y_{ij} \quad (6)$$

3.1.3 Coupling Coordination Degree Model

The coupling coordination degree model consists of two parts: coupling degree and coordination degree. The coupling degree characterizes the strength of mutual influence and constraint between systems, while the coordination degree measures the actual effect of benign interaction and synergistic development between systems [15]. To investigate the level of synergistic development between the two major systems in the four provinces and cities, this paper constructs a coupling coordination degree model for empirical analysis. The specific calculation steps are as follows:

$$C = 2 \times \frac{\sqrt{U_1 \times U_2}}{U_1 + U_2} \quad (7)$$

$$T = \alpha U_1 + \beta U_2 \quad (8)$$

$$D = \sqrt{C \times T} \quad (9)$$

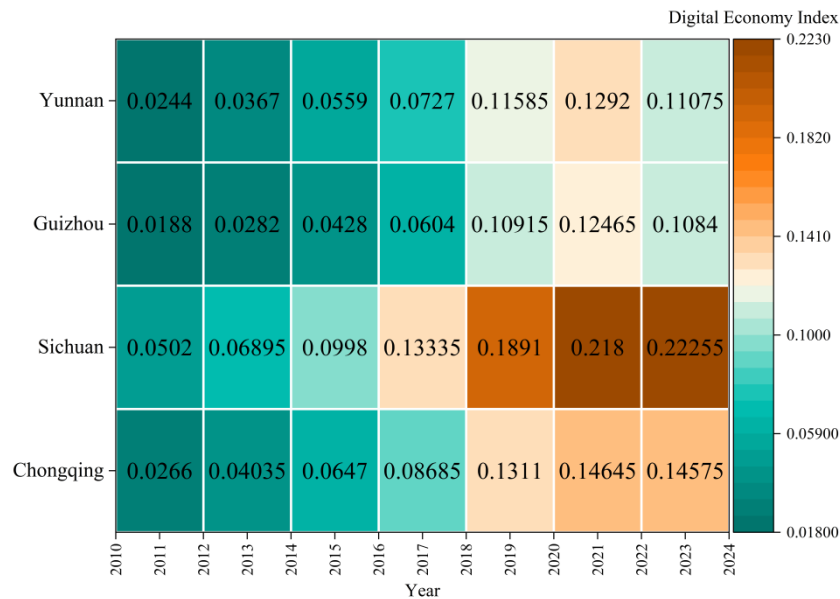
where C denotes the coupling degree; T represents the comprehensive coordination index of the digital economy and economic resilience; U_1 and U_2 refer to the comprehensive development levels of the digital economy and economic resilience, respectively. α and β are the weight coefficients. Given that the digital economy and economic resilience are of equal importance to social development, we set $\alpha = \beta = 0.5$. The value of the coupling coordination degree (D) ranges from 0 to 1.

The data required for this paper are sourced from the Chongqing Statistical Yearbook, Sichuan Statistical Yearbook, Yunnan Statistical Yearbook, Guizhou Statistical Yearbook, and the statistical bulletins of the four provinces and cities.

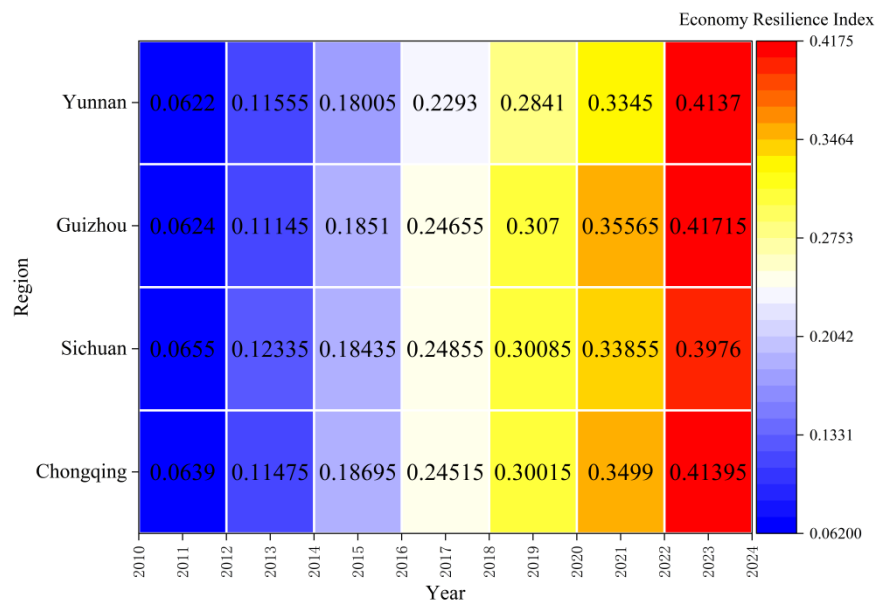
4. Empirical Results

4.1 Analysis of the Two-System Index Results

From a temporal perspective, the period 2011–2016 represents the initial accumulation stage for the digital economy in the four provinces and cities, with overall development indices remaining relatively low. From 2017–2020, it entered a phase of rapid growth, highly aligned with the national advancement of the “Digital China” strategy. From 2021–2023, influenced by the COVID-19 pandemic shock and base effect, the indices generally experienced slight correction or stabilized. In terms of regional patterns, Sichuan holds an absolute leading position in digital economy development, with its index reaching 0.2341 in 2020—the only region among the four to exceed 0.2—reflecting the strongest development foundation. Chongqing follows closely, with its index steadily rising to 0.1638, forming the second tier. Yunnan and Guizhou belong to the third tier, with similar and relatively low index levels, reaching phased peaks of 0.1544 and 0.1462, respectively, in 2020. As shown in Figure 1.

Figure 1: Measurement Results of the Digital Economy

The economic resilience indices of the four provinces and cities exhibit a continuous linear upward trend overall, increasing from the range of 0.06–0.07 in 2011 to 0.42–0.45 in 2023—an increase of more than sixfold—demonstrating a systematic enhancement in regional economic risk resistance capabilities. At the same time, inter-regional gaps have significantly narrowed. By 2023, the indices for Yunnan (0.4462), Guizhou (0.4395), Chongqing (0.4385), and Sichuan (0.4245) are highly close, displaying pronounced “latecomer catch-up” and regional convergence characteristics. As shown in Figure 2.

Figure 2: Measurement Results of Economic Resilience

There is a significant positive synergistic effect between the digital economy and economic resilience. Sichuan, which leads in digital economy development, also maintains a relatively high level of economic resilience. In contrast, Yunnan and Guizhou, which started later in the digital economy, exhibit faster growth rates in economic resilience indices, indicating that the penetration and application of digital technologies have effectively improved economic production efficiency, innovation capabilities, and risk resistance. The two also show phased differentiation characteristics: from 2021–2023, digital economy indices generally declined slightly, while economic resilience indices continued to rise, suggesting that improvements in economic

resilience not only depend on the digital economy but also benefit from industrial diversification, expansion of domestic demand markets, and effective support from macroeconomic policies.

Based on the above characteristics, each province and city can adopt targeted strategies: Sichuan should consolidate its first-mover advantage in the digital economy, deepen the integration of digital technologies with the real economy, and build nationally influential digital industry clusters; Chongqing needs to explore more efficient transformation pathways between the digital economy and economic resilience, with a focus on laying out intelligent manufacturing, digital finance, and other fields; Yunnan and Guizhou should seize national strategic opportunities such as “East Data West Computing,” accelerate digital infrastructure construction, and leverage the digital economy as a key new engine for enhancing economic resilience.

4.2 Analysis of Coupling Coordination Degree Results

4.2.1 Overall Evolutionary Characteristics

From 2011 to 2023, the coupling coordination degree between economic resilience and the digital economy in Yunnan, Guizhou, Sichuan, and Chongqing shows a significant upward trend overall. The coordination relationship evolves progressively from an early state of imbalance to high-level coordination. In general, at the beginning of the study period, the coupling coordination degrees in each region were at relatively low levels (primarily in imbalance categories). Subsequently, with improvements in comprehensive development levels, the coupling coordination degree continued to rise, crossing stages from “barely coordinated—primary/intermediate coordinated—good coordinated” in the mid-to-late period, and ultimately reaching the “high-quality coordination” level across all regions by 2023.

4.2.2 Regional Differences and Horizontal Comparison

From a regional comparison perspective, the coupling coordination degrees in all four regions achieved leapfrog improvements, but differences exist in the pace and stability of advancement. Sichuan exhibits the smoothest and most sustained upward path in coupling coordination degree, entering high-level coordination intervals earlier and reaching the highest level among the four by 2023. This reflects more continuous and stable synergistic evolution between digital economy development and economic resilience enhancement. Chongqing also shows significant overall improvement and enters the “high-quality coordination” interval in the later period, though it experiences brief declines followed by recoveries in the mid-to-late stages, indicating that high-level synergy may still fluctuate under periodic shocks or structural adjustments. Yunnan and Guizhou display “continuous catch-up” characteristics: both achieve significant increases in coordination degree during the study period and ultimately enter “high-quality coordination,” but experience certain pullbacks at high-level stages, suggesting that further strengthening of digital economy support for industrial resilience and governance resilience is needed to consolidate coordination quality. Overall, the 2023 coupling coordination degree levels present a pattern of “Sichuan highest, Chongqing second, and Guizhou and Yunnan relatively close,” reflecting the stronger synergistic advantages of the Chengdu-Chongqing region in digital economy empowerment and resilience system building. While Yunnan and Guizhou have achieved notable improvements, enhancing stability and sustained high-quality coordination remains a key focus for future advancement.

Table 3: Coupling Coordination Types in the Four Provinces and Cities

Year	Sichuan	Chongqing	Guizhou	Yunnan
2011	Severe imbalance	Severe imbalance	Severe imbalance	Severe imbalance
2012	Mild imbalance	Moderate imbalance	Moderate imbalance	Moderate imbalance
2013	Verge of imbalance	Verge of imbalance	Mild imbalance	Verge of imbalance
2014	Barely coordinated	Barely coordinated	Verge of imbalance	Verge of imbalance
2015	Barely coordinated	Barely coordinated	Barely coordinated	Barely coordinated
2016	Primary coordinated	Primary coordinated	Barely coordinated	Barely coordinated
2017	Intermediate coordinated	Intermediate coordinated	Primary coordinated	Primary coordinated
2018	Good coordinated	Good coordinated	Intermediate coordinated	Intermediate coordinated
2019	Good coordinated	Good coordinated	Good coordinated	Good coordinated
2020	High-quality coordinated	High-quality coordinated	High-quality coordinated	Good coordinated
2021	High-quality coordinated	Good coordinated	Good coordinated	Good coordinated
2022	High-quality coordinated	High-quality coordinated	Good coordinated	Good coordinated
2023	High-quality coordinated	High-quality coordinated	High-quality coordinated	High-quality coordinated

5. Conclusions and Policy Recommendations

5.1 Conclusions

This paper takes the four southwestern provinces and cities as the research sample and systematically analyzes the spatiotemporal evolution characteristics of the digital economy and economic resilience from 2011 to 2023, as well as the coupling coordination relationship and linkage mechanisms between the two. Based on the empirical results, the following core conclusions are drawn:

First, digital economy development exhibits distinct temporal phased characteristics and significant regional heterogeneity. Temporally, the digital economy development in the four provinces and cities has gone through three stages: the initial accumulation period (2011–2016), the rapid growth period (2017–2020), and the steady callback period (2021–2023), which is highly consistent with the advancement of the “Digital China” strategy and changes in the external environment. Regionally, Sichuan possesses the strongest foundation in the digital economy, with its index breaking through 0.2 in 2020 and maintaining an absolute leading position; Chongqing forms the second tier; Yunnan and Guizhou constitute the third tier, with similar but overall relatively low index levels. Regional gradient differences are pronounced.

Second, economic resilience has achieved systematic improvement with clear regional convergence characteristics. From 2011 to 2023, the economic resilience indices of the four provinces and cities increased from the range of 0.06–0.07 to 0.42–0.45—an increase of more than sixfold—indicating a significant enhancement in the comprehensive capabilities of regional economies to resist risks, promote recovery, and strengthen adaptation. In terms of regional gaps, by 2023 the economic resilience indices of the four provinces and cities are highly close (Yunnan 0.4462, Guizhou 0.4395, Chongqing 0.4385, Sichuan 0.4245), with the disparity significantly narrowed, demonstrating a clear “latecomer catch-up” effect and a trend toward balanced regional economic resilience development.

Third, there exists a positive synergistic effect between the digital economy and economic resilience, with the coupling coordination level achieving leapfrog improvement. The coupling coordination degree evolved from an imbalanced state in 2011, progressively crossing the stages of barely coordinated, primary coordinated, intermediate coordinated, and good coordinated, ultimately reaching the high-quality coordination level across all four provinces and cities by 2023. In regional comparison, Sichuan exhibits the smoothest and most stable upward path in coupling coordination degree, reflecting the strongest synergistic stability; Chongqing shows significant improvement but with periodic fluctuations; Yunnan and Guizhou display “continuous catch-up” characteristics.

Fourth, the linkage relationship between the two presents phased differentiation features. The digital economy has a significant empowering effect on economic resilience: regions leading in digital economy development maintain higher overall levels of economic resilience, while Yunnan and Guizhou, which started later in the digital economy, exhibit faster growth rates in economic resilience, confirming the enhancing role of digital technology in economic risk resistance capabilities. However, from 2021 to 2023, digital economy indices generally experienced callbacks while economic resilience indices continued to rise, indicating that improvements in economic resilience not only depend on the digital economy but are also influenced by multiple factors such as industrial diversification, expansion of domestic demand markets, and macroeconomic policy support.

5.2 Policy Recommendations

Based on the above research conclusions and taking into account the regional characteristics and developmental shortcomings of the four southwestern provinces and cities, the following targeted policy recommendations are proposed to promote deep synergy and high-quality development between the digital economy and economic resilience:

Promote differentiated digital economy development to narrow regional gradient gaps. Sichuan should consolidate its first-mover advantage in the digital economy, focus on deep integration of digital technologies with the real economy, prioritize building nationally influential digital industry clusters, and strengthen its radiating and driving role toward surrounding provinces and cities. Chongqing should optimize the transformation pathways between the digital economy and economic resilience, with emphasis on developing

intelligent manufacturing, digital finance, and other fields to address periodic fluctuations in synergistic development and enhance coordination stability. Yunnan and Guizhou should seize national strategic opportunities such as “East Data West Computing,” accelerate digital infrastructure construction to remedy weaknesses in digital foundations, leverage ecological resources and the distinctive features of ethnic minority areas to cultivate new forms of digital economy, and promote rapid catch-up in digital economy development.

Strengthen multi-dimensional construction of economic resilience to consolidate “latecomer catch-up” achievements. All four provinces and cities should continue to improve systems for measuring and enhancing economic resilience: consolidate foundational support indicators such as per capita GDP and disposable income of residents to strengthen the basic capacity to withstand risks; reinforce adaptation and upgrading indicators such as patent innovation and talent cultivation to enhance long-term development potential; and, in combination with southwestern regional characteristics, incorporate ecological resilience and governance resilience into the resilience-building system, shifting economic resilience from “quantity improvement” to “quality optimization.” At the same time, increase investment in talent cultivation and other adaptation-upgrading indicators to provide a solid foundation for the digital economy’s empowerment of economic resilience [3].

Improve mechanisms for synergistic development between the two to enhance coupling coordination quality. Establish long-term mechanisms for the coordinated development of the digital economy and economic resilience, promote deep penetration of digital technologies into areas such as industrial upgrading, governance optimization, and factor allocation, and strengthen the empowering role of the digital economy on economic resilience. To address the insufficient coordination stability in Yunnan and Guizhou, strengthen digital cooperation and talent exchanges with the Chengdu-Chongqing region, draw on the synergistic development experience of the Chengdu-Chongqing area to remedy shortcomings in industrial digitalization and digital applications. At the same time, pay attention to the impact of external environmental changes on synergistic development, improve the macroeconomic policy support system, and alleviate pressure from periodic fluctuations.

Optimize development paths based on regional characteristics to build a southwestern synergistic model. Leverage the construction of the Chengdu-Chongqing Twin-City Economic Circle to promote integrated digital economy development between Sichuan and Chongqing, creating a core demonstration zone for synergistic development of the digital economy and economic resilience. Yunnan and Guizhou should build on their ecological resource advantages, develop green digital economy, and promote the integration of digital technologies with ecological industries and ethnic characteristic industries to form differentiated synergistic development models. The four provinces and cities should jointly establish a monitoring and early warning mechanism for the synergistic development of the digital economy and economic resilience, promptly identify and address prominent issues in the process, and position the southwestern region as a model area in western China for digital economy empowerment of economic resilience.

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The Complementary Mechanisms and Collaborative Governance Construction between Street Vendors and Formal Community Commerce

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Abstract

China's urbanization has entered a new stage characterized by high-quality development and refined governance. Street vendors and community-based commerce coexist as integral components of livelihood services. From the perspective of functional complementarity, this paper first analyzes the characteristics of street vendors and formal community commerce in terms of service positioning, spatiotemporal layout, business structure, and demand responsiveness. Second, it examines the differences and complementarities in their commercial functions, identifying complementarities in time, product categories, pricing, and goods provision. Finally, by clarifying the dimensions of complementarity and the interaction logic between the two within the community commercial ecosystem, the paper proposes a framework for their collaborative governance. This study provides a reference for balancing urban order, livelihood security, and community vitality, and promotes the formation of a new pattern of community commerce that is convenient, orderly, and dynamic, characterized by "formal commerce as the mainstay and street vendors as a supplement."

Keywords

street vendors, community-based commerce, functional complementarity, commercial ecosystem, informal economy, urbanization

1. Introduction

At present, China and Western countries are experiencing fundamentally different trajectories of urbanization. China is transitioning from a model driven by "speed and scale" to one emphasizing "quality and substance," while facing the issue of "semi-urbanization" and advancing urbanization in a gradual and steady manner. In contrast, Western countries have largely entered a stage of stock renewal and re-urbanization, progressively shifting toward green, smart, and inclusive urban development. Meanwhile, urbanization in both China and the West not only serves as a driving engine of domestic development but also provides a critical lens for understanding global economic dynamics, governance rule competition, and the contestation of development models.

Street vendors are small-scale operators engaged in mobile forms of trade, commonly found in high-traffic areas such as urban streets and market surroundings. Their business activities typically rely on mobile

tools such as handcarts and tricycles, and are characterized by the absence of fixed stalls, high flexibility, and low operating costs. Community-based commerce, by contrast, serves as the core carrier for ensuring residents' daily needs and for constructing the "15-minute convenient living circle." Together, the two form a complete ecosystem of grassroots urban commercial services. As China's urbanization enters a stage of high-quality development and refined governance, urban governance philosophy is shifting from "rigid control" to a more flexible and inclusive approach that combines regulation with accommodation. Street vendors, once treated primarily as objects of regulation, are increasingly recognized as important contributors to livelihood services and community vitality. At the same time, formal community commerce faces practical challenges, including insufficient service coverage, homogenization of business formats, and lagging responsiveness to residents' immediate needs. In contrast, street vendors play an irreplaceable role in filling service gaps, satisfying diverse consumption demands, and absorbing flexible employment. However, they also pose governance challenges related to order, safety, and the urban environment.

Given that street vendors and formal community commerce are often regarded as competitive or substitutive relationships, existing studies have largely focused on conflict management and unilateral regulation. Nevertheless, research on their intrinsic functional complementarity, spatial coordination, and differentiated business positioning remains insufficient. As a result, there is a lack of systematic analysis explaining how the two can enhance the overall efficiency of community commerce through division of labor and cooperation. Notably, various local practices—such as "time-shared markets," "designated vending zones," and "integrated outdoor business operations"—have begun to demonstrate preliminary effects of symbiosis.

Taking functional complementarity as the analytical starting point, this paper systematically examines the differences between street vendors and formal community commerce in terms of service positioning, spatial layout, business structure, and consumer demand. It further clarifies their multidimensional complementary relationships and interaction mechanisms within the community service system, and on this basis constructs a collaborative development framework adaptable to grassroots governance practices. Closely aligned with the practical demands of modernizing urban governance, this study not only provides a theoretically grounded and practically relevant pathway for balancing urban order, livelihood security, and community vitality, but also contributes to the formation of a new community commercial pattern that is convenient, orderly, and dynamically coexistent, characterized by "formal commerce as the foundation and street vendors as a supplement."

2. Characteristics of Urban Street Vendors and Formal Community Commerce

2.1 Characteristics of Urban Street Vendors

- 1) **Operating Hours:** Street vendors exhibit a high sensitivity to time. Through prolonged observation and experience, they develop a clear understanding of activity patterns across different time periods. Accordingly, vendors adjust their operating hours in response to the behavioral patterns of their target customer groups.
- 2) **Product Categories:** Differences in product categories among street vendors often lead to the phenomenon of turnover within vendor groups. Zhou Xiaosui and Wu Xiao [1], in their investigation of street vendors around the Yuelu Mountain university district, found that when operating hours are highly concentrated, group turnover is rare; however, when operating hours are more dispersed, shifts in business categories tend to occur.
- 3) **Pricing:** Due to the absence of rent and relatively low labor costs, most street vendors set their prices below those of community-based commercial establishments (such as supermarkets), thereby enhancing their local competitiveness and attracting consumers.
- 4) **Spatial Distribution:** Hu Ying and Shen Jintao [2], based on a study of street vendors in Suzhou, found that vendors tend to attach themselves to different types of public spaces according to their business content and competitive advantages, in order to maximize their operating profits.

2.2 Characteristics of Formal Community Commerce

- 1) **Operating Hours:** Formal community commerce, such as branded chain stores and community supermarkets, typically operates within fixed business hours. Their service hours correspond to the regular daily and weekly routines of residents, rather than catering to sporadic or unplanned consumption.
- 2) **Product Categories:** The business structure of formal community commerce reflects a composite of three functions: basic livelihood (e.g., convenience stores and produce shops), quality-enhancing services (e.g., premium supermarkets and fitness centers), and public services (e.g., childcare services), thereby continuously providing daily-life services for residents.
- 3) **Pricing Strategy:** Formal community commerce generally adopts moderate pricing and often offers membership-based discounts or prepaid benefits, with a focus on retaining repeat customers. Emphasizing affordability and accessibility, it seeks to establish long-term trust relationships within the community.
- 4) **Spatial Distribution:** Its spatial layout is deeply embedded within residential areas, with the “15-minute convenient living circle” serving as its core organizing principle. Formal community commerce typically exhibits a networked and nodal distribution across communities, neighborhood centers, and transportation hubs, and is mainly located at everyday points of passage for nearby residents.

Table 1: Comparison of key characteristics between street vendors and formal community commerce

Dimension	Street Vendors	Formal Community Commerce
Time	Highly flexible, appearing during “non-standard” periods such as morning/evening peaks and nighttime	Fixed operating hours following standardized schedules
Product Categories	Highly specialized and immediate (e.g., breakfast, late-night food, seasonal fruits, specialty snacks)	Standardized and comprehensive, mainly packaged food and daily necessities
Space	Non-fixed and highly mobile, occupying “interstitial” spaces such as street corners and metro entrances	Fixed and planned, located in legally designated shops or commercial complexes
Price	Very low (no rent, decoration, or high labor costs)	Medium to low (covering fixed costs and taxes)

From the above, it is evident that urban street vendors and formal community commerce exhibit significant differences in their characteristics. In the past, they were often regarded as competitors, and governance approaches tended to follow a binary logic of “eliminating one side to protect the other,” resulting in a zero-sum outcome. Today, however, both are increasingly viewed as integral components of the urban commercial system. Governance approaches have accordingly shifted toward “boundary delineation, regulated guidance, and integrative empowerment,” giving rise to a complementary relationship. This transformation represents a key manifestation of the evolution of urban management from “simple exclusion” to “refined governance” in fostering a healthy community commercial ecosystem.

3. Complementarity between Urban Street Vendors and Formal Community Commerce in Consumer Demand

The emergence of street vending as an occupation is fundamentally driven by market demand. With ongoing socioeconomic development and expansion, the diversification of public demand continues to increase, while urban retail systems struggle to fully satisfy the varied levels of consumer needs in terms of price, location, and services [3]. For example, street vendors provide personalized and distinctive breakfast and late-night food options, thereby compensating for the limited offerings of conventional breakfast shops, which often focus on traditional items. Urban street vendors thus precisely fill the gaps left by formal commerce across multiple dimensions—including time, product categories, pricing, and consumption scenarios—forming a complementary relationship on the demand side.

3.1 Temporal Complementarity: Extending Service Hours

Urban street vendors complement formal commerce through the misalignment and supplementation of operating hours, thereby serving as an important extension of instant consumption. Vendors can flexibly adjust their business hours according to residents' daily mobility patterns. For instance, breakfast stalls typically operate from 6:00 to 9:00 a.m. to serve commuters, while night markets and snack stalls operate from 6:00 to 11:00 p.m. to meet evening leisure consumption needs. In doing so, they precisely fill temporal gaps left by formal commerce—such as insufficient early-morning supply, limited nighttime services, and inadequate flexibility during holidays—transforming community consumption supply from “fixed time periods” to all-day coverage. From the perspective of temporal complementarity, the “off-peak operation” feature of street vendors can be naturally and appropriately understood. The “time-shared vending zones” established in Nanchuan District provide a representative example: vendors selling vegetables and fruits operate from 6:00 to 9:00 a.m. and from 4:00 to 7:00 p.m., while night market vendors selling braised foods and snacks operate from 6:00 to 9:30 p.m. This arrangement not only satisfies residents' immediate consumption needs but also effectively avoids direct, full-time competition with formal commerce. Ding Zhuhui, Chen Xuan, and Zhang Chenyu [4] provide an insightful analysis, noting that night markets have long been key targets of urban governance campaigns such as “civilized city construction.” These spaces, characterized by both economic activity and informal spatial usage, have gradually shifted from city centers into community interiors. Governance policies exhibit clear cyclical fluctuations, transitioning from strict spatial control toward encouraging the development of the nighttime economy.

3.2 Product Complementarity: Meeting Immediate and Non-Standardized Demand

Urban street vendors meet residents' fragmented consumption needs—characterized by “grab-and-go” and immediate use—through the provision of instant goods. Formal commerce primarily offers standardized, branded, and pre-packaged products, with its product structure constrained by supply chains, storage, and display space, making it difficult to provide large quantities of freshly prepared foods, local snacks, or seasonal small commodities. In contrast, the product offerings of street vendors are more closely aligned with residents' daily essential needs, focusing on hot foods, fresh foods, simple fruits and vegetables, and convenient small items. These offerings are characterized by small batch sizes, diverse varieties, high turnover, and convenience. As such, street vendors effectively fill the gaps in formal commerce in areas such as non-standard prepared foods, instant snacks, low-cost fresh produce, and emergency daily necessities.

3.3 Price Complementarity: Covering Multi-Level Consumption Capacity

Urban street vendors match consumer groups through low-cost operations. Due to higher costs associated with rent, labor, and management, formal commercial establishments generally set higher prices than informal operators. In contrast, street vendors benefit from the absence of store rent, relatively low tax burdens, and controllable operating costs, enabling them to offer essential livelihood goods at lower prices. This allows them to precisely serve price-sensitive groups, low-income populations, and consumers with temporary or immediate needs. Moreover, because such low-cost, essential demand is often difficult for formal commerce to cover—and is therefore recognized by formal business operators—the presence of street vendors contributes to a layered complementary structure within community consumption. Specifically, it combines high cost-performance essential goods with standardized, higher-quality offerings, thereby enhancing the inclusiveness and accessibility of community commerce and covering multiple tiers of consumption demand.

3.4 Scenario Complementarity: Enhancing Consumption Convenience

Urban street vendors enhance the applicability of consumption scenarios through rapid spatial mobility. Formal commerce is typically concentrated in fixed stores or commercial spaces, involving physical entry points and spatial thresholds. By contrast, street vendors can flexibly position themselves at community entrances, road intersections, metro stations, and areas surrounding schools—key nodes of pedestrian flow. This enables the creation of highly accessible consumption spaces characterized by zero distance, no entry barriers, and reachability within approximately 30 seconds on foot. For residents who prefer not to enter shopping malls or who seek quick purchases, street vendors provide a more convenient alternative. This shifts consumption behavior from “purpose-driven store entry” to “spontaneous, incidental purchasing,”

thereby further expanding the scope and conversion of community consumption scenarios. Huang Gengzhi, Xu Kongdan, and Xue Desheng [5] conducted a study on the agglomeration and complementary relationship between street vendors and surrounding formal shops. Street vendors are often regarded as illegal economic actors that disrupt fair market competition and are thus subject to complaints from formal merchants. However, the study systematically demonstrates that the relationship between the two is by no means antagonistic; rather, appropriate spatial arrangements can facilitate mutual complementarity. Empirical evidence reported by *Chongqing Daily* (2026) further illustrates this point: in Nanchuan, “time-shared vending zones” allow farmers to sell produce in designated areas during fixed periods. By February 2026, 31 such zones had been established in the urban area, providing 2,100 free vending spaces. This flexible spatiotemporal arrangement effectively resolves the longstanding tension between urban management and livelihood needs. From the perspective of spatial layout, it can thus be reasonably concluded that formal community commerce generally follows market principles and is located in areas with high population density and strong consumption capacity, while street vendors, through their high flexibility, fill the “location blind spots” of formal commerce. Similarly, from the perspective of temporal supply, the relatively fixed operating hours of formal commerce are complemented by the “time-shared” operations of street vendors, which fill temporal gaps.

The spatiotemporal complementarity mechanism essentially represents a natural and well-aligned integration of the “stability” embodied by formal commerce and the “flexibility” represented by street vendors. Chen Xuan, Ding Zhuhui, and Qi Dan et al. [6] conducted a systematic and insightful longitudinal study of the night market in Yangfan Resettlement Community in Changsha over a twenty-year period. Their findings clearly demonstrate that the regenerative development of community-based night markets contributes to activating production resources and increasing public revenue. Such growth is grounded in the dynamic openness of grassroots governance communities, which are capable of proactively and prudently balancing multiple objectives even under the pressure of comprehensive urban environmental regulation. Therefore, it can be reasonably concluded that, in the context of spatial value transformation and upgrading, a new pathway for the stable regeneration of community commerce—rooted in social relations—is gradually taking shape.

4. Urban Governance and the Governance Model of Commercial Ecosystems

When the relationship between urban street vendors and formal community commerce in a given area shifts from competition to coordinated coexistence, it signifies a transformation from a zero-sum game to a complementary and symbiotic commercial ecosystem. Such an ecosystem not only alleviates tensions in urban management but also fosters vibrant, “lived-in” consumption scenes that continuously attract residents and tourists, thereby enhancing the overall appeal of the area.

The phenomenon in 2025 in which the “Fried Chicken Vendor” (popularly known as *Jipai Ge*) attracted a surge of tourists to Jingdezhen serves as an example of the mutual reinforcement between urban governance models and commercial ecosystem transformation. Rather than adopting a one-size-fits-all prohibition policy, the local government implemented flexible measures, including the scientific designation of vending zones, prudent issuance of business permits, and strengthened food safety supervision, thereby incorporating street vendors into a standardized regulatory framework. In this process, the vendor himself gradually transformed from a participant in the informal economy into a more formalized business entity characterized by brand awareness, quality orientation, and a stable customer base. This transformation not only improved the sustainability of his business but also enabled him to engage in interaction and cooperation with surrounding formal commercial entities, jointly integrating into the broader urban commercial network.

This shift reflects a profound evolution in China’s urban governance philosophy—from traditional “rigid control” toward a model emphasizing “flexible inclusiveness and a balance between regulation and accommodation.” In the context of rapid urbanization, street vendors are not only important carriers of livelihood employment but also integral components of urban cultural diversity and community vitality. Through institutional innovation and management optimization, incorporating them into a regulated development framework can both safeguard urban order and public safety and stimulate the creativity of microeconomic actors, thereby achieving a win-win outcome for social governance and economic performance.

The story of *Jipai Ge* can thus be viewed as a vivid microcosm of China's urban transformation in the 21st century. It illustrates how, under a people-centered and refined governance approach, cities can cultivate a healthy commercial ecosystem through inclusive policies, enabling traditional and informal business forms to be revitalized within a regulated framework, and ultimately advancing toward a more resilient and humane path of sustainable urban development.

5. Conclusions and Implications

Street vendors and formal community commerce do not constitute a simple competitive or substitutive relationship; rather, they form a comprehensive system of functional complementarity across multiple dimensions, including time, space, product categories, and pricing. The realization of this complementary mechanism hinges on recognizing the legitimacy and value of street vendors as part of the informal economy, and on promoting a shift in urban governance from "exclusionary control" to "inclusive governance." This includes adopting flexible management instruments such as designated vending zones and "time-shared" vending areas, thereby providing informal economic actors with legitimate and orderly spaces for operation. In this way, a governance model integrating urban management and commercial ecosystems can be constructed, contributing to the advancement of China's urbanization and modernization.

Looking ahead, urban governance should proactively and systematically explore mechanisms that integrate institutionalization, refinement, and flexibility. At the planning level, street vendors should be formally incorporated into the overall layout of community commercial systems, with their indispensable role in urbanization clearly recognized. At the regulatory level, flexible time-based licensing systems for informal economic activities should be designed, alongside strict supervision of safety and hygiene standards to enhance the overall quality of the informal economy. At the community level, efforts should be made to promote interaction between formal businesses and street vendors, facilitate reasonable sharing of customer flows, and encourage differentiated development between the two. Through such multidimensional complementarity, a symbiotic pattern of community commerce can be established, characterized by functional coordination and orderly operation. This approach not only preserves the institutional order of urban governance but also safeguards livelihood needs and stimulates the vitality of the community commercial ecosystem, ultimately fostering a community-oriented commercial environment that is convenient, green, and socially inclusive.

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House Price and Consumption Inequality in China: Micro Evidence from CFPS

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Abstract

Based on microdata from the China Family Panel Studies (CFPS) from 2010 to 2022, this paper constructs the Kakwani index to measure household consumption relative deprivation and uses a high-dimensional fixed-effects model to examine the impact of housing prices on consumption inequality. The results show that rising housing prices significantly aggravate consumption inequality, and this conclusion remains stable after a series of robustness tests. Heterogeneity analysis indicates that the unequal effect of housing prices is prominent in eastern China and the elderly group, but is not significant or even negative in central and western regions and young groups. This paper theoretically explains the transmission channels from the perspectives of wealth effect, purchase budget constraint and spatial differentiation, but does not conduct empirical mechanism tests. The conclusions provide micro evidence for the formulation of differentiated real estate regulation and consumption equity policies.

Keywords

housing prices, consumption inequality, Kakwani index

1. Introduction

Over the past few decades, China has maintained a relatively high economic growth rate. However, at the same time, the inequality in the distribution of residents' income and consumption has been significant [1]. Income inequality and consumption inequality in China are at a relatively high level and have shown a significant upward trend for a considerable period of time [2]. According to the latest official statistics, the per capita disposable income of urban residents was 28,844 yuan in the first half of the year, while that of rural residents was 11,936 yuan. Meanwhile, the per capita consumption expenditure of urban residents was 17,545 yuan, while that of rural residents was 9,733 yuan [3]. By observing the two indicators, it is not difficult for us to find that there is a significant gap in both per capital disposable income and per capital consumption between urban and rural areas. According to statistics released by the National Bureau of Statistics in 2017, China's income Gini coefficient fluctuated between 0.462 and 0.491 from 2003 to 2016, all above the international warning red line of 0.4, indicating that income inequality and consumption inequality have long existed in China.

In comparison with many developed economies, the wealth structure of Chinese residents has a prominent feature: household wealth is highly concentrated in housing assets, and the degree of household wealth

inequality is much higher than that of income inequality. Based on the data research of CFPS in 2012, the bottom 50 percent of households held only about 8 percent of the total wealth, while the top 1 percent of households held more than one-third of the total wealth [4]. Further research has found that the proportion of housing assets in family wealth is close to 74 percent, and this indicator is close to 79 percent in urban families, which is higher than the level of 40-50 percent in European and American countries [4]. This means that in the social context of China where “real estate is regarded as the core asset of a family”, fluctuations in housing prices will not only affect the economic operation of society at the macro level, but also have a profound impact on the consumption patterns and asset levels of individual families at the micro level.

Based on our further research, we infer that there is a certain connection between the changes in housing prices and the inequality in residents’ consumption. This article will take this as a starting point to examine the relationship between housing prices and residents’ consumption inequality at the micro level. In the subsequent part, this article will use the data from the China Household Tracking Survey from 2010 to 2022 to establish an individual consumption inequality index at the micro level, and comprehensively analyze the impact of housing prices on consumption inequality and its mechanism of action.

2. Literature Review and Theoretical Analysis

2.1 Influence of House Pricing on Consumption Inequality

In the wealth structure of China, housing dominates [4]. Under such circumstances, the fluctuation of housing prices is not only a matter of the rise and fall of household assets, but also directly affects the consumption and savings behaviors of households. Chen et al. (2020) utilized microdata such as the China Household Finance Survey to study the relationship among housing wealth, income and consumption, and found that an increase in housing wealth would significantly enhance the household consumption level [5]. Li and Zhang (2021) utilized a series of cross-border macro data to estimate the elasticity between housing wealth and consumption [6]. They also reached the conclusion that housing wealth promotes consumption and pointed out that the elasticity of housing wealth in China is relatively higher than that in other sample countries [6]. These studies collectively indicate that in China, the main channels for preserving and accumulating wealth are concentrated in investment in the real estate sector. For residents with a large number of properties, high housing prices mean an expansion of family assets, and their propensity to consume also expands accordingly. Conversely, for residents with few or no properties, the expansion of housing prices has increased the cost of obtaining properties for them, forcing their propensity to consume to decline.

At the mechanism level, Painter et al. (2022) further used urban household panel data to estimate the marginal propensity to consume housing wealth and found that for every 1% increase in housing wealth, consumption increased by approximately 0.14% [7]. This study holds that housing is a precautionary savings channel: families with more housing assets have less concern about future uncertainty and are more willing to reduce precautionary savings and increase current consumption [7]. From the perspective of macro data, this means that the uneven distribution of housing assets will cause different families to adjust their consumption to different magnitudes under risk shocks, thereby affecting consumption inequality.

On the other hand, a rise in housing prices does not always mean an increase in consumption, and its impact on different types of families is highly heterogeneous. Waxman et al. (2020) based on the national credit card and debit card transaction data and combined with the fluctuations of urban housing prices, found that when urban housing prices rise, residents, especially potential home buyers with no property, will significantly reduce non-housing consumption expenditures to accumulate the down payment for purchasing a house [8]. Estimates suggest that a 10% increase in house prices could lead to a decline of approximately 9% in non-housing consumption [8]. This research indicates that high housing prices, by raising the threshold for home purchase and imposing heavier budget constraints, impose greater pressure on homeowners and highly leveraged families in terms of consumption.

Housing constraints, combined with population mobility and the process of urbanization, will also affect inequality through space. Fang and Huang (2022) constructed a quantitative equilibrium model including internal migration and housing supply constraints and found that a large inflow of population to high-productivity cities pushed up housing prices and rents in core cities under the background of land and housing supply constraints [9]. Overall income inequality within cities is significantly positively correlated with net

population inflow [9]. Local residents benefit from high housing prices through property appreciation and rental income, while the migrant population flowing into the city has to bear high living costs and high rents, and their consumption capacity is relatively limited. This indicates that high housing prices and housing constraints not only alter the average consumption level of cities but also create differences in consumption levels among different groups within cities.

Theoretically, Etheridge (2019) constructed a model of housing price shocks and consumption inequality [10], emphasizing the heterogeneity of housing ownership status, leverage ratios, and liquidity constraints: Rising house prices will increase the value of housing assets, but the impact on highly leveraged homeowners, low-leveraged multi-homeowners and homeowners without a home is completely different. Positive shocks to house prices usually lead to an increase in consumption inequality [10]. Zhao (2015) explained from a long-term perspective that in an environment where alternative assets are insufficient, housing will become a rational value storage tool for investors [11]. High-income and early entry groups can achieve multiple accumulative wealth over the long term through multiple houses, further widening the wealth gap and potential consumption gap [11].

Based on the above-mentioned literature, it can be seen that the impact of housing prices on the economy and household behavior includes not only the significant influence on residents' consumption propensity due to the high correlation between assets and housing prices on the whole, but also the restrictive effect on the consumption propensity of a large number of homeless residents through constraints in aspects such as budget, migration and housing supply. This provides the necessary theoretical basis and practical motivation for the subsequent microscopic research of this article.

2.2 Measurement for Consumption Inequality

Before formally studying housing prices and consumption inequality, this paper needs to clarify how to characterize and measure the differences in "consumption".

At the macro level, in the study comparing China and India, Grad'in and Wu (2020) utilized indicators such as the Gini coefficient of income and consumption and found that the level of consumption inequality in China has remained at a relatively high position for a long time and has shown an upward trend for a considerable period after the reform and opening up [2].

At the micro level, there are already various inequality and relative deprivation indices based on the individual or family level in the academic circle. The traditional approach is to directly use indicators such as the Gini coefficient or the Thiel index, which have good statistical characteristics, but their explanations are more inclined towards "the degree of dispersion of the overall distribution". To better describe the gap between an individual and the average social level, this paper considers it from the perspective of the theory of relative deprivation. Yitzhaki (1979) proposed a relative deprivation index based on cumulative distribution and average difference to measure the average gap between an individual and those who are "richer" than themselves [12]. However, this index has certain limitations in terms of normalization and dimensionless nature. Kakwani (1984) proposed the relative deprivation curve and related indices on this basis, redefining the degree of deprivation, which enables the indicators to be normalized to the interval of [0,1] under certain conditions, making it more convenient for comparison among different samples [13]. In the Chinese context, Jiang et al. (2023) introduced Kakwani's idea of relative deprivation into the measurement of household consumption inequality [14]. This study utilized the three phases of CFPS data from 2014 to 2018 to construct the Kakwani index of consumption at the household level, and used this as the dependent variable to investigate the impact of e-commerce development on consumption inequality [14]. This study found that the popularization of e-commerce can significantly reduce household consumption inequality on the whole, and the improvement effect is particularly obvious for vulnerable groups such as the elderly and families with low educational attainment [14]. This approach provides us with inspiration and guidance for using the Kakwani index to depict consumption inequality on the same data source.

2.3 Hypothesis Setting

By analyzing the existing literature on the impact of housing prices on the economy and household behavior, as well as the review of the characterization and measurement of consumption inequality, two directions of understanding are obtained.

Firstly, starting from the wealth effect, in the context of China, where housing assets account for the majority of household wealth, the rise in housing prices will increase the nominal wealth of residents in households with existing housing and enhance their consumption level through reducing precautionary savings, improving consumption propensity, etc. [5, 6, 7]. However, housing assets are unevenly distributed among residents [4], and a considerable number of families either have no housing or own housing but have a relatively high leverage ratio. For these families, the increase in house prices is more reflected in the raised threshold for home purchase and the increased debt pressure, thereby leading them to compress non-housing consumption [8]. Therefore, the impact of rising house prices on consumption among different households is significantly heterogeneous and may push up consumption inequality overall [9, 10].

Secondly, from the perspectives of structure and space, population migration, constraints on land and housing supply will further amplify the impact of housing prices on consumption inequality. The model of Fang and Huang (2022) shows that economically developed cities have absorbed a large number of inflow population under the condition of limited land supply, pushing up housing prices and rents [9]. Local residents benefit from property appreciation and rental income, while the migrant population bears high costs and low consumption capacity. This structure implies that the rise in housing prices not only widens the gap in asset distribution but also translates into consumption inequality through differences in living costs and consumption budgets. Zhao (2015)'s rational housing bubble framework indicates that in the long term, high-income and early home-buying groups further accumulate wealth through multiple houses, thereby widening the gap between housing prices and residents' wealth levels and potential consumption [11].

As a result, the research perspective of this article will be significantly different from that of most existing literature. Most of the existing research on housing prices and inequality is based on aggregated data at the macro or urban level, and it is difficult to reveal the detailed differences in consumption behavior among different families. Meanwhile, some studies on consumption inequality that utilize national microdata, such as CFPS, mainly focus on factors like the development of e-commerce or digital inclusive finance. Although they have begun to adopt relative deprivation indicators like Kakwani, the core explanatory variable is not the factor of "house prices". Therefore, this paper will simultaneously observe "housing" and "consumption inequality based on the Kakwani index" at the household level, and directly examine the impact of housing price changes on consumption distribution among different households based on CFPS microdata, thereby attempting to fill the research gap in the field of the impact of housing prices on consumption inequality at the micro level.

Therefore, based on the existing research and logistic analysis, this paper makes the hypothesis:

H1: Individuals facing higher housing prices experience correspondingly greater consumption inequality.

3. Research Data and Method

3.1 Variable Selection

3.1.1 Kakwani Index

According to relative deprivation theory, the higher an individual's consumption level within a specific group, the lower their degree of relative deprivation, manifested as a reduction in consumption inequality. Based on existing research, this study uses other individuals within the same county as the selected individual as a reference group, then compares respondents' total consumption expenditures with those of other individuals in their county, using the Kakwani index to measure individuals' consumption relative deprivation. In this case, higher values indicate greater consumption inequality.

To be more specific, suggests that the mean of individuals' consumption in a certain county is $\bar{x}$, and we rank the consumption from smallest to largest, define the consumptions which are larger than the mean $\bar{x}$ to be x_i^+ , the proportion of observations exceeding the consumption level of our selected individual x_i relative to the total number of observations to be $\#x_i$. Therefore, we construct the formula of the Kakwani index to be [14]:

$$\text{Kakwani}(x, x_i) = \frac{1}{n} \sum_{j=i+1}^n (x_j - x_i) = \vartheta_{x_i}^* \left[\frac{x_i^+ - x_i}{\bar{x}} \right] \quad (1)$$

3.1.2 House Price

This variable represents the average sales price of commercial housing in region i at time t . The data originates from the regional housing sales tables published by the China Stock Market & Accounting Research (CSMAR) database, calculated by dividing the total commercial housing sales value by the total commercial housing sales area.

3.1.3 Control Variables

At the individual's level, we control the individual's age (Age), sex (Gender), educational level (Education), and household registration (Hukou). At the household level, this study controls the household assets (FA), the household expenditure (FE), the household debt (FD), and the region the household is located in (Region).

3.2 Data Source and Processing

Individuals' and households' detailed data are collected from the China Family Panel Studies (CFPS), which is a nationwide longitudinal survey project with extensive sample coverage across 25 provinces (autonomous regions and municipalities) in China. It provides researchers with microdata on Chinese households' economic activities, educational dynamics, population health, and other social information. The CFPS project conducted preliminary pilot surveys in Beijing, Shanghai, Guangdong, and other locations in 2008 and 2009 to test the validity of survey methods and instruments. Following two years of testing, the project commenced full-scale implementation in 2010. After the 2010 baseline survey, all household members and their future offspring—whether biological or adopted—were enrolled in CFPS's long-term follow-up cohort. The project has given us seven updates from 2010, and the latest report is the 2022 CFPS database. This longitudinal design enables researchers to conduct in-depth analyses of how Chinese households' micro-level behavioral responses to economic dynamics, such as the fluctuation of house prices.

In this research, the dataset is processed by dropping the observations with the key variables missing to ensure consistency and completeness of data. Meanwhile, those observations are dropped whose total income, total expenditure, or total assets are negative to eliminate the disturbance created by the extreme values. Finally, the continuous variables are applied a logarithmic transformation.

3.3 Research Methods

To examine how the fluctuation of house prices affects the consumption inequality, this paper establishes the model:

$$CI_{it} = \beta_0 + \beta_1 \cdot \text{HousePrice}_{it} + X'_{it}\eta + \alpha_i + \delta_t + \varepsilon_{it} \quad (2)$$

The subscript i implies individual, and t stands for time. The explained variable CI_{it} stands for the consumption inequality; the explanatory variable HousePrice_{it} stands for the regional average house price. X'_{it} indicates the control variables; α_i represents the individual fixed effect, δ_t represents the year fixed effect, ε_{it} represents the random error term. The coefficient β_1 captures the causal effect of housing price on consumption inequality. More specifically, if $\beta_1 > 0$, it indicates that individuals exposed to higher housing prices experience correspondingly greater consumption inequality. If $\beta_1 < 0$, it indicates that the decline in housing prices has exacerbated consumption inequality.

4. Results

4.1 Descriptive Statistics

Table 1 presents the descriptive statistics for each variable after preliminary processing. The mean value of the Kakwani index, which reflects individual consumption inequality, is 0.1706, with a standard deviation of 0.0354. Before taking the logarithm, the mean of housing prices was 0.7294, with a standard deviation of 0.5140, indicating significant variation in housing prices. Due to missing data in certain variables, the panelized CFPS data constitute unbalanced panel data. In descriptive statistics, variables such as household assets and expenditures may be affected by negative values. This paper has excluded illogical negative values.

Table 1: Descriptive statistics

Variable	N	Mean	SD	Min	Max
Kakwani Index	233,650	0.1706	0.0354	0	0.4214
House Price	238,076	0.7294	0.5140	0.1663	4.9301
Age	235,461	3.4064	0.8651	0	4.6540
Gender	235,261	0.5045	0.5000	0	1
Education	190,033	2.6504	1.3837	1	8
Hukou	233,518	0.2538	0.4352	0	1
Family Assets	235,473	11.8131	2.2674	0	18.1992
Family Expenditures	235,473	10.6601	0.9531	0	15.9090
Family Debts	235,473	1.9676	4.2912	0	15.8950

Note: This table reports the number of observations (N), mean, standard deviation (SD), minimum (Min), and maximum (Max) of the main variables.

4.2 Benchmark Regression Model Estimation

Table 2 presents the benchmark regression results. Columns (1) and (2) display regression results with only the dependent variable and core explanatory variables, respectively. Column (1) shows t-statistics calculated using robust standard errors based on estimated coefficients and corresponding significance levels, while Column (2) presents t-statistics and significance levels calculated using cluster-robust standard errors at the household level. Columns (3) and (4) present regression results incorporating individual-level control variables. Column (3) displays t-statistics calculated using robust standard errors based on estimated coefficients and corresponding significance levels, while column (4) shows t-statistics calculated using household-level cluster-robust standard errors and significance levels. Columns (5) and (6) present regression results incorporating household- and region-level control variables. Column (5) displays t-statistics and corresponding significance levels calculated using robust standard errors based on estimated coefficients, while Column (6) shows t-statistics and significance levels calculated using cluster-robust standard errors at the household level. The model results presented in Column (6) are selected as the benchmark regression model in this paper.

Table 2: Benchmark regression results

	(1) CI	(2) CI	(3) CI	(4) CI	(5) CI	(6) CI
House Price	-0.0488*** (-5.68)	-0.0488*** (-2.78)	-0.0303*** (-3.31)	-0.0303* (-1.90)	0.0964*** (10.78)	0.0964*** (6.35)
Age			-0.9239*** (-18.82)	-0.9239*** (-14.70)	-0.7690*** (-16.03)	-0.7690*** (-12.49)
Gender			0.0211 (0.51)	0.0211 (0.50)	0.0280 (0.74)	0.0280 (0.73)
Education			-0.0376*** (-7.67)	-0.0376*** (-6.76)	-0.0356*** (-7.36)	-0.0356*** (-6.49)
Hukou			-0.0456*** (-4.67)	-0.0456*** (-3.97)	-0.0425*** (-4.36)	-0.0425*** (-3.72)
Family Assets					0.0004 (0.47)	0.0004 (0.32)
Family Expenditures					-0.0177*** (-8.12)	-0.0177*** (-5.06)
Family Debts					-0.0027*** (-6.35)	-0.0027*** (-3.87)
Region					0.7585*** (17.04)	0.7585*** (10.05)
Constant	0.0077*** (7.78)	0.0077*** (6.32)	3.5758*** (19.65)	3.5758*** (15.40)	1.7347*** (8.24)	1.7347*** (5.79)
Individual FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Clustered SE	N	Y	N	Y	N	Y
Observations	219,823	219,823	175,773	175,773	175,773	175,773
R-squared	0.835	0.835	0.834	0.834	0.839	0.839

Robust t-statistics in parentheses. Clustered SE are at the household level (columns 2, 4, and 6).

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 2 shows that a 1 percent increase in housing prices raises the Kakwani index by 0.0964, meaning the sum of consumption gaps between an individual and those with higher consumption levels increases by 9.64 percent, thereby aggravating relative deprivation in individual consumption. This further demonstrates that rising housing prices significantly exacerbate individual consumption inequality. Discussing individual characteristics, age has a significant negative impact on consumption inequality, indicating that consumption inequality among the elderly is significantly lower than among middle-aged and young groups.

Educational attainment also has a significant negative impact on consumption inequality, suggesting that individuals with higher skills and education experience smaller income and consumption differentiation, with less pronounced inequality. Gender has no significant effect on consumption inequality. At the household level, household expenditure and debt exert a significant negative influence on consumption inequality, indicating that higher household expenditure and debt correlate with lower consumption inequality.

4.3 Robustness Analysis

To ensure the reliability and validity of our benchmark regression results, the study conducts a series of robustness checks. First, the paper examines whether the findings are driven by specific sample selections or outlier observations. Second, the results are tested for structural stability by investigating whether the COVID-19 pandemic induced a significant change in the relationship between housing prices and consumption inequality.

4.3.1 Robustness Check

Before conducting the structural stability test, the paper conducts a series of robustness checks to verify that the positive association between local housing prices and household-level consumption inequality is not driven by sample composition or extreme observations. The results are shown in Table 3.

Table 3: Robustness Check Regression Results

	(1) CI	(2) CI	(3) CI
House Price	0.1008***	0.0962***	0.0883***
Age	(5.14)	(6.14)	(4.60)
	-1.1470***	-0.7734***	-1.0100***
	(-11.77)	(-13.11)	(-9.00)
Gender	0.0405	0.0255	0.0119
Education	(0.75)	(0.68)	(0.38)
	-0.0271***	-0.0323***	-0.0308***
Hukou	(-3.33)	(-6.15)	(-4.18)
	-0.0412***	-0.0416***	-0.0398***
Family Assets	(-2.83)	(-3.76)	(-3.01)
	-0.0002	0.0005	-0.0013
	(-0.11)	(0.35)	(-0.83)
Family Expenditures	-0.0188***	-0.0193***	-0.0212***
	(-4.53)	(-5.67)	(-5.14)
Family Debts	-0.0023***	-0.0026***	-0.0025***
	(-3.04)	(-3.91)	(-3.28)
Region	0.7825***	0.7566***	0.7485***
	(8.65)	(10.56)	(8.24)
Constant	3.1157***	1.7642***	2.7136***
	(7.18)	(6.18)	(5.60)
Sample restriction	Job = 1	Winsorized variables	22 < Age < 65
Individual FE	Y	Y	Y
Year FE	Y	Y	Y
Clustered SE	Y	Y	Y
Observations	116,398	175,773	124,269
R-squared	0.842	0.849	0.847

Robust *t*-statistics in parentheses. All regressions include individual and year fixed effects and cluster standard errors at the household level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

First, restricting the sample to individuals who are currently employed (job = 1) leaves the main result virtually unchanged (shown as column 1): the coefficient on standardized log housing prices remains positive and highly significant, and its magnitude is very close to that in the baseline specification. Second, the main continuous variables (consumption inequality index, housing prices, age, education, and household income components) are winsorized at the 0.5th and 99.5th percentiles to mitigate the influence of outliers (shown as column 2). The estimated effect of housing prices is again positive, statistically significant, and similar in size to the baseline estimate. Third, when the paper restricts the sample to prime-age individuals between 22 and 65 years old, thereby excluding very young and very old observations, the coefficient on housing prices remains robustly positive and significant (shown as column 3). Across all these alternative samples and specifications, the signs and magnitudes of the control variables are also broadly stable, reinforcing the view of our main finding. This implies that higher local housing prices are associated with higher consumption inequality is not an artifact of a particular sample choice or a few extreme values.

4.3.2 Structural Stability Test

The structural stability of the econometric model is a critical prerequisite for reliable estimation. Major exogenous shocks, such as the COVID-19 pandemic that began in late 2019, could potentially alter the intrinsic relationship between housing prices and consumption inequality by affecting macroeconomic operations and household expectations. To test whether the regression coefficients differ significantly before and after the pandemic, the study applies the Chow test logic by introducing a time dummy variable and an interaction term into the benchmark model. The specific model specification is as follows:

$$CI_{it} = \beta_0 + \beta_1 \text{Houseprice}_{it} + \beta_2 \text{Post2019}_t + \beta_3 (\text{Houseprice}_{it} \times \text{Post2019}_t) + X'_{it} \eta + \alpha_i + \delta_t + \varepsilon_{it} \quad (3)$$

Where Post2019_t is a dummy variable that takes the value of 1 for the year 2019 and subsequent years, and 0 otherwise. The coefficient of the interaction term, β_3 , captures the structural change in the impact of housing prices on consumption inequality following the outbreak of the pandemic.

The results of the structural stability test are reported in Table 4. The coefficient of the core explanatory variable, Houseprice , is 0.0896 and remains statistically significant at the 1% level, which is consistent with our benchmark findings. Crucially, the coefficient of the interaction term ($\text{Houseprice} \times \text{Post2019}$) is 0.0055 with a p-value of 0.463. Furthermore, the F-test for the interaction term yields an F-value of 0.54 ($p \approx 0.46$), failing to reject the null hypothesis that the coefficients are identical across the two periods.

These results suggest that the COVID-19 pandemic did not cause a significant structural break in the relationship between housing prices and consumption inequality. We attribute this stability to two primary factors. First, housing assets account for a substantial proportion of Chinese household wealth, creating a “rigid” wealth effect that is not easily altered by short-term external shocks. Second, effective economic stabilization policies implemented during the pandemic helped buffer the shock to household income and consumption. Therefore, the exacerbating effect of housing prices on consumption inequality appears to be a robust structural law rather than a temporary phenomenon driven by specific events.

Table 4: Chow-type structural break test around 2019

	(1) CI
HousePrice	0.0896*** (4.03)
HousePrice × Post2019	0.0055 (0.73)
Individual FE	Y
Year FE	Y
Clustered SE	Y
Observations	175,773
R-squared	0.839
Chow F-test for Post2019 break	0.54
p-value	0.463

The bottom rows report the F-statistic and p-value from the Chow-type test of parameter stability around 2019, based on the null hypothesis that the coefficient on the interaction term is equal to zero.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.4 Heterogeneity Analysis

The benchmark regression results establish that, on average, rising housing prices exacerbate consumption inequality. However, this aggregate effect may mask significant heterogeneity across different regions and demographic groups. In this section, this paper stratifies the sample by region (East, Central, and West) and age (Young, Middle-aged, and Elderly) to investigate how the impact of housing prices on consumption inequality varies across varying levels of economic development and lifecycle stages.

Table 5: Heterogeneity analysis by region and age

	(1) CI	(2) CI	(3) CI	(4) CI	(5) CI	(6) CI
House Price	0.0947*** (5.98)	-0.1565*** (-2.77)	-0.1391*** (-3.62)	-0.0805*** (-3.06)	-0.0371 (-1.39)	0.0774*** (4.09)
Age	-0.7065*** (-6.85)	-0.6214*** (-6.04)	-0.5935*** (-7.81)	0.4000** (2.54)	-0.1468 (-0.51)	-0.3431 (-0.89)
Gender	0.0486 (1.12)	0.0222 (0.27)	-0.0176 (-0.37)	-0.0002 (-0.00)	0.0413 (0.75)	0.0556 (0.89)
Education	-0.0313*** (-3.62)	-0.0214** (-2.48)	-0.0493*** (-5.56)	-0.0564*** (-6.48)	0.0011 (0.13)	-0.0007 (-0.08)
Hukou	-0.0344** (-2.23)	-0.0483** (-2.39)	-0.0495** (-2.04)	-0.0583** (-2.13)	-0.0319** (-2.15)	-0.0216 (-1.58)
Family Assets	-0.0004 (-0.21)	-0.0022 (-0.83)	0.0032* (1.69)	0.0072** (2.31)	-0.0017 (-1.17)	-0.0022 (-1.45)
Family Expenditures	-0.0153*** (-2.69)	-0.0140** (-2.28)	-0.0174*** (-3.93)	-0.0327*** (-4.49)	-0.0147*** (-3.46)	-0.0076* (-1.67)
Family Debts	-0.0011 (-0.99)	-0.0038*** (-2.75)	-0.0012 (-1.57)	-0.0021* (-1.66)	-0.0022*** (-2.83)	-0.0011 (-0.95)
Constant	2.6166*** (6.63)	2.5075*** (6.45)	2.7834*** (9.65)	-0.8705* (-1.73)	0.7479 (0.67)	1.5623 (0.95)
Individual FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Clustered SE	Y	Y	Y	Y	Y	Y
Observations	70,404	52,323	51,953	53,471	73,377	41,549
R-squared	0.830	0.848	0.898	0.771	0.887	0.915

Robust *t*-statistics in parentheses. All specifications include individual and year fixed effects and cluster standard errors at the household level.

Columns (1)–(3) report results for eastern, central, and western regions, respectively. Columns (4)–(6) report results for different age groups ($\text{age} \leq 35$, $35 < \text{age} < 60$, and $\text{age} \geq 60$).

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.4.1 Regional Heterogeneity

China's real estate market and economic development exhibit substantial spatial disparities. The study categorizes the sample into Eastern, Central, and Western regions to examine these geographical differences.

The first three columns of Table 6 report the regression results for regional heterogeneity. We observe a striking divergence in the relationship between housing prices and consumption inequality across regions.

As shown in column 1, in the economically developed Eastern region, the coefficient of housing prices is 0.0947 and statistically significant at the 1% level. This result, consistent with the full-sample benchmark, suggests that in the East, housing ownership is imbalanced, due to the higher housing price; the houses are owned by a small group of people, while the majority are renters. Rising prices significantly widen the wealth gap between homeowners and non-homeowners, thereby exacerbating consumption inequality through the wealth effect.

As shown in columns 2 and 3, conversely, the coefficients for the Central and Western regions are -0.1565 and -0.1391, both significantly negative. This indicates that in these developing regions, rising housing prices are associated with a reduction in consumption inequality. A plausible explanation is that housing price appreciation in inland provinces is closely tied to the urbanization process and general income growth. Moreover, in these areas, house ownership is more balanced. With the majority of people having housing assets,

the rise in housing prices will generally stimulate consumption. The development of the real estate market often accompanies infrastructure improvement and economic opportunities that benefit lower-income groups, thereby narrowing the consumption gap.

4.4.2 Age Cohort Heterogeneity

Housing plays different roles at different stages of the life cycle. We further divide the sample into three age cohorts: Young (age ≤ 35), Middle-aged ($35 < \text{age} < 60$), and Elderly (age ≥ 60).

The last three columns of Table 6 present the results by age group, revealing distinct life-cycle patterns. First, as shown in the fourth column, for the Young cohort, the coefficient is -0.0805, significantly negative. This suggests that among younger generations, higher housing prices are associated with lower consumption inequality. This counterintuitive finding can be attributed to a “selection effect”: young people who manage to stay and work in high housing price cities tend to possess similar levels of high human capital and income potential. Furthermore, many people in this group are in a transitional phase, relying on parental support, which causes the wealth effects brought by the housing to be less significant.

Second, as shown in the fifth column, for the Middle-aged cohort, the coefficient is -0.0371 and is insignificant ($p > 0.1$). This group faces conflicting forces: existing homeowners benefit from the wealth effect, while they still have other assets and a reliable income, which have a greater impact on their consumption. These opposing mechanisms partially offset each other, resulting in a weak negative correlation and thus are not significant.

Finally, as shown in the last column, for the Elderly cohort, the coefficient is 0.0774 and significantly positive at the 1% level. This indicates that rising housing prices significantly exacerbate consumption inequality among the elderly. For this demographic, housing is often the primary component of accumulated wealth. Elderly homeowners enjoy increased consumption capacity through property appreciation, while non-homeowners rely on fixed pensions and face rising living costs. Thus, housing price inflation acts as a powerful “amplifier” of inequality within the elderly population.

5. Conclusion

5.1 Research Summary and Main Findings

As China’s economy transitions into a stage of high-quality development, the structural transformation of the housing market and residential consumption has become a critical lens for understanding economic operations and social welfare. Based on micro-level panel data from the China Family Panel Studies (CFPS) spanning 2010 to 2022, this paper constructs a household-level Kakwani index to measure consumption inequality and utilizes a high-dimensional fixed effects model to identify the net impact of regional housing price fluctuations.

Unlike existing literature that focuses on macro-level Gini coefficients or average consumption levels, this study emphasizes micro-individual relative deprivation. The primary finding is that rising housing prices significantly exacerbate residential consumption inequality. The benchmark regression indicates that for every 1% increase in regional housing prices, the household Kakwani index rises by approximately 0.0964 units. This implies that in the context where “housing is wealth,” housing price appreciation does not uniformly improve welfare; instead, it widens the relative gap between high-consumption and low-consumption groups.

To ensure the reliability of this conclusion, this study conducted a series of rigorous tests. Results remained robust across various specifications of control variables and clustering methods. And the Chow test using 2019 as a breakpoint showed an interaction term coefficient of only 0.0055 ($p = 0.463$) and an F-value of 0.54, confirming that the impact of housing prices on inequality is a structural law determined by household wealth structure rather than a short-term fluctuation driven by the COVID-19 pandemic.

5.2 Heterogeneity Analysis and Mechanism Discussion

While the aggregate analysis reveals a positive correlation, the heterogeneity analysis uncovers distinct divergences across regions and lifecycle stages.

5.2.1 Regional Divergence

The distributional effect of housing prices exhibits a clear dichotomy between the “Eastern Wealth Effect” and the “Central/Western Development Effect.” Empirical results show that in the economically developed Eastern region, rising housing prices significantly exacerbate inequality ($\beta = 0.0947$, $t = 5.98$). In contrast, in the Central ($\beta = -0.1565$) and Western ($\beta = -0.1391$) regions, housing prices are negatively correlated with inequality. This divergence stems from distinct regional differences: in the highly developed East, real estate ownership is not balanced, which serves as a key wealth stratifier; whereas in the Central and Western regions, price increases often coincide with rapid urbanization and industrial upgrading, where the inclusive dividends of development shared by a more balanced real estate ownership outweigh the asset differentiation effect.

5.2.2 Age Misalignment

The study observes significant intergenerational differences. For the elderly (age ≥ 60), rising housing prices significantly exacerbate inequality ($\beta = 0.0774$), as housing assets constitute the bulk of their accumulated wealth, creating a divide between property owners and renters. Conversely, for the youth (age ≤ 35 , $\beta = -0.0805$) and middle-aged groups (35-60, $\beta = -0.0371$), high housing prices are associated with reduced inequality. Two similar phenomena point to different possible explanations. For the youth, the counterintuitive finding can be attributed to the “selection effect”: young people who are able to settle and work in high-price housing cities often possess similar levels of high human capital and income potential. Moreover, the parental financial support also masks the consumption gap. Meanwhile, for the middle-aged, the combined effect of the wealth effect is offset by their more diverse assets distributions and their reliable incomes, resulting in a negligible outcome.

5.3 Policy Implications

Based on these findings, the study argues that policy formulation must shift from aggregate control to structural optimization

5.3.1 Supply-Side Structural Reform

Given that housing bubbles exacerbate the wealth gap, the government should accelerate the development of the long-term rental market and affordable housing. For new citizens and youth squeezed by high prices, “rent-and-purchase” concurrent strategies are essential to sever the transmission chain where housing costs crowd out consumption.

5.3.2 Differentiated Regional Policies

Policies should avoid a “one-size-fits-all” approach. In the East, the focus should be on using tax instruments to smooth the wealth distribution effect of assets. In Central and Western regions, policymakers should objectively view the urbanization process accompanying price increases and ensure that vulnerable groups continue to share development dividends.

5.3.3 Age-Appropriate Financial Mechanisms

To address asset differentiation among the elderly, we recommend exploring “reverse mortgage” models to help asset-rich but cash-poor elderly homeowners release consumption capacity. Simultaneously, strengthening public pension and medical security systems independent of housing assets is crucial to prevent non-homeowning elderly from falling into a consumption trap.

5.4 Limitations and Future Outlook

This study has certain limitations. First, the Kakwani index measures relative inequality and may not fully capture changes in absolute welfare levels. Second, limited by data availability, the study relied on regional average sales prices, which cannot distinguish quality differences within cities.

Future research could expand in three dimensions: (1) matching high-frequency, fine-grained real estate transaction data with micro-household surveys to identify financial transmission channels more precisely; (2) utilizing quasi-natural experiments (e.g., purchase restrictions) to reinforce causal identification; and (3)

extending the analysis beyond consumption to broader welfare dimensions such as intergenerational mobility and subjective well-being.

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The Policy of Separate R&D Expense Allocation and Capital Market Stability: Empirical Evidence Based on Stock Liquidity

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Abstract

Taking the 2018 revision by the Ministry of Finance regarding the “separate listing of R&D expenses” as the research context, this study employs a difference-in-differences (DID) model to examine the impact of separate R&D expense listing on stock liquidity fluctuations in the capital market. The results indicate that the separate R&D expense listing policy significantly improves corporate stock liquidity, and this conclusion remains valid after robustness tests. Mediating mechanism tests show that the policy enhances stock liquidity through two pathways: improving the comparability of accounting information and alleviating corporate financing constraints. Heterogeneity analysis reveals that the policy effect is more pronounced in small and medium-sized enterprises (SMEs) and enterprises with lower levels of external media supervision. This study provides empirical evidence for understanding the impact of accounting information disclosure policies on capital market stability, and offers references for policy optimization and corporate decision-making.

Keywords

separate listing of R&D expenses, stock liquidity, difference-in-differences model, accounting information, financing constraints

1. Introduction

Under the background of innovation-driven development strategy, enterprise innovation has become a key source of enterprise core competitiveness. Increasing R&D investment can enhance a firm's innovation performance and positively affect its market value [1, 2]. This effect is observed in both traditional and emerging enterprises, where increased R&D investment significantly promotes innovation [3]. Sustained investment in R&D ensures long-term high performance and maintains firm value [4]. Furthermore, key R&D and innovation information influences investors' decisions in the capital market. As the core indicator of the stable operation of the capital market, the level of stock liquidity can directly reflect market efficiency and resource allocation effect; while accounting information disclosure is an important bridge between enterprises and the capital market. It remains unclear whether the reporting position of this information can improve the information environment and thus affect the stock liquidity of enterprises.

Existing research indicates that accounting information on R&D expenses is not fully incorporated into the capital market, leaving investors with limited knowledge of firms' R&D activities [5]. Consequently, stock prices often fail to capture the true value created by these R&D investments, leading to an underestimation of their contribution to firm value [6, 7]. First of all, some listed firms may strategically manipulate R&D investment in response to industrial policies, and the increased R&D input through manipulation cannot increase the innovative output of the enterprise, which further weakens the ability of stock prices to accurately reflect R&D investment or misreact the R&D input information of the enterprise. Secondly, before 2018, the accounting information of R&D expenses was included in the “management expenses” and reported in the profit statement, which would lead to a large number of R&D-oriented enterprises to generate higher management expenses due to high R&D investment, which was considered low management efficiency, which would not be conducive to the capital market and investors' correct estimation of the real value of the enterprise, and thus affecting the capital market performance and stock liquidity of the enterprise.

From the firm's perspective, stock liquidity may be influenced by whether the enterprise has implemented standardized processes. Standardization enhances market vitality and can improve stock liquidity by facilitating the flow of resources from the factor market to the capital market [9]. Additionally, digital transformation can further enhance stock liquidity by reducing information asymmetry in accounting disclosures [10]. From the perspective of the stock trading system and accounting policies in the capital market, after the restrictions on the rise and fall of the stock trading market has been relaxed, investors have reduced herd behavior and excessive speculation, and the stock liquidity in the capital market has been improved; under the background of digitalization, investors will also take the data assets disclosed by enterprises in financial statements as an important basis for investment decision-making. At the same time, data assets also enhance investor confidence, thus improving the stock liquidity of enterprises.

In June 2018, the Ministry of Finance issued the Notice on the Revision and Issuance of the Format of the 2018 General Enterprise Financial Statement, which stipulates that the expensed R&D expenditure should be separated from the “management expenses” and listed separately in the profit statement as “R&D expenses”, so that investors can directly read the profit statement to understand the amount of R&D expenses (hereinafter referred to as the “R&D Expense Separate Policy”). However, after the release of the policy, there is no conclusion on whether the implementation of the policy will improve the comparability of accounting information of enterprises and thus improve the liquidity of stocks. Therefore, this study examines the separate policy of R&D expenses as the scenario and employs a difference-in-differences (DID) approach to explore the impact of the separate policy of R&D expenses on stock liquidity. The main findings of this study are as follows: First, the implementation of the policy of listing R&D expenses will lead to a significant improvement in the liquidity of enterprise stocks. This study uses the double difference method to draw this conclusion using the financial statement data of listed companies from 2012 to 2018 and the stock liquidity data. After the robustness test, the conclusion is still valid, and this study finds that the separate policy of R&D expenses has a more significant effect on improving the stock liquidity of small-scale enterprises and enterprises with low media supervision. Second, this study conducted an intermediary mechanism test and found that the implementation of the separate R&D cost policy improves stock liquidity by improving the comparability of accounting information between enterprises and easing the financing constraints of enterprises.

The main contributions of this study are as follows. Theoretically, it extends the literature on the economic consequences of accounting policies by conducting a quasi-natural experiment using the 2018 R&D expenditure separate reporting policy. This study systematically examines, for the first time, the impact of changing the accounting project listing position on stock liquidity. It also addresses a gap in the literature regarding the relationship between policy efficiency and the capital market and enriches the understanding of the underlying transmission mechanism. Furthermore, it opens the “policy implementation – intermediary – policy effect” black box, providing new insights into how the quality of accounting information affects capital market efficiency. At the practical level, this study provides an empirical basis for the financial department to optimize the accounting information disclosure policy, standardize the R&D information disclosure format, and promote the reform of the accounting system. At the same time, this study also provides a path reference for high-tech enterprises to improve financing efficiency through R&D information. Enterprises can improve the asymmetry of accounting information and alleviate financing constraints by strengthening R&D information disclosure, so as to optimize the external information environment to enhance their recognition in

the capital market. This study also provides a basis for investors to use R&D cost data to reduce information interpretation and reduce investment risks.

2. Institutional Background and Research Hypotheses

2.1 Institutional Background

Enterprise Accounting Standard No. 6 - Intangible Assets issued by the Ministry of Finance in 2006 clearly defines the accounting treatment of enterprise research and development expenditure, dividing it into two categories: research stage expenditure and development stage expenditure. Among them, there is high uncertainty about whether the expenditure in the research stage will bring economic benefits to the enterprise in the future because it involves exploratory knowledge acquisition activities. Articles 7 and 8 of the guidelines clearly require that such expenditures should be fully expensed, directly included in profits and losses in the current period, and reported through the “management expenses” items in the profit statement. Expenditure in the development stage specifically refers to targeted expenditure on the transformation of early research results into design, improvement, etc. before commercial production. Only if the five capitalization conditions stipulated in Article 9 of the guidelines are met at the same time can they be recognized as intangible assets. If the capitalization conditions are not met, they still need to be treated as expenses and classified as “management expenses”.

Under this specification, the R&D expenses are nested in the “management expenses” item for a long time for profit listing, and the specific amount is only disclosed separately in the secondary detailed account of management expenses notes in the financial statements. This reporting model blurs the essential difference between R&D expenses and management expenses, resulting in the obscuring of the informational value of R&D expenses. It is difficult for investors to identify the scale and intensity of enterprise R&D investment directly from the main table, which is not conducive to its accurate assessment of enterprise innovation potential. China Accounting News launched a special analysis of this issue as early as 2016. By comparing the accounting logic and economic connotation of R&D expenses and management expenses, it proved the rationality and necessity of listing R&D expenses separately as expenses for the independent period.

In order to solve the dilemma of the above information disclosure and adapt to the needs of the national innovation-driven development strategy, the Ministry of Finance issued the Notice on the Revision and Issuance of the Format of 2018 General Enterprise Financial Statements in 2018, which made major adjustments to the format of enterprise financial statements. One of the core requirements is to separate R&D expenses from “management expenses” and list them separately as independent projects in the profit statement. The core goal of this system reform is to improve the transparency and availability of R&D information, strengthen the information transmission of R&D investment, and then guide capital market resources to innovative enterprises. The introduction of this policy has built a natural quasi-natural experimental scenario, which provides a research opportunity for the empirical test of this article.

2.2 Theoretical Analysis and Hypothesis Proposal

2.2.1 Accounting Information and Capital Market

Since it is difficult for the capital market and investors to correctly understand and recognize the R&D investment of enterprises and include it in the stock price information, the quality of accounting information disclosure and the fit of investors' information needs are particularly important. Studies have shown that high-quality accounting information can improve the phenomenon of market failure and “inferior currency expels good currency” under the scenario of information asymmetry. To improve the problems of inefficient resource allocation, insufficient investment or excessive investment of listed companies in the capital market, the infrastructure of the financial reporting and disclosure system should be improved, so as to better play the role of accounting information in capital allocation. At the same time, the accounting information voluntarily disclosed by executives of listed companies can alleviate the information asymmetry between small and medium-sized investors and institutional investors. This voluntary disclosure can improve stock liquidity. The R&D incentive policy formulated by the government will cause executives of listed companies to have the right behavior of “R&D manipulation”, which will not only reduce the R&D performance of enterprises, but also inevitably make investors fall into the trap of “R&D manipulation”

Since the implementation of the separate policy of R&D expenses in 2018, listed companies need to adjust R&D expenditure from note disclosure to separate reporting in the profit statement, which has significantly changed the efficiency of R&D information dissemination and market access. According to the theory of limited attention of investors, for technology-intensive enterprises, this change will also attract investors' attention, which will affect their investment behavior. Judging from the research results of the existing academic community, the separate reporting of R&D expenses can guide investors to pay more attention to R&D information, suppress the manipulation of R&D expenses by enterprises, improve the information value of R&D expenses, and effectively alleviate the market's misevaluation of the value of technology-intensive enterprises. So whether this change will lead to fluctuations in stock liquidity in the capital market is still unknown, so this article puts forward the following assumptions:

H1: The implementation of the R&D Expense Separate Policy will significantly improve the stock liquidity of the enterprise.

2.2.2 Accounting Information Comparability and Financing Constraints

If the above assumption H1 is established, it means that the R&D Expense Separate Policy will significantly improve the stock liquidity of the enterprise. So what is its mechanism? This study continues to study its mechanism of action. Studies have confirmed that the comparability of accounting information of enterprises will be affected by the external environment and internal governance. However, the macroeconomic system and industry environment of various enterprises in the domestic market are basically the same, so the comparability of accounting information is more affected by the enterprise level. For example, in recent years, the rapid development of digital transformation of enterprises in China has significantly improved the comparability of accounting information. So whether the comparability of accounting information is affected by the external accounting disclosure policy, and it is not yet known whether it affects stock liquidity as a transmission mechanism. This article proposes accordingly:

H2: The comparability of accounting information plays an intermediary role between the R&D Expense Separate Policy and the liquidity of enterprise stocks, that is, the "R&D Expense Separate Policy promotes the improvement of stock liquidity by improving the comparability of accounting information."

Myers and Majluf (1984), who proposed the theory of preferential financing, believe that the difference in the external financing cost of enterprises will generate financing constraints, which will hinder the innovative output of enterprises. The research of Lu Xin et al. (2013) also proposed that the financing constraints in China's high-tech industries are not conducive to R&D investment within enterprises. After the implementation of the policy of listing R&D expenses alone, this study speculates that this will reduce the information friction between technology-intensive enterprises and capital providers, thereby improving stock liquidity and promoting the efficient allocation of capital market resources. Based on the above analysis, the following assumptions are put forward:

H3: Financing constraints play an intermediary role between the R&D Expense Separate Policy and the liquidity of enterprise stocks, that is, the R&D Expense Separate Policy promotes the improvement of stock liquidity by alleviating the financing constraints of enterprises.

2.2.3 Heterogeneity Analysis

The difference in the characteristics of the enterprise itself will lead to significant heterogeneity in the implementation effect of accounting policies and regulatory systems. In terms of enterprise scale, Luo Zhengying and Duan Jiaguo (2006) pointed out that small and medium-sized enterprises face more severe financing constraints, and insufficient information disclosure is an important reason for their financing difficulties, which makes small and medium-sized enterprises more sensitive to mandatory information disclosure policies, and the marginal improvement effect brought by the policy is also more prominent. The single list of research and development expenses can effectively make up for the shortage of information disclosure of small and medium-sized enterprises, provide investors with previously missing key innovative information, more significantly alleviate market doubts, and improve their stock trading activity.

In terms of external supervision, the research of Zhang Qunzhi et al. (2025) shows that the perfection of the external governance environment will regulate the market response of enterprise behavior. Enterprises with

weak external supervision have a less perfect information environment, and the information improvement space brought by policies is more significant 错误!未找到引用源。. As a mandatory information disclosure system, the single listing of research and development costs can provide standardized information transmission channels for low-media supervision enterprises, effectively make up for the information gap caused by insufficient external supervision, and have a stronger effect on stock liquidity. These studies provide an important theoretical basis and research ideas for this article to explore the heterogeneity of policy effects from the two dimensions of enterprise scale and external media supervision. Based on this, this paper puts forward the following assumptions:

H4: The R&D Expense Separate Policy has a more significant effect on enhancing stock liquidity in small and medium-sized enterprises.

H5: The effect of the R&D Expense Separate Policy on enhancing stock liquidity is more significant in enterprises with a lower level of external media supervision.

3. Research Design

3.1 Sample Selection

The initial sample of this study comes from A-share listed companies, and the six years after the R&D expenses are listed, that is, 2018-2023, as the processing window, and the six years before the R&D expenses are listed, that is, 2012-2018 as the comparison window, and the samples are selected, and the following are excluded: (1) listed companies in the financial industry; (2) ST and *ST listed companies. After deleting the missing values, 28,425 samples were finally obtained.

In the data adopted by the institute, the data of R&D expenses from 2012 to 2017 is taken from the detailed items of management expenses in the notes of the financial statements, from the China Research Data Service Platform (CNRDS); the data of R&D expenses from 2018-2023 is taken from the profit statement, from the CSMAR database. The rest of the financial data comes from the CSMAR database. In order to avoid the influence of extreme values, this study carried out upper and lower 1% reduction treatment for all continuous variables; in order to alleviate the impact of heterovariance, this study used robust standard error to test the significance of variable coefficients; in order to alleviate the correlation impact of variables on the time series, this study also carried out company-level clustering.

3.2 Variable Definition

3.2.1 Explained Variable

Stock liquidity (Liquidity). This article draws on the research methods of Amihud and Mendelson (1986) to account for stock non-liquidity indicators (ILLIQ) according to Formula (1):

$$ILLIQ = \frac{1}{D_{i,t}} \sum_{d=1}^{D_{i,t}} \sqrt{\frac{|r_{i,t,d}|}{V_{i,t,d}}} \quad (1)$$

In the above formula, $|r_{i,t,d}|$ the rate of return of enterprise i considering cash dividend reinvestment on the d trading day of year t ; $|V_{i,t,d}|$ represents the transaction amount of enterprise i on the d trading day of year t , in units of millions of yuan, $D_{i,t}$ is the number of trading days of enterprise i in year t . Therefore, intuitively, $\frac{|r_{i,t,d}|}{V_{i,t,d}}$ represents the change in the yield caused by the transaction amount per unit of stock i on the d trading day of the t -year, after adding the total average value to it, it is an illiquidity measure. $ILLIQ_{i,t}$, The larger the value, the greater the impact of the unit transaction amount on the stock price, the higher the investor's transaction cost, the lower the stock liquidity, and vice versa. In order to make the empirical results simple and easy to read, referring to the practice of Wu Fei et al. (2021), the *Liquidity* of the stock liquidity indicator in this article is measured by the inverse of the illiquidity measure. The calculation method is as follows:

$$Liquidity = -ILLIQ \quad (2)$$

The larger the *Liquidity* value, the higher the liquidity of the enterprise's stocks.

3.2.2 Explain the Variable

(1) The treatment dummy variable (*Treat*) is used to judge whether the enterprise is a technology-intensive enterprise. If the value is 1, otherwise it is 0. This variable follows the official standard of Article 11 of the Measures for the Recognition and Administration of High-tech Enterprises, and is screened based on the core condition of the proportion of R&D expenses. Calculate the total R&D expenses and total sales revenue of each sample in the past three years through panel data rolling, R&D intensity is defined as the ratio of total R&D expenditure to total sales revenue in the same period. For firms with an operating history of less than three years, the ratio is calculated based on the actual operating period. Specifically, firms are classified as technology-intensive ($Treat = 1$) if they meet the following criteria: (1) for firms with annual sales revenue ≤ 50 million yuan, $R\&D\ intensity \geq 5\%$; (2) for firms with annual sales revenue between 50 million and 200 million yuan, $R\&D\ intensity \geq 4\%$; (3) for firms with annual sales revenue > 200 million yuan, $R\&D\ intensity \geq 3\%$. Otherwise, *Treat* is set to 0.

(2) Time dummy variable (*Post*) equals 1 for the years 2018 and thereafter, and 0 otherwise.

(3) Difference-In-Differences (*DID*), following Beck and Wen Zhonglin, is constructed to capture the net effect of the R&D expense separate reporting policy. The calculation method is:

$$DID = Post \times Treat \quad (3)$$

This paper will focus on examining the regression coefficients of the crossover term $Treat \times Post$.

3.2.3 Control Variable

$Controls_{i,t}$ referring to existing authoritative literature, in order to improve the research accuracy, this study selected 10 control variables, including the scale of the enterprise (*Size*), Leverage Ratio (*Lev*), Degree of Financial Leverage (*DFL*), Institutional Ownership (*INST*), Return on Assets (*ROA*), Largest Shareholder Ownership (*Top1*), Revenue Growth Rate (*Growth*), Institutional Ownership (*Institution*), State Ownership (*SOE*), Tobin's Q (*TobinQ*).

The specific variable definitions are shown in the Table 1.

Table 1: Variable definition

Variable Name	Symbol	Description
Stock Liquidity	$Liquidity_{i,t}$	The Amihud illiquidity index is obtained by taking the negative value of the original index.
The time dummy variable	$Post_t$	After the policy shock year (2018), the value of t is taken as 1; otherwise, it is taken as 0
The treatment dummy variable	$Treat_i$	Whether the enterprise is a technology-intensive one or not, if it is, take 1; otherwise, take 0
Difference-In-Differences	DID	$DID = Post_t \times Treat_i$ The crossover term captures the net effect of the "single-column" policy shock
Scale of the enterprise	$Size$	The total assets of an enterprise are taken as the natural logarithm
Leverage Ratio	Lev	Total liabilities/total assets
Degree of Financial Leverage	DFL	$(Net\ profit + income\ tax\ expense + Financial\ Expense) / (Net\ profit + Income\ tax\ expense)$
Firm Ownership	SOE	Virtual variables: If it is a state-owned enterprise, take 1; otherwise, take 0
Return on Assets	ROA	Net profit/total assets
Institutional Ownership 1	$INST1$	The proportion of the total number of shares held by all institutional investors to the tradable A-shares of the listed company.
Institutional Ownership 2	$INST2$	The proportion of the total number of shares held by all institutional investors to the total share capital of the listed company.
Largest Shareholder Ownership	$Top1$	The ratio of the number of shares held by the largest shareholder to the total number of shares of the company
Firm Growth	$Growth$	The growth rate of an enterprise's current year's operating income relative to the previous year's operating income
Tobin's Q	$TobinQ$	Measure whether the enterprise value of an enterprise is overvalued or underestimated
Error Term	$\varepsilon_{i,t}$	Including all other factors that affect the liquidity of the enterprise's stocks but were not included in the experiment or have not yet been observed

3.3 Model Construction

Referring to the practice of Beck and Wen Zhonglin, this paper constructs the following difference-in-differences (DID) model to study the impact of the separate policy of R&D costs on the liquidity of enterprise stocks.

$$Liquidity_{i,t} = \beta_0 + \beta_1 \times Post_t + \beta_2 \times Treat_i + \beta_3 \times DID_{i,t} + \gamma Controls_{i,t} + Year_t + Firm_i + \varepsilon_{i,t} \quad (4)$$

In model (4), in addition to the above-mentioned variables, in order to improve the persuasiveness of the results, this study also processed it as follows: first, $\varepsilon_{i,t}$ is added as random error terms, which includes all other factors that affect the liquidity of enterprise stocks but are not included or have not been observed in the experiment; second, in all regression equations, the t statistic mis-adjusted by the robustness standard of Cluster clustering is default; finally, this study controls the virtual variables of time (*Year*) and enterprise (*Stkcd*) at the same time to absorb the fixed effect as much as possible.

When further studying the impact mechanism of the R&D Expense Separate Policy on the stock liquidity of enterprises, drawing on the intermediary effect test method proposed by Baron and Kenny (1986) and Wen Zhonglin et al., this paper studies the information transmission mechanism of the single policy to improve stock liquidity and the mechanism of easing financing constraints, that is, assuming H2 and H3. The model setting for testing the intermediary effect is as follows:

$$Compacc_{i,t} = \beta_0 + \beta_1 \times DID_{i,t} + \gamma Controls_{i,t} + Year_t + Firm_i + \varepsilon_{i,t} \quad (5)$$

$$FC_{i,t} = \beta_0 + \beta_1 \times DID_{i,t} + \gamma Controls_{i,t} + Year_t + Firm_i + \varepsilon_{i,t} \quad (6)- (1)$$

$$SA_{i,t} = \beta_0 + \beta_1 \times DID_{i,t} + \gamma Controls_{i,t} + Year_t + Firm_i + \varepsilon_{i,t} \quad (6)- (2)$$

The difference between model (5) and (6) is that the explained variables are different. In model (5), the interpreted variable is the comparability of accounting information (*Compacc*). The larger the *Compacc*, the higher the comparability of the accounting information of the enterprise. This study uses the research methods of De Franco and Tang Xuesong (2019) to estimate the comparability of accounting information, and measure the annual accounting information comparability of enterprises compared with other companies in the same industry, including the top four means (*Compacc1*) and the top ten means (*Compacc2*). In model (6), the explained variable is the degree of financing constraint of the enterprise. This study uses the FC index constructed by Hadlock and Pierce (2009) and the SA index constructed by Ju Xiaosheng et al. (2013) to measure the degree of financing constraint of the enterprise. The larger the index, the higher the degree of financing constraint faced by the enterprise.

If the coefficients before DID in models (4), (5) and (6) are significant, continue to carry out the following regression to test the intermediary effect:

$$Liquidity_{i,t} = \beta_0 + \beta_1 \times DID_{i,t} + \beta_2 \times Compacc_{i,t} + \gamma Controls_{i,t} + Year_t + Firm_i + \varepsilon_{i,t} \quad (7)$$

$$Liquidity_{i,t} = \beta_0 + \beta_1 \times DID_{i,t} + \beta_2 \times FC_{i,t} + \gamma Controls_{i,t} + Year_t + Firm_i + \varepsilon_{i,t} \quad (8)- (1)$$

$$Liquidity_{i,t} = \beta_0 + \beta_1 \times DID_{i,t} + \beta_2 \times SA_{i,t} + \gamma Controls_{i,t} + Year_t + Firm_i + \varepsilon_{i,t} \quad (8)- (2)$$

By examining the coefficients before DID in models (4) to (6) and the coefficients before the comparability of accounting information *Compacc*, the financing constraint FC index and the SA index in models (7) and (8), we can test whether there is an intermediary effect (Wen Zhonglin et al., 2004). By further examining the coefficients before DID in models (7) and (8), we can judge whether this mediation effect is a complete mediation effect.

4. Empirical Results

4.1 Descriptive Statistics

Table 2 shows the descriptive statistics of the main variables. As shown in Table 2, the mean value of Liquidity is -0.203, with a standard deviation of 0.989. The minimum and maximum values are -8.378 and -0.002, respectively, indicating substantial variation in stock liquidity across firms. The average value of *DID* is 0.399, indicating that 39.9% of the samples are affected by the R&D Expense Separate Policy; the average value of *Post* is 0.638, and the proportion of samples before and after the implementation of the response

policy is nearly half, which is in line with the time node characteristics of this study; the mean value of *Treat* is 0.605, indicating that technology-intensive enterprises account for a relatively high proportion of the sample.

In terms of control variables, the average value of *Size* is 22.226 and the standard deviation is 1.279, indicating that the scale distribution of sample enterprises is relatively uniform and the degree of dispersion is relatively high; the average value of *Lev* is 0.385, indicating that the debt repayment capacity of most sample enterprises is relatively stable. The average value of *SOE* is 0.282, indicating that the proportion of Chinese enterprises in the sample is about 28.2%, and the proportion of non-state-owned enterprises is higher.

Table 2: Descriptive statistics

Variable	Observations	Average value	Standard deviation	Minimum	25 th percentile	Median	75 th percentile	Maximum
<i>Liquidity_{i,t}</i>	28425	-0.203	0.989	-8.378	-0.059	-0.030	-0.015	-0.002
<i>Post_i</i>	28425	0.638	0.481	0.000	0.000	1.000	1.000	1.000
<i>Treat_i</i>	28425	0.605	0.489	0.000	0.000	1.000	1.000	1.000
<i>DID</i>	28425	0.399	0.490	0.000	0.000	0.000	1.000	1.000
<i>Size</i>	28425	22.226	1.279	20.030	21.305	22.016	22.928	26.331
<i>Lev</i>	28425	0.385	0.188	0.053	0.232	0.374	0.524	0.828
<i>DFL</i>	28425	1.294	0.899	0.336	0.973	1.043	1.240	7.189
<i>SOE</i>	28425	0.282	0.450	0.000	0.000	0.000	1.000	1.000
<i>ROA</i>	28425	0.059	0.046	0.001	0.024	0.049	0.082	0.232
<i>INST1</i>	28425	78.774	94.318	0.534	30.449	54.339	80.817	617.360
<i>INST2</i>	28425	42.500	25.468	0.317	19.858	43.610	63.582	91.523
<i>Top1</i>	28425	34.100	14.546	8.650	22.820	32.080	43.670	73.560
<i>Growth</i>	28425	0.135	0.540	-0.907	-0.075	0.068	0.229	3.765
<i>TobinQ</i>	28425	2.578	1.785	0.829	1.405	2.019	3.081	10.505

4.2 The R&D Expense Separate Policy and Stock Liquidity

The result of using the model (4) to check whether the R&D Expense Separate Policy will affect the stock liquidity of listed companies is shown in Table 3. Column (1) is the regression result that does not include control variables, column (2) adds control variables at the enterprise level, and column (3) further controls the enterprise and annual fixed effect. All three regressions are adjusted by mistake by the company-level cluster robust standard. Across all three specifications, the coefficient of *DID* is significantly positive at the 1% level. The results are consistent, indicating that the policy significantly improves stock liquidity for technology-intensive firms in 2018, the stock liquidity of technology-intensive enterprises is more significant than that of non-technology-intensive enterprises, and H1 has been verified.

Table 3: The impact of the policy of listing research and development expenses separately on stock liquidity

Variable	Liquidity (1)	Liquidity (2)	Liquidity (3)
<i>DID</i>	0.3480***	0.3583***	0.4145***
	(11.25)	(11.77)	(10.19)
<i>Post</i>	0.1562***	0.0749***	-0.4117***
	(9.85)	(4.75)	(-10.24)
<i>Treat</i>	-0.3826***	-0.2311***	-0.2507***
	(-12.49)	(-8.37)	(-7.67)
<i>Size</i>		0.1134***	0.1711***
		(16.80)	(6.87)
<i>Lev</i>		-0.4620***	0.3404***
		(-11.71)	(3.74)
<i>DFL</i>		0.0081**	-0.0321***
		(2.22)	(-5.65)
<i>SOE</i>		-0.0474***	-0.1243***
		(-4.05)	(-3.09)
<i>ROA</i>		-1.0535***	-1.1701***
		(-6.07)	(-4.65)
<i>INST1</i>		-0.0020***	-0.0029***
		(-16.45)	(-14.82)

Variable	Liquidity (1)	Liquidity (2)	Liquidity (3)
<i>INST2</i>		0.0052*** (14.43)	0.0061*** (6.96)
<i>Top1</i>		-0.0020*** (-4.12)	0.0000 (0.02)
<i>Growth</i>		0.0185*** (3.18)	0.0205*** (2.98)
<i>TobinQ</i>		-0.0702*** (-10.01)	-0.1265*** (-10.23)
<i>Constant</i>	-0.2097*** (-13.36)	-2.3454*** (-15.89)	-3.4755*** (-6.64)
<i>Control</i>	NO	YES	YES
<i>Company</i>	NO	NO	YES
<i>Year</i>	NO	NO	YES
<i>N</i>	28425	28425	27921
<i>F</i>	172.463***	68.684***	43.759***
<i>R²</i>	0.043	0.119	0.299
<i>Adj. R²</i>	0.043	0.118	0.174

Note: The *t*-statistic is in parentheses. ***, ** and * indicate significance at the 1%, 5%, and 10% levels. Unless otherwise specified, the same applies below.

4.3 Robustness Test

4.3.1 Parallel Trend Test

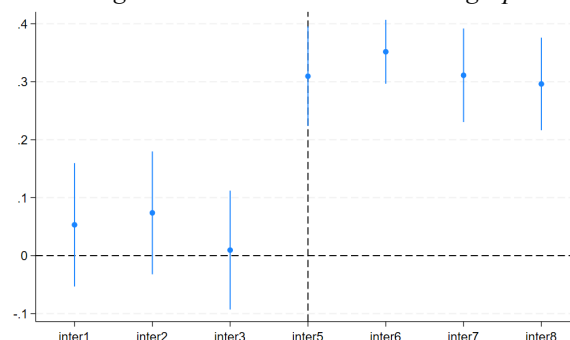
In order to ensure the validity of the estimated results of the double differential model, the key premise of “parallel trend” must be met, that is, before the policy shock occurs, the result variables of the treatment group and the control group should have the same trend of change. In order to verify this hypothesis, this paper refers to the idea of the event research method and constructs a model (9):

$$Liquidity_{i,t} = \alpha + \sum_{\tau \neq inter4} \beta_{\tau} (Treat_i \times D_t^{\tau}) + \gamma Controls_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (9)$$

In order to make the research more convincing, this paper groups the years and sets the previous group of policy implementation (inter4) as a reference period to avoid multiple collinearity. Among them, D_t^{τ} is the year virtual variable. When the year is τ , the value is 1, otherwise it is 0. The coefficient β_{τ} captures the difference in mobility between the treatment group and the control group in the τ year relative to the reference period.

The results of the parallel trend test using Stata are shown in Figure 1. It can be seen that before the implementation of the policy (before 2018), the estimated values of all β_{τ} were statistically not significant, and their confidence intervals included zero values. This shows that there is no systemic difference in the trend of liquidity change between the processing group and the control group before the policy intervention, which satisfies the parallel trend hypothesis. After the implementation of the policy, the estimated value of β_{τ} became significantly positive, indicating that the R&D Expense Separate Policy did have a significant positive effect on stock liquidity, and the effect was continuous. The passing of the parallel trend test provides key support for the unbiasedness and reliability of the estimated results of the DID model in this paper.

Figure 1: Parallel trend test result graph



4.3.2 Placebo Test

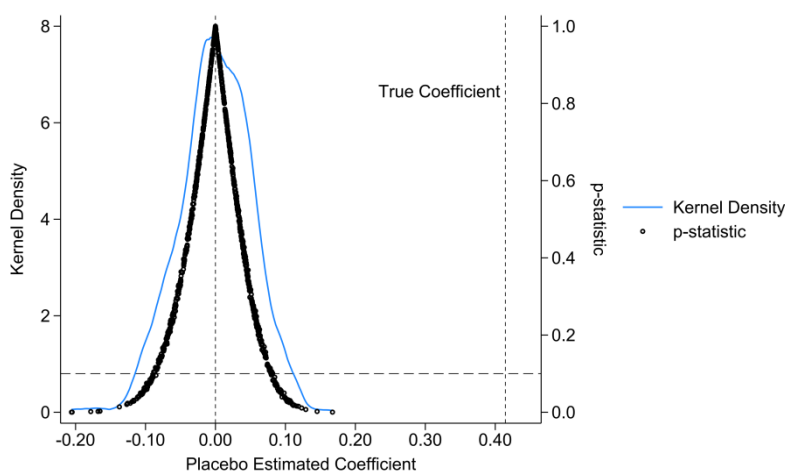
(1) Time placebo

The impact of time changes on the liquidity of stocks in the capital market needs to be tested. The signal of the gradual improvement of the R&D cost-alone policy and the gradual progress of the Ministry of Finance's overall planning and publicity may have a certain impact on the liquidity of stocks in the capital market, so it is not easy to identify the direct effect of the policy. In order to avoid the interference of the time expectation effect, the implementation time of the R&D Expense Separate Policy is advanced by 2 years, forming a false policy the time dummy variable. The regression result is shown in column (1) of Table 4. The DID coefficient is not significant at the level of 10%, indicating that the expectation of the R&D Expense Separate Policy has not had a significant impact on the high-quality development of the local economy.

(2) Fictional processing group

Although the time placebo test suggests that changes in stock liquidity are driven by the policy, further tests are conducted to rule out potential confounding factors. Following La Ferrara et al. (2012), a placebo test is performed using randomly assigned treatment groups. (2021) for placebo testing. Specifically, the false experimental group and control group are constructed by random sampling method, so as to construct a false processing variable $Treat\_False$ and the corresponding interaction item $Treat\_False \times Post$. In order to improve the credibility of the placebo test, this article repeats the above operation 1,000 times. Theoretically speaking, if the result of the benchmark regression is indeed brought about by the R&D Expense Separate Policy, the estimated coefficient of the false interaction item $Treat\_False \times Post$ should not be significantly different from 0. The estimated coefficient nuclear density and p-value distribution diagram of the 1000 randomly selected control group are shown in Figure 2. It can be seen that the estimated coefficient distribution is near 0, and the mean is far away from the real value obtained from the benchmark regression, and the vast majority of the estimated coefficients are not significant. They passed the placebo test.

Figure 2: Kernel density map of 1000 random regression coefficients



4.3.3 Eliminate the Impact of the Epidemic

Considering that the global COVID-19 pandemic in 2020 has seriously affected the performance of China's capital market and may affect the results of this article, after removing the sample in 2020, this paper re-runs the above empirical analysis. The results are shown in Table 4. Columns (2)-(4) show that after excluding the 2020 sample, the DID coefficient is significantly positive at the 1% level, and with the addition of control variables and fixed effects, the direction and significance of the coefficient have not changed substantially, indicating that the results of this article are robust.

4.3.4 Shorten the Sample Period

In order to avoid the long sample period leading to data deletion and data distortion that interferes with the empirical results, the sample period is adjusted from 2012-2023 to 2015-2020 for regression. The results are in Table 4 (5)-(7). It can be seen from column (5) of Table 4 that the sample size was reduced from 28425 to

13612, and the data was reduced but the accuracy and concentration were improved. At this time, the DID regression result was still significantly positive, and the coefficient was increased from 0.3480 to 0.5663, indicating that after shortening the sample period, the results of this article are still robust.

4.3.5 Replace the Explanatory Variable

In order to ensure the robustness of the benchmark regression conclusion, this paper further replaces the explained variable - the measurement index of stock liquidity for re-estimation. In benchmark regression, the non-liquidity indicator of Amihud (2002) is used to measure stock liquidity. In this test, the annual average daily turnover rate (Turnover) is used as an alternative indicator of liquidity. The larger the value, the higher the trading activity of the stock, the stronger the liquidity.

The regression results are shown in column (8) of Table 4. The coefficient of DID is still significantly positive at the level of 1%, which is exactly the same as the baseline regression results in Table 2. This shows that the improvement effect of the R&D Expense Separate Policy on stock liquidity will not change due to changes in the way of measuring liquidity, and the results of this article are still robust.

Table 4: Regression results of the robustness test

Variable	Time placebo test	Eliminate the impact of the epidemic			Shorten the sample period			Replace the explanatory variable
	Liquidity (1)	Liquidity (2)	Liquidity (3)	Liquidity (4)	Liquidity (5)	Liquidity (6)	Liquidity (7)	Turnover (8)
DID	0.0224 (0.7032)	0.3464*** (11.15)	0.3511*** (11.50)	0.4245*** (10.03)	0.5663*** (11.45)	0.5902*** (12.08)	0.5651*** (8.92)	0.2125*** (5.91)
Constant	-3.8826*** (-7.3080)	-0.2097*** (-13.36)	-2.4140*** (-14.75)	-3.1691*** (-5.82)	-0.3028*** (-11.32)	-4.8566*** (-15.99)	-8.5241*** (-5.82)	6.0664*** (9.80)
Control	YES	NO	YES	YES	NO	YES	YES	YES
Company	YES	NO	NO	YES	NO	NO	YES	YES
Year	YES	NO	NO	YES	NO	NO	YES	YES
N	27921	25583	25583	25064	13612	13612	13103	25064
F	43.819***	166.785***	66.791***	43.935***	178.391***	66.828***	50.730***	212.969***
R2	0.293	0.041	0.214	0.321	0.064	0.186	0.405	0.550
Adj.R2	0.166	0.041	0.214	0.183	0.064	0.185	0.233	0.459

5. Further Analysis

5.1 Intermediary Mechanism Test

The above results show that the implementation of the R&D Expense Separate Policy will significantly improve the stock liquidity of enterprises and this result is robust, but what mechanism does the policy use to affect the stock liquidity of enterprises? This study has not further studied the mechanism black box between the two. This article draws on the mediation effect test model discussed by Baron and Kenny (1986) and Wen Zhonglin (2004).

5.1.1 Comparability of Accounting Information

As the basis for investors to compare the value of enterprises horizontally, the comparability of accounting information is the key carrier for the R&D expenditure single policy to improve the information environment. Whether the single policy reduces the cost of information processing and information asymmetry by enhancing the comparability of enterprise accounting information with companies in the same industry is the purpose of this part of the study. The results of the mediation mechanism test conducted in this study are shown in Table 5.

Following the methods of De Franco and Tang Xuesong (2019) to estimate the comparability of accounting information, and use the variable of the company's annual accounting information comparability level relative to other companies in the same industry. This study uses the top 4 means (Compacc1) and the top 10 means (Compacc2) to measure the comparability of accounting information. The coefficients in models (4), (5) and (7) are estimated. The key regression results are recorded in Table 5. In order to facilitate the presentation of coefficients, this study expands both Compacc1 and Compacc2 by 1000 times for regression.

Table 5: Regression results of the mediating effect based on the comparability of accounting information

variable	The four companies with the most similar accounting systems			The 10 companies with the most similar accounting systems		
	Liquidity (1)	Compacc1 (2)	Liquidity (3)	Liquidity (4)	Compacc2 (5)	Liquidity (6)
DID	0.0037*** (2.49)	0.6839*** (4.27)	0.0026*** (2.79)	0.0026* (1.84)	0.7570*** (4.19)	0.0026*** (2.80)
Compacc1			0.0002** (2.25)			
Compacc2						0.0002** (2.13)
Control, Company, Year	YES	YES	YES	YES	YES	YES
N	14697	14697	14697	14697	14697	14697
Adj.R ²	0.557	0.507	0.569	0.569	0.543	0.569

Column (1) of Table 5 presents the regression result of model (4). In this test, the regression coefficient of DID is still significantly positive; column (2) is the regression result of model (5), and the regression coefficient of DID is still significantly positive, indicating that the implementation of the R&D Expense Separate Policy can improve the comparability of accounting information of enterprises; column (3) is the regression result of model (7), and it can be seen that the coefficients of DID and Compacc are both significantly positive, indicating that the improvement of the comparability of accounting information can promote the improvement of enterprise stock liquidity, and the coefficient of DID in model (7) is slightly lower than the coefficient of DID in model (4), indicating that the comparability of accounting information plays a partial intermediary role. After replacing the top ten means (Compacc2) to measure the comparability of accounting information, the regression results are shown in column (4)-column (6) of Table 5, and the conclusion obtained is consistent with the above conclusion.

It can be seen that the R&D Expense Separate Policy can indirectly promote the improvement of stock liquidity by improving the comparability of accounting information and improving the information asymmetry environment. The improvement of the comparability of accounting information is an intermediary channel for the R&D Expense Separate Policy to improve the liquidity of enterprise stocks, which proves the previous hypothesis H2.

5.1.2 Financing Constraints

The continuous promotion of research and development activities depends on stable financial support, and the financing constraints caused by information asymmetry are important factors restricting the market performance of enterprises. Whether the single-list policy of R&D expenses can reduce the external financing cost of enterprises, alleviate financing constraints (measured by FC index and SA index) by transmitting more innovative signals to investors, inject vitality into enterprise operations and enhance the attractiveness of stocks, is the research purpose of the market. For this reason, the second mediation mechanism test was carried out in this study, and the test results are shown in Table 6.

Table 6: Regression results of the mediating effect based on financing constraints

Variable	FCindex			SA index		
	Liquidity (1)	FC (2)	Liquidity (3)	Liquidity (4)	SA (5)	Liquidity (6)
DID	0.3030*** (7.75)	-0.0170*** (-5.41)	0.1697*** (6.28)	0.3030*** (7.75)	-0.0223*** (-8.89)	0.1175*** (4.45)
FC			-0.8563*** (-11.73)			
SA						-2.9937*** (-13.63)
Control, Company, Year	YES	YES	YES	YES	YES	YES
N	23307	23307	23307	23307	23307	23307
Adj.R ²	0.193	0.903	0.198	0.193	0.972	0.212

Column (1) of Table 6 is the regression result of the model (4), and the DID coefficient is still significantly positive, which is the same as the conclusion of the main test. Column (2) is the regression result of the model (6)-(1), and the DID coefficient is significantly negative, indicating that the single-list policy of research and development expenses can significantly reduce the financing constraints of enterprises; Column (3) is the regression results of model (8)-(1). The coefficient of DID is significantly positive and the coefficient of FC is significantly negative, indicating that the relief of enterprise financing constraints can promote the improvement of stock liquidity in the capital market, and the DID coefficient in model (8)-(1) is slightly lower than the DID coefficient in model (4), which shows that the financing constraints play the role of some intermediaries. After replacing the FC index with the SA index, the above conclusion is still valid.

It can be seen that the R&D Expense Separate Policy can indirectly improve stock liquidity by easing the financing constraints of enterprises and improving the fundamentals of enterprises. The easing of financing constraints is an intermediary mechanism for the R&D Expense Separate Policy to improve stock liquidity, which proves the previous hypothesis H3.

5.2 Heterogeneity Analysis

In order to further identify the impact of the R&D Expense Separate Policy on the changes in stock liquidity in the capital market, the sample enterprises are based on the scale of the enterprise and external media supervision, construct group variables and use their cross-multiplication terms with DID to conduct heterogeneous regression analysis to explore the different impacts on the conclusions of this article.

Table 7: Regression results of heterogeneity analysis

Variable	Liquidity (1)	Liquidity (2)
DID	0.7047*** (15.23)	0.3359*** (10.72)
DID×Size Group	-0.8305*** (-17.97)	
DID×Media Group		-0.1357*** (-5.68)
Control, Company, Year	YES	YES
N	27921	27921
Adj.R ²	0.192	0.172

5.2.1 Enterprise Scale

Taking the median of the total assets of the enterprise as the boundary, the whole sample is divided into large-scale enterprise groups and small-scale enterprise groups, and the regulatory effect of enterprise scale on the policy effect is tested through interaction. The test results are shown in column (1) of Table 7. The regression results show that the coefficient of “*DID×Size Group*” is significantly negative, indicating that compared with large-scale enterprises, the R&D Expense Separate Policy in small-scale enterprises has a stronger increase in stock liquidity. This is because the information disclosure of large-scale enterprises is more complete, the awareness of investors is higher, and the marginal value of information brought by policies is diluted. Therefore, the promoting effect of policies on stock liquidity weakens with the expansion of enterprises. On the contrary, the information transparency of smaller enterprises is inherently lower, and they usually face more serious information asymmetry and financing constraints. The “information increment” brought about by the change of R&D expenses from note disclosure to a profit list is more significant, which can effectively reduce the degree of information asymmetry of investors, thereby improving stock liquidity to a greater extent.

It can be seen that the effect of the R&D Expense Separate Policy on the improvement of stock liquidity is more significant in smaller enterprise groups, which is in line with expectations and proves the above assumption H4.

5.2.2 External Media Supervision

Taking the median number of media news reports as the boundary, the sample is divided into high-media supervision group and low-media supervision group, and the regulating effect of external media supervision on policy effects is tested through interaction. The test results are shown in column (2) of Table 7.

The regression results show that the coefficient of “DID×Media grouping” is significantly negative, indicating that compared with enterprises with higher level of media supervision, among enterprises with lower level of media supervision, the R&D Expense Separate Policy has a stronger increase in stock liquidity. This is because when the level of media supervision is high, the market has obtained more enterprise information through the media, and the “incremental value of information” brought by the policy is diluted, so the effect of the policy on improving stock liquidity is weakened; on the contrary, when the level of media supervision is low, the transparency of enterprise information is poor, and the information increment brought by the policy through the “separate reporting of research and development expenses” is more significant. Therefore, the policy of separate R&D expenses has a stronger effect on the improvement of stock liquidity.

It can be seen that the effect of the R&D Expense Separate Policy is more significant for enterprises with poor external supervision, which further shows that the policy has a significant effect on the improvement of the external information environment of enterprises, thus proving the above hypothesis H5.

6. Research Conclusion and Significance of the Study

This study takes 28,425 samples of A-share listed companies from 2012 to 2023, and uses a difference-in-differences (DID) model to explore the impact of the separate policy of R&D expenses on stock liquidity. It confirms that the separate policy of R&D expenses significantly improves the stock liquidity of enterprises, and the effect of the separate policy is clear; the single policy plays a role by improving the comparability of accounting information and alleviating financing constraints; the effect of the separate policy is heterogeneous, and the role of improving relatively small enterprises and enterprises with low media supervision is more prominent.

This research expands the research boundaries of accounting policy and economic consequences, enriches the theoretical chain of “accounting standards-information environment-capital market”; deepens the research on the mechanism of information disclosure affecting stock liquidity, makes up for the insufficient discussion of the transmission mechanism, and provides a reference perspective for follow-up research.

At the same time, this study provides empirical support for regulatory authorities to optimize the information disclosure system and formulate differentiated policies; provides a path to improve liquidity with standardized disclosure for small and medium-sized enterprises with imperfect information environment; helps investors to make accurate decisions using single R&D cost data to reduce risks; proves the practical value of the accounting system reform service innovation-driven strategy, and helps enterprise resources to lean towards the field of innovation.

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Consumer Behavior Research under the Sharing Economy Model

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Abstract

With the rapid development of Internet technology, platform economy has emerged and flourished. The sharing economy, as a typical representative of platform economy, has rapidly risen globally. The sharing economy takes the sharing of idle resources as the core, and connects the supply and demand sides through the Internet platform, realizing the optimal allocation and efficient use of resources. This article aims to explore the changes in consumer behavior and their influencing factors under the sharing economy model. Through literature review and empirical research, this article analyzes the characteristics of consumer motivation transformation, personalized consumption patterns, and enhanced social attributes in the sharing economy model. Meanwhile, this article also explores the impact of economic, socio-cultural, and technological factors on consumer behavior. However, the research results indicate that there are also some problems with the sharing economy model, and this article will propose relevant suggestions based on these issues. The research in this article is of great significance for understanding the operational mechanism of the sharing economy model, optimizing consumer experience, and promoting the sustainable development of the sharing economy model in the era of platform economy.

Keywords

platform, sharing economy, consumer behavior, business model

1. Introduction

The concept of the sharing economy was first proposed in 1978 by Marcus Felson, a sociology professor at Texas State University, and Joel Spence, a sociology professor at the University of Illinois. It refers to a third-party information technology platform that acts as a bridge connecting supply and demand sides [1]. This platform overcomes the limitations of time and space, enabling individuals to exchange unused items and share their experiences, skills, and resources. This sharing model has evolved from the traditional unpaid form into a new model capable of generating economic returns. It not only meets users' diverse needs but also significantly enhances the liquidity of resources and achieves efficient utilization of resource value.

The emergence of the sharing economy model has profoundly transformed people's lifestyles and consumption habits. Under the sharing economy model, consumers can obtain the right to use required resources at a lower cost through internet platforms to satisfy their needs [2]. The advent of this model has not only brought convenience and affordability to consumers but has also impacted traditional economic

models. Therefore, researching consumer behavior under the sharing economy model holds important theoretical and practical significance.

However, China's sharing economy has developed rapidly and covers a wide range of fields, yet its development history is relatively short [3]. Currently, there are still lags in regulation and standards. Service providers may enter the market without sufficient preparation, thereby affecting service quality and consumer experience. Secondly, because the sharing economy requires strong technological support, there may be industry monopolies [1], leading to price wars and vicious competition that harm consumer rights and interests. Finally, sharing economy platforms obtain user information through the internet, which may lead to information security risks [4]. Based on the above issues, this paper will put forward relevant suggestions.

2. Current Situation of the Sharing Economy in China

According to "The Practical Dilemmas and Countermeasures of Sharing Economy Development [5]," "A Brief Analysis of the Problems and Development Countermeasures of the Sharing Economy in the New Era [6]," and "A Brief Analysis of the Sharing Economy Business Model and Development Suggestions: Taking Shared Bicycles as an Example [7]," China's sharing economy has developed vigorously over the past decade. Since June 2015, a large number of shared bicycle companies have emerged on the market, with more than 30 shared bicycle companies registered [7]. The sharing economy began to gain public recognition. In October 2015, with the introduction of the new development concept of "innovation, coordination, greenness, openness, and sharing," the sharing economy began to flourish in China [5].

At present, shared goods have become important resources in many industries, such as transportation resources, medical resources, and educational resources [6]. In the area of mobility, shared bicycles and shared cars such as "Qingju" and "Meituan" have brought great convenience to citizens, solved the problem of difficult urban travel, reduced traffic pressure, and promoted sustainable development. In the medical field, the emergence of shared medical platforms such as "Chunyu Doctor" allows patients and doctors to select each other through online platforms, thereby improving the efficiency of medical consultations. In the field of education, platforms such as "Zhangmen 1-on-1" enable employers and teachers to choose each other, making it convenient for employers to inquire and for university students to engage in part-time tutoring jobs. The sharing economy can achieve a win-win situation for platforms, sellers, and buyers across various aspects of life. According to the prediction in Analysis of Logistics Business Model Optimization under the Sharing Economy Background [12], the new forms of the sharing economy have promising development prospects in the future.

Currently, the most prominent characteristic of the domestic sharing economy is that "right to use" is more important than "right to ownership" [8]. The sharing economy generally involves individuals, enterprises, and organizations as transaction subjects. Through platform intermediaries, individuals and enterprises temporarily transfer the right to use idle resources rather than transferring ownership. For example, power bank rentals and shared bicycle services both reflect the paid temporary borrowing of usage rights [1]. The core of the sharing economy is "one item, multiple uses," which efficiently utilizes idle resources. In essence, it involves the short-term transfer of usage rights for underutilized assets, achieving "short-term leasing" [8].

3. Changes in Consumer Behavior under the Sharing Economy Model

3.1 Shift in Consumption Motivation

The sharing economy is a collaborative consumption model that transcends ownership to obtain the right to use products or services [10]. Under the sharing economy model, consumers' consumption motivations have undergone significant changes, shifting from emphasizing ownership to placing greater importance on the right to use—"not to own, but to use" [10]. In the traditional consumption model, consumers pursued the unity of product ownership and usage rights. In contrast, under the sharing economy model, consumers focus more on acquiring the right to use. In the past, people often worried about the separation of ownership and usage rights of goods. However, with the improvement of education levels, people's perceptions have

become more open, and the separation anxiety brought by the sharing economy has been alleviated [9]. People's consumption concepts have also changed, and the new consumption and development view of "valuing use over possession" has grown increasingly strong. In the sharing economy, consumption is for use rather than ownership [11]. Consumers are no longer guided by the desire for possession; instead, their primary focus has shifted to the actual utility and value of products. The principles of matching, appropriateness, and moderation have regained emphasis under the sharing economy—a new production model that stresses reciprocity, sharing, and cooperation—and are regaining new vitality in professional fields.

3.2 Personalization of Consumption Methods

Under the sharing economy model, consumers can select products and services that better meet their individualized needs according to their own requirements. Consumers are no longer limited to the standardized products and services provided under the traditional economic model; instead, they can make choices based on their personal preferences and needs. "The Dark Side of the Sharing Economy under Algorithmic Management: Conceptual Framework and Prospects" [2] points out that the matching and control of supply and demand resources is key to the development of the sharing economy. Platforms use technological means such as algorithms and data analysis to intelligently match supply and demand sides, enabling resources to be utilized in the most reasonable manner. This matching mechanism provides consumers with more personalized services.

3.3 Enhancement of Social Attributes

The essence of the sharing economy model is resource sharing. Consumers share resources with others through sharing economy platforms to achieve resource sharing and mutual benefit. Sharing platforms build social spaces where strangers share with one another, creating numerous social opportunities. For example, hosts on Airbnb often share local travel and transportation guides with their guests, and even share food recommendations [10]. Similarly, shared mobility allows passengers to obtain information from ride-hailing drivers. The consumption process in the sharing economy requires communication, interaction, and sharing with strangers [13], which strengthens the social attributes of consumer behavior.

4. Factors Influencing Consumer Behavior under the Sharing Economy Model

4.1 Economic Factors

Income Level: Consumers' income level is a key factor determining their purchasing power and consumption choices. In the sharing economy, consumers usually need to consider the cost-benefit ratio of services or products [14]. If consumers have a higher income level, they are more likely to choose high-quality, higher-priced shared services, such as short-term rentals of private apartments. Conversely, if their income level is lower, consumers may pay more attention to price factors and opt for lower-cost shared services.

Price Elasticity: The price elasticity of shared economy services or products also influences consumer behavior [15]. Price elasticity refers to the degree to which changes in price affect consumer demand. In the sharing economy, if price elasticity is high—that is, price changes have a significant impact on consumer demand—consumers tend to be more sensitive to price fluctuations and are more inclined to purchase or use services when prices are lower.

4.2 Social Factors

Income and Education Level: Income and education level significantly influence consumer behavior when facing shared goods [15]. Lutz (2018) found that there exists a demographic divide between users and non-users of the sharing economy, particularly in terms of income and education. In his survey, 25% of individuals in the high-income bracket (US\$75,000+) and high-education group (college graduates) reported having used shared services, whereas only 4% of those in the low-income bracket (less than US\$30,000) and lower-education group (high school graduates or below) had done so.

Socio-Cultural Factors: Socio-cultural factors also exert an important influence on consumer behavior. The emergence of the sharing economy model aligns with modern society's pursuit of environmental protection and sustainable development. Articles such as "Discussion on the Profit Model, Economic Consequences, and Countermeasures of the Sharing Economy [1]," "Case Study on Sustainable Operation and Management of the Sharing Economy [4]," and "How sustainable is the sharing economy? On the sustainability connotations of sharing economy platforms" [16] collectively point out that, under the sharing economy, sharing consumer goods rather than owning them exclusively can reduce resource depletion caused by consumption. Therefore, consumers who uphold sustainable values can contribute to sustainable development through the sharing economy.

Moral Climate: Due to the anonymity and lack of consumer ownership in the sharing economy consumption process [17], the sharing economy is closely related to societal moral climate. Bardhi and Eckhardt (2012) [18] found in their interviews that consumers tend to be more self-interested under the sharing economy model. Liu Jianxin et al. (2020) [19] also discovered that destructive unethical behaviors among consumers increase in the sharing economy. Guo Zhen et al. (2023) argued that the lack of psychological ownership over shared products is the main cause of such unethical behaviors [17]. Therefore, stronger moral norms are necessary in the sharing economy model.

Urban Construction: Urban construction also significantly affects the development of the sharing economy, especially in the area of shared mobility. For example, according to statistics from the China Academy of Urban Planning and Design, Chengdu has seen an increase in shared bicycle usage on weekends due to its greenway construction. Similarly, Hangzhou has experienced improved shared bicycle usage rates on weekends owing to the development of the West Lake scenic area [20].

4.3 Technical Factors

With the evolution of the times, technology has become an indispensable core support for the sharing economy. In the early stages, sharing economy platforms mainly served as bridges connecting supply and demand sides, with their supply-demand matching models relying primarily on manual labor to complete this core task [21]. However, with the rapid growth of demand and increasing requirements for resource matching efficiency and quality control, traditional matching models have become insufficient to meet the needs of market development.

In response to these challenges and to seize opportunities, many enterprises have begun introducing algorithmic management into sharing economy activities. This innovative measure has significantly improved the matching efficiency among consumers, digital workers, and merchants [2]. The introduction of algorithmic management not only ensures rapid and effective resource allocation but also enhances matching accuracy through intelligent methods, thereby optimizing user experience.

It is worth noting that, according to the research results of "A Study on Factors Influencing the Development Potential of China's Sharing Economy [3]," the level of internet development ranks first in its contribution to the development potential of the sharing economy. This finding further confirms the central role of science and technology in the sharing economy and also indicates that technology will play an even more important role in promoting the development of the sharing economy in the future.

5. Theoretical Modeling

Based on the above analysis, a theoretical model of consumer behavior under the sharing economy model is constructed. This model includes the following core elements:

Consumer Motivation: As an independent variable, it includes ownership-seeking motivation and usage-right-seeking motivation.

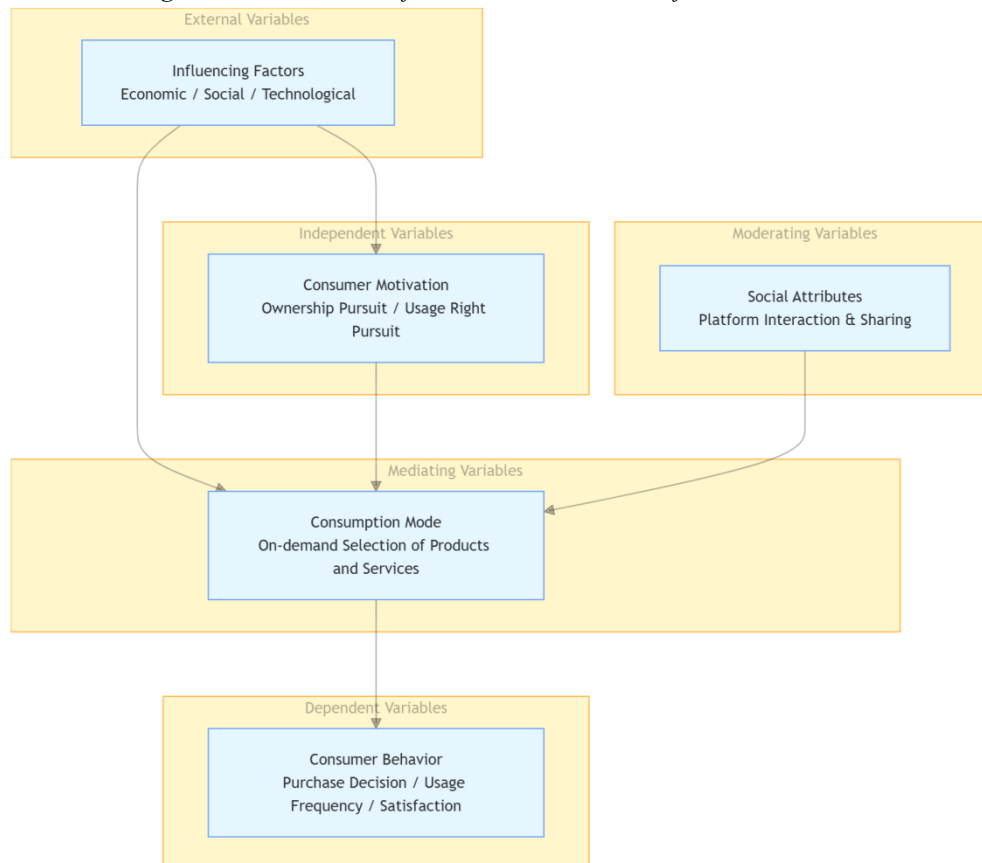
Consumption Method: As a mediating variable, it reflects how consumers select products and services according to their needs.

Social Attributes: As a moderating variable, it influences consumers' interaction and sharing behaviors on sharing economy platforms.

Influencing Factors: As external variables, including economic factors, social factors, and technical factors, these indirectly affect consumer behavior by influencing consumer motivation and consumption methods.

Consumer Behavior: As a dependent variable, it includes purchase decisions, frequency of use, satisfaction, and so on.

Figure 1: Construction of the Theoretical Model of Consumer Behavior



As shown in Figure 1, in the theoretical model of consumer behavior under the sharing economy model, the various components interact with one another and collectively constitute the behavioral logic of consumers on sharing economy platforms. The mutual influence relationships among them are elaborated in detail as follows:

1) The Influence of External Variables (Influencing Factors) on Consumer Motivation and Consumption Methods

Economic Factors:

Income level directly affects consumption methods. A higher income level may lead consumers to emphasize service quality while pursuing convenience, making them more willing to try high-end shared economy services, such as short-term rentals of private apartments. Conversely, when income levels are lower, consumers tend to focus more on price factors and opt for lower-cost shared services.

In terms of price elasticity, the pricing strategies of sharing economy platforms directly influence consumer motivation. Attractive pricing can amplify consumers' usage-right-seeking motivation and increase the likelihood of purchase decisions. For example, when shared bicycle platforms launch low-priced monthly passes, they attract more consumers to try the service and increase usage frequency.

Social Factors:

From a socio-cultural perspective, different social and cultural backgrounds influence consumers' values and consumption concepts. In cities that advocate environmental protection and sustainable development,

consumers' usage-right-seeking motivation tends to be stronger, and they are more inclined to choose the sharing economy model to reduce resource waste. This also affects consumption methods, making consumers more willing to select environmentally friendly shared products.

Regarding education level, consumers with higher levels of education are generally more open to new things and new ideas. They have a higher level of understanding and acceptance of the sharing economy, and their usage-right-seeking motivation is more pronounced. When choosing shared economy services, they tend to pay greater attention to features such as intelligence and personalization, thereby influencing their consumption methods.

In terms of moral climate, a favorable moral environment helps enhance consumers' sense of responsibility and self-discipline, encouraging them to use shared economy products in a regulated manner. For instance, in communities with a strong moral climate, incidents of shared bicycle damage and unauthorized occupation are relatively rare. Consumers are more likely to choose and use shared bicycles reasonably, which in turn affects consumption methods and usage frequency.

Urban construction also directly drives the development of the sharing economy. It influences consumer motivation and consumption methods. For example, the construction of greenways in Chengdu stimulates consumers to choose shared mobility options.

Technical Factors:

Well-developed internet infrastructure and high-speed, stable network connections enable consumers to more conveniently access information on sharing economy platforms, make comparisons, and select services, thereby strengthening their usage-right-seeking motivation. At the same time, internet technology supports diversified consumption methods, such as one-click car rental and online payment through mobile apps. In addition, intelligent technologies (such as algorithm recommendations and smart locks) can recommend suitable shared economy products and services to consumers based on their historical usage records and preferences, thereby influencing consumption methods. Technologies such as smart locks further improve the convenience and security of using shared products, stimulating consumers' usage-right-seeking motivation even more.

2) The Influence of Consumer Motivation on Consumption Methods

When the ownership-seeking motivation is weak and the usage-right-seeking motivation is strong, consumers are more inclined to choose the sharing economy model. They prefer to satisfy their needs through leasing or sharing rather than purchasing product ownership. For example, for occasional short-distance travel needs, consumers may choose shared bicycles instead of buying a personal bicycle. This motivation directly determines their adoption of sharing economy consumption methods.

When the usage-right-seeking motivation becomes dominant, consumers flexibly select different types of sharing economy services according to their own needs and usage scenarios. For instance, they may choose shared cars for long-distance travel and shared electric scooters for short-distance instant delivery. This clearly demonstrates the guiding role of motivation on consumption methods.

3) The Moderating Effect of Social Attributes on Consumer Motivation, Consumption Methods, and Consumer Behavior

Influence on Consumer Motivation: Social attributes can enhance consumers' usage-right-seeking motivation. On sharing economy platforms, interactions and sharing behaviors among consumers—such as user reviews and recommendations—allow consumers to better understand the advantages and usage experiences of shared products, thereby stimulating their desire to try them.

Influence on Consumption Methods: Social attributes influence consumers' choice of consumption methods. Consumers may select sharing economy platforms or products based on recommendations and evaluations from their social circles.

Influence on Consumer Behavior: Social attributes affect consumers' purchase decisions, frequency of use, and satisfaction. Positive social interactions and sharing can increase consumers' trust and favorable feelings toward sharing economy platforms, thereby raising the likelihood of purchase decisions. At the same time, word-of-mouth communication within social circles also influences usage frequency. If people around

them are using a particular shared service, consumers are more likely to participate more frequently. In addition, social attributes can improve consumer satisfaction through user feedback and service improvements.

4) The Influence of Consumption Methods on Consumer Behavior

Purchase Decision: The choice of consumption methods directly affects consumers' purchase decisions. Convenient and personalized consumption methods, such as quickly searching for and booking shared products through mobile apps, increase the likelihood that consumers will purchase services. Conversely, complex consumption processes may deter consumers and reduce their purchase intention.

Usage Frequency: Well-designed consumption methods can increase consumers' frequency of use. For example, flexible rental periods and diversified billing options provided by sharing economy platforms can meet consumers' different usage needs, encouraging them to use shared products more frequently.

Satisfaction: A positive consumption experience enhances consumer satisfaction. If the service process on a sharing economy platform is smooth, easy to operate, and problems encountered during use can be resolved promptly, consumers will feel satisfied with the service, thereby increasing the likelihood of reuse.

5) The Feedback Influence of Consumer Behavior on Consumer Motivation, Social Attributes, and External Variables

Influence on Consumer Motivation: Consumers' behaviors, such as purchase decisions, usage frequency, and satisfaction, in turn affect their motivations. If consumers have a positive experience after using sharing economy services and report high satisfaction, their usage-right-seeking motivation will be further strengthened, making them more willing to continue using such services. Conversely, poor experiences may weaken their motivation.

Influence on Social Attributes: Consumer behavior influences social attributes. For example, after using sharing economy services, consumers often share their experiences and evaluations on social platforms. This sharing behavior enriches the content of social interactions and affects other consumers' social experiences and participation levels.

Influence on External Variables: Consumer behavior also exerts a certain feedback effect on external variables. For instance, high-frequency use of a particular shared service by a large number of consumers may prompt platforms to further optimize pricing strategies and improve service quality, thereby affecting economic and technical factors. Meanwhile, consumer behavior can also influence socio-cultural factors, promoting the dissemination and popularization of sharing economy concepts and changing societal consumption views and moral climate.

6. Problems and Suggestions

6.1 Issues of Unfair Competition and Monopoly

With the development of the sharing economy, mainstream platforms have excessively pursued traffic, leading to unfair competition phenomena such as traffic fraud and hijacking. A few enterprises control a large amount of traffic, which restricts the market expansion of smaller platforms and exacerbates resource waste. At the same time, large platforms accumulate customers through their advantages, resulting in significant income gaps among service providers and high consumption prices for consumers. These platforms also leverage technological advantages to implement data monopolies, consolidate their positions through mergers and acquisitions, and form monopoly loops, thereby harming consumer interests [1,7,9].

6.2 Issues of Imperfect Legal Framework

The sharing economy in China is still in its early stage. Relevant laws, regulations, and supervision are insufficient, and platforms have weak legal binding force, increasing the risk of fraud. Platform management faces challenges of credit and cultural deficiencies. Although it has promoted employment, problems such as low entry barriers and non-standardized operations exist, including the lack of business licenses and unclear labor relations. If not regulated promptly, these issues may have adverse effects on society [1,5,6,7,8,9].

6.3 Information Security Issues

Sharing economy platforms accumulate large amounts of user personal information during operations, including sensitive data such as identity, bank transaction records, and addresses. However, these platforms still face problems in information security, such as illegal collection, excessive acquisition, forced authorization, information misuse, and data breaches. Once these platforms are subjected to cyberattacks, users' private information faces serious leakage risks. In addition, some large-scale sharing platforms are controlled by foreign capital, which exposes national information security to risks of cross-border data flows and may even threaten the overall information security of the country, affecting national security [1,2,7].

6.4 Suggestions

1) Strengthen Laws and Regulations to Curb Unfair Competition and Monopoly

In view of the unfair competition and monopoly behaviors in the sharing economy, it is necessary to strengthen the construction of laws and regulations to ensure the healthy development of the sharing economy. First, existing laws and regulations should be comprehensively reviewed and improved to address their deficiencies, clearly distinguishing the legal boundaries between the general economy and the sharing economy. Based on general economic laws and regulations, targeted regulations should be formulated in combination with the characteristics of the sharing economy to clarify the scope of norms. At the same time, comprehensive guidance should be provided according to the development stage of the sharing economy to protect the legitimate rights and interests of all enterprises, especially non-mainstream enterprises. The publicity of laws and regulations should be strengthened to raise enterprises' awareness of rights protection, such as encouraging patent applications. Economic behaviors should be effectively constrained through legal means to create a rule-of-law environment conducive to the development of the sharing economy.

2) Build a Robust Information Security and Regulatory System to Ensure Steady Development

While the sharing economy is developing rapidly, it faces risks such as cybercrime and information leakage. To ensure its steady development, a comprehensive information security system should be established in conjunction with a credit system to effectively resist cyberattacks and safeguard user information security and transaction security. Information security is not only an important component of enterprise competitiveness but also the cornerstone of industry development. Therefore, various industries should establish detailed and diversified regulatory systems tailored to the characteristics of the sharing economy to ensure the healthy and sustainable development of the industry.

7. Conclusion

In summary, this study systematically explores the changes in consumer behavior under the sharing economy model, with particular attention to the rapidly developing sharing economy landscape in China. Through analyzing the shift in consumer motivation from ownership to usage rights, the personalization of consumption methods, and the enhancement of social attributes on sharing economy platforms, a deeper understanding of consumer behavior dynamics under this new economic paradigm has been achieved.

The research shows that the sharing economy has promoted the transformation of consumption patterns from ownership to usage rights, driven jointly by economic, social, and technological factors. The theoretical model indicates that consumer motivation (ownership-seeking and usage-right-seeking) influences purchase decisions, usage frequency, and satisfaction through consumption methods, with social attributes playing a moderating role and external factors indirectly affecting behavior. In response to the problems of unfair competition, imperfect legal frameworks, and information security facing China's sharing economy, it is recommended to strengthen regulatory construction, build information security systems, and cultivate a healthy social culture. Enterprises represented by Meituan Bike should optimize user experience, improve service quality, strengthen technological innovation and compliance management, pay attention to the shift in consumer motivation, optimize consumption methods with the help of technology, and enhance platform social attributes to increase user stickiness and competitiveness.

In the future, with the continuous development and maturation of the platform economy, the sharing economy model will play an even more important role in promoting efficient resource utilization and

sustainable development. As consumer behavior continues to evolve and technology advances, research on consumer behavior under the sharing economy model will also face new challenges and opportunities, requiring scholars to continuously explore and deepen their studies.

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Determinants of Stock Prices: A Quantitative Literature Review

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Abstract

Stock price behavior remains a central focus in financial economics, spanning macroeconomics, corporate finance, and behavioral finance. Traditional theory posits that stock prices reflect discounted future cash flows; however, empirical evidence shows that prices are also shaped by macroeconomic conditions, firm-level fundamentals, and investor sentiment. This paper provides a quantitative literature review of the determinants of stock prices, categorizing them into macroeconomic, microeconomic, and behavioral factors. Macroeconomic variables—such as interest rates, inflation, GDP growth, and policy interventions—affect market-wide valuations and volatility. Firm-specific fundamentals, including earnings, cash flow, leverage, and corporate governance, explain cross-sectional differences in returns, as captured by models like the Fama-French factor frameworks. Behavioral factors, such as overconfidence, herding, and loss aversion, account for deviations from fundamental values and market anomalies. Evidence suggests that no single factor alone fully explains stock price dynamics; instead, their interaction produces complex market behavior. The study highlights the need for integrated quantitative models that combine econometric, machine learning, and behavioral approaches to improve the understanding and modeling of stock price dynamics. Additionally, it identifies research gaps, including high-frequency data integration, cross-market spillovers, and the influence of algorithmic trading, pointing to future directions for more holistic frameworks in financial analysis.

Keywords

stock prices, macroeconomic indicators, firm fundamentals, investor sentiment, behavioral finance

1. Introduction

Stock prices are widely regarded as key indicators of economic health, corporate performance, and investor expectations [1]. They reflect both the perceived value of individual firms and aggregate information about broader market conditions. In modern financial markets, stock price formation has become increasingly complex, influenced by a dynamic interplay of macroeconomic fundamentals, firm-level characteristics, and investor behavior. Macroeconomic variables, such as interest rates, inflation, GDP growth, and monetary policy, shape expectations regarding future corporate earnings and risk-adjusted returns. Firm-specific fundamentals, including earnings, profitability, cash flow, leverage, and accounting quality, provide intrinsic signals about a company's operational efficiency, financial health, and growth potential. Meanwhile,

behavioural factors, such as investor sentiment, herding behavior, overconfidence, and reactions to news or social media, can drive short-term deviations from fundamental values [2].

Despite extensive empirical research, evidence on stock price determinants remains heterogeneous. Prior studies produce varying results due to differences in econometric models, market structures, time periods, and data frequency. Some research emphasizes macroeconomic conditions in shaping market-wide trends, while others highlight the predictive power of firm-level fundamentals. Behavioural finance studies show that psychological biases and sentiment can generate significant anomalies and short-term volatility, which cannot be fully explained by traditional models [3]. This divergence underscores the need for a comprehensive approach accounting for multiple dimensions simultaneously.

This study systematically reviews and synthesizes stock price determinants from a quantitative perspective, categorizing them into macroeconomic indicators, firm fundamentals, and behavioural factors. For each domain, it evaluates the explanatory power and directional effects of key variables, such as interest rates, inflation, GDP growth, earnings, book value, cash flow, investor sentiment, trading volume, and market volatility. Integrating these insights, the study develops a holistic framework for understanding stock price dynamics, bridging gaps between traditional asset pricing theory, empirical evidence, and behavioural finance.

The findings have significant implications for multiple stakeholders. For investors, understanding the combined influence of macroeconomic trends, firm fundamentals, and behavioural biases can inform portfolio allocation, risk management, and trading strategies. For corporate managers, insights into how fundamentals and market sentiment affect stock valuations guide financial planning, capital structure decisions, and performance evaluation. For policymakers and regulators, recognizing the interplay of macroeconomic conditions, market fundamentals, and investor behavior enhances market monitoring, policy design, and risk mitigation. Overall, this study contributes to a more nuanced understanding of stock price formation in complex and interconnected financial markets.

This study addresses the following research questions:

- (1) What are the key macroeconomic variables that influence stock prices, and how do they affect stock price movements across different market conditions?
- (2) To what extent do firm-level fundamentals, such as earnings, profitability, cash flow, and leverage, explain variations in stock prices from a quantitative perspective?
- (3) How do behavioural factors, including investor sentiment, trading activity, and market volatility, contribute to short-term stock price fluctuations beyond fundamental information?

2. Macroeconomic Factors Influencing Stock Prices

Macroeconomic variables establish the broader financial environment in which firms operate and investors allocate capital. They influence stock prices through both direct channels-such as discount rate adjustments-and indirect channels, including expectations about corporate earnings and risk premiums. Quantitative evidence indicates that macroeconomic indicators are crucial for explaining both market-wide valuation trends and volatility, and they are widely incorporated into econometric and asset-pricing models.

2.1 Interest Rates and Monetary Policy

Interest rates are a central determinant of asset pricing. Higher interest rates increase the cost of capital, reduce the present value of future cash flows, and typically exert downward pressure on stock prices. Empirical studies, including Fama and Schwert (1977) and Bernanke and Kuttner (2005), demonstrate that both expected and unexpected monetary policy adjustments have immediate and measurable impacts on stock returns. Moreover, interest rates influence investor allocation across asset classes, altering capital flows between equities, bonds, and alternative investments. This channel underscores the importance of monetary policy for both short-term market fluctuations and long-term investment strategies [4].

2.2 Inflation and Price Stability

Inflation affects corporate profitability, real returns, and market risk. While early studies suggested a positive correlation between nominal stock returns and inflation (Fisher, 1930), subsequent research indicates that higher inflation generally depresses stock prices in the short run due to increased uncertainty and diminished purchasing power [5]. Inflation also impacts discount rates and risk premiums, which are central to modern asset-pricing models. Furthermore, persistent inflationary pressures can affect investor expectations and market sentiment, influencing trading behavior and equity valuation over both short- and long-term horizons.

2.3 Economic Growth and Industrial Production

Indicators of real economic activity, such as GDP growth and industrial production, provide important signals about future corporate earnings and overall market conditions. Chen, Roll, and Ross (1986) and Fama (1990) show a bidirectional relationship, where stock returns can both reflect and predict economic activity. High economic growth generally increases expectations of cash flow, profitability, and corporate investment, thereby raising stock valuations, while economic slowdowns reduce earnings prospects and investor confidence, exerting downward pressure on stock prices [6]. These dynamics highlight the crucial role of real economic activity in shaping both short-term market sentiment and long-term valuation trends.

2.4 Exchange Rates and Global Integration

In increasingly globalized financial markets, exchange rate fluctuations can materially affect multinational firms' stock prices. Appreciation or depreciation of domestic currency influences export competitiveness, input costs, and earnings translation effects [7]. Empirical studies show that exchange rate volatility can impact both sector-specific and market-wide equity performance, especially in export-oriented economies. Additionally, international capital flows, foreign investment exposure, and trade linkages amplify the transmission of exchange rate movements to domestic stock markets, highlighting the interconnectedness of global financial systems.

In summary, macroeconomic factors provide a structural foundation for understanding stock price dynamics, shaping discount rates, earnings expectations, and market sentiment. An integrated consideration of interest rates, inflation, economic growth, and exchange rate movements is essential for comprehensive quantitative asset-pricing models and for informing investment, corporate, and policy decisions.

3. Firm Fundamentals and Stock Price Movements

Firm-specific characteristics capture the intrinsic value components of equity pricing and play a central role in explaining cross-sectional differences in stock returns. Empirical evidence consistently shows that financial performance, growth prospects, risk profiles, and corporate governance mechanisms are crucial determinants of stock price movements. Understanding these fundamentals is essential for both investors and corporate managers when assessing firm value and market behavior. Integrating these measures into quantitative models improves prediction accuracy and provides actionable insights for financial decision-making. Moreover, firm fundamentals interact with macroeconomic conditions and investor sentiment, meaning that comprehensive models must consider both internal and external influences to fully capture stock price dynamics.

3.1 Earnings and Profitability

Earnings per share (EPS), return on equity (ROE), and other profitability measures are key indicators of firm value. Studies after 2006 reinforce that high-quality earnings directly influence valuation precision and investor confidence. Strong profitability signals operational efficiency, sustainable cash flow, and growth potential, positively affecting stock prices. Firms with stable and predictable earnings also enjoy a lower cost of capital and higher valuation multiples across varying market conditions [8, 9]. Furthermore, consistently high earnings performance can attract institutional investors and improve market liquidity, amplifying the long-term impact of profitability on stock valuation.

3.2 Book Value, Cash Flow, and Growth Metrics

Book value, operating cash flow, and expected growth are central to quantitative valuation models. The residual income model shows that firm value depends on book value and abnormal earnings. Recent research finds that high book-to-market ratios and strong cash flows correlate with higher expected returns. Growth expectations influence investor perceptions, valuation multiples, and market pricing. Firms with robust cash flow and promising growth prospects are better positioned to withstand market shocks [10]. In addition, investors increasingly integrate forward-looking growth metrics, such as R&D intensity or strategic expansion plans, into valuation models, further enhancing the explanatory power of cash flow and book value measures.

3.3 Accounting Quality and Fundamental Signals

High-quality accounting reduces information asymmetry and improves valuation precision. Fundamental signals-including inventory levels, receivables, gross margins, R&D expenditures, and dividend policies-retain significant predictive power for stock returns. Transparent and reliable reporting attracts long-term investors and stabilizes valuations, demonstrating the interplay between disclosure, investor trust, and market efficiency. High-quality accounting also enables more accurate risk assessment and better portfolio allocation [11, 12]. Additionally, firms that adhere to high accounting standards tend to experience lower borrowing costs and improved governance ratings, reinforcing their overall financial stability and investor confidence.

3.4 Leverage and Capital Structure

Capital structure choices influence stock price volatility and sensitivity to macroeconomic shocks. Studies after 2006 show that high leverage increases financial risk and can amplify stock price fluctuations, especially in adverse market conditions. Prudent leverage management balances growth opportunities with risk mitigation, enhancing investor confidence and supporting sustainable long-term firm performance [13]. Moreover, optimal capital structure decisions can improve credit ratings and reduce the likelihood of financial distress, which in turn stabilizes stock prices and attracts long-term investment.

In a word, firm fundamentals-including earnings, cash flow, book value, accounting quality, growth metrics, and leverage-provide essential signals for intrinsic value estimation and cross-sectional return variation. Incorporating these metrics into quantitative models enhances predictive power, supports portfolio allocation, and guides effective corporate financial management. Importantly, the integration of these factors with macroeconomic and behavioral data enables a more holistic assessment of stock price movements, improving both investment decisions and strategic corporate planning.

4. Behavioral Factors and Market Sentiment

Behavioral finance highlights that psychological, social, and cognitive factors significantly influence stock price movements, particularly in the short term. Investor behavior can amplify price volatility, create persistent mispricing, and generate market anomalies that cannot be fully explained by fundamentals alone. Recent research emphasizes that integrating behavioral measures into quantitative models can improve explanatory power and predictive accuracy.

4.1 Investor Sentiment

Investor sentiment - reflecting aggregate optimism or pessimism beyond what fundamentals justify - has a measurable impact on stock returns. Recent global-scale evidence shows that elevated sentiment often precedes lower future returns, indicating possible overvaluation and subsequent correction [14]. In some markets, heightened sentiment is also associated with increased volatility in cash flows and discount rates, thereby affecting firm-level performance and valuation dynamics. This suggests that sentiment shocks can distort expected returns and undermine long-term performance, especially when sentiment is not anchored in fundamentals.

4.2 Trading Volume, Liquidity, and Volatility

High trading volume and low liquidity are often linked to increased price volatility. Shifts in investor attention, risk perception, and reactions to news events or external shocks frequently amplify these effects.

Recent studies using high-frequency market data and sentiment indices show that sudden sentiment changes can drive liquidity shortages and higher intraday volatility, particularly in emerging markets. Recognizing these behavioral drivers is critical for accurate volatility modeling and risk management [15].

4.3 Media, Social Networks, and Data-Driven Sentiment

Advances in machine learning and natural language processing enable extraction of real-time sentiment from news, financial reports, and social media. Positive or negative media coverage strongly influences investor perceptions and market behavior. Studies demonstrate that social media sentiment can predict short-term market movements and identify periods of irrational trading or herding behavior. Incorporating these alternative data sources into quantitative models enhances prediction accuracy and timeliness [16, 17].

4.4 Herd Behavior and Cognitive Biases

Herding occurs when investors follow the actions of others, often disregarding fundamentals, while cognitive biases like overreaction or underreaction contribute to short-term price misalignments. Recent evidence shows that institutional and retail investors alike exhibit stronger herding during high-sentiment or high-uncertainty periods, amplifying volatility and deviations from intrinsic value. Recognizing these behaviors is essential for modeling short-term anomalies and risk management in modern financial markets [18, 19].

To summarize, behavioral factors - including investor sentiment, trading volume and liquidity, social media-driven sentiment, herding, and cognitive biases - play a crucial role in stock price dynamics, especially in the short term. Integrating these behavioral determinants into quantitative models complements macroeconomic and firm-level fundamentals, enabling more accurate prediction of volatility, price deviations, and market anomalies across different time horizons.

5. Conclusion

This study integrates macroeconomic, firm-specific, and behavioral determinants to provide a comprehensive quantitative understanding of stock price dynamics. Macroeconomic factors-including interest rates, inflation, GDP growth, and exchange rate fluctuations-establish the broad market environment, shaping discount rates, earnings expectations, and investor sentiment. Firm fundamentals, such as earnings, cash flow, book value, accounting quality, and leverage, serve as intrinsic value signals, explaining cross-sectional variations in returns and providing guidance for corporate financial management. Behavioral factors, including investor sentiment, herding, overreaction, and media-driven information, account for short-term deviations from fundamental values, volatility, and market anomalies [20].

The integration of these determinants into unified quantitative models enhances forecasting accuracy and provides actionable insights for multiple stakeholders. Investors can improve portfolio allocation and risk management by accounting for macroeconomic shifts, firm-level signals, and behavioral patterns. Corporate managers benefit from understanding how fundamentals and market sentiment interact to influence valuation, informing capital structure and strategic decision-making. Regulators can strengthen market oversight and policy design by monitoring the interplay of economic conditions, corporate fundamentals, and behavioral drivers.

Future research should focus on incorporating high-frequency trading data, cross-market spillovers, algorithmic trading effects, and alternative data sources such as social media sentiment to refine predictive models. Additionally, exploring the dynamic interactions among macroeconomic shocks, firm fundamentals, and investor behavior can reveal complex systemic patterns, further improving both theoretical modeling and practical financial decision-making. Advancing interdisciplinary approaches that combine econometrics, machine learning, and behavioral finance will be critical for developing adaptive, real-time predictive frameworks capable of capturing evolving market dynamics and supporting sustainable market growth.

Ultimately, a holistic approach that integrates macroeconomic conditions, firm-specific fundamentals, and behavioral insights provides a robust foundation for resilient investment strategies, informed corporate governance, and effective financial market policies in increasingly interconnected global markets.

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Explaining Heterogeneous Effects of KOL–KOC Combinations: A Persuasion-Knowledge Framework for Multi-Source Influencer Marketing

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Abstract

Both key opinion leaders (KOLs) and key opinion consumers (KOCs) are frequently deployed by brands in short-video social commerce. In the existing studies on the effects of such multi-influencer combinations, there are various results ranging from synergy to no significant effect, and even negative consequences. This review synthesizes research on influencer marketing, multi-source information integration, and the Persuasion Knowledge Model (PKM) and develops a framework centered on consumers' interpretation processes to explain this heterogeneity. We hold the opinion that the combination of KOL and KOC is not inherently complementary. Its effectiveness depends on how consumers perceive the relationship between them. When the level of persuasion knowledge or skepticism is low, consumers are more likely to interpret multiple cues as independent confirmations, thereby enhancing the diagnosticity of perceived information and promoting purchase. When the level of persuasion knowledge is high, the same configuration is more likely to be interpreted as a coordinated persuasive behavior, thereby stimulating consumers' inference of the manipulative intention and psychological resistance, weakening or even reversing the persuasive effect. Integrating prior empirical and review evidence, we propose a dual-pathway, multi-source persuasion framework that explains when KOL–KOC combinations function as complements versus substitutes. By unifying diagnosticity-based information processing with reactance-based resistance mechanisms, this review clarifies the theoretical origins of heterogeneous influencer-mix effects and provides guidance for future research design and influencer portfolio strategies in short-video commerce.

Keywords

key opinion leaders (KOLs), key opinion consumers (KOCs), persuasion knowledge(PK), perceived diagnosticity, psychological reactance

1. Introduction

Short-video social commerce has transformed consumer decision-making from a linear “exposure–purchase” sequence into a multi-touch process that requires integrating information across sources. For instance, in a single decision-making process, consumers are often exposed to two distinct types of influencer cues: key opinion leaders (KOLs) (who convey professionalism and authority), and key opinion consumers (KOCs) (who emphasize peer similarity and real experiences). Therefore, the determinants of purchasing

decisions are shifting from the sole effect of a single source to how consumers integrate and interpret the information from multiple sources of influencers.

Although previous studies have shown that influencer marketing is generally effective on average, meta-analyses and review studies have also documented significant heterogeneity in effects across different contexts, types of influencers, and execution characteristics. This phenomenon is particularly evident in multi-influencer scenarios. The same KOL + KOC combination sometimes enhances perceived diagnosticity of information through cross-source verification, thereby generating a complementary effect; however, when consumers interpret this combination as redundant or strategically coordinated persuasion, it does not bring additional benefits and may even cause backlash. These results indicate that the KOL-KOC combination does not inherently have a synergistic effect; its impact depends on how consumers interpret the relationships between different sources.

This paper adopts the persuasion knowledge model (PKM) as the unified theoretical perspective and integrates relevant studies on KOL, KOC, and multi-source persuasion in short-video social e-commerce to explain the above inconsistencies. We propose that consumers' persuasion knowledge and their level of skepticism determine whether the combined KOL-KOC exposure is interpreted as independent confirmation - thereby enhancing perceived diagnosticity and promoting purchase - or as coordinated persuasion, thereby activating manipulation intention inference and psychological resistance, weakening or reversing the persuasive effect. By reviewing and integrating existing research, this paper (1) explains the sources of heterogeneity in the effect of KOL-KOC combinations, (2) proposes a multi-source influencer persuasion framework centered on the consumer interpretation process, and (3) provides theoretical guidance for future research on how to design experiments and how brands can combine influencer combinations.

2. Method: Literature Search and Selection Procedure

This study adopts a semi-systematic literature review approach, focusing on influencer marketing effectiveness, persuasion knowledge, and multi-source endorsement mechanisms. We conducted structured searches in Web of Science, Scopus, EBSCO Business Source Complete, and Google Scholar. The review covers relevant studies published between 1994 (the year the Persuasion Knowledge Model was introduced) and 2025.

To ensure comprehensive coverage, backward and forward citation tracking was conducted for foundational and high-impact studies.

The inclusion criteria were peer-reviewed journal articles published in English that examined influencer effectiveness or endorsement mechanisms and involved identifiable psychological processes (e.g., diagnosticity, persuasion knowledge activation, authenticity, disclosure effects, or psychological reactance). Industry reports, conference abstracts, and purely descriptive analyses lacking theoretical grounding were excluded.

The initial search yielded 386 records. After removing duplicates, 301 unique articles remained. Title and abstract screening reduced the sample to 124 studies addressing influencer heterogeneity, persuasion knowledge, or multi-source persuasion. Following full-text evaluation, 68 articles met the inclusion criteria. Among these, 20 core studies were identified as foundational for theoretical integration.

The retained studies were coded along five dimensions: (1) influencer type, (2) focal mechanism, (3) mediating variables, (4) moderating conditions, and (5) outcome variables. Through comparison and analysis, two primary explanatory pathways were identified, which form the organizing structure of the subsequent theoretical framework. The first is a positive mechanism, whereby perceived source independence enhances information diagnosticity and strengthens persuasive outcomes. The second is a negative mechanism, whereby perceived coordination triggers manipulative intent attribution and psychological reactance, thereby reducing persuasive effectiveness.

3. Literature Review and Conceptual Development

3.1 Influencer Types as Distinct Source Signals in Short-Video Commerce

In short-video social commerce, consumers use creator attributes (such as follower count, verification badges, profile labels, and stylistic presentation) as cues to make initial judgments about credibility. Research consistently distinguishes between more professionalized, large-scale influencers and smaller, peer-like creators, and shows systematic differences between these two groups in engagement patterns and conversion outcomes [1, 2]. Key opinion leaders (KOLs) are typically associated with expertise, authority, and professional credibility. Empirical evidence indicates that when credibility cues are salient, top-tier/macro influencers tend to generate greater exposure and translate their strategic positioning into performance outcomes [3]. Key opinion consumers (KOCs), by contrast, are more akin to peer-based electronic word-of-mouth, emphasizing lived experience and perceived authenticity [4]. Meta-analytic research finds that influencer marketing effectiveness varies with source characteristics, indicating that source type fundamentally shapes the persuasion process rather than merely expanding exposure reach [1]. Therefore, distinguishing between KOLs and KOCs reflects differences in the dominant inference mechanisms consumers rely on: competence-based trust versus identification-based trust.

Table 1: Conceptual Differences Between KOL and KOC Source Cues

Dimension	KOL	KOC
Core Signal	Expertise / Authority	Similarity / Authenticity
Platform Indicators	Verification badge, high follower count	Ordinary profile, lifestyle framing
Primary Trust Mechanism	Competence-based trust	Identification-based trust
Potential Risk	Perceived commercialization	Limited technical credibility

3.2 Multi-Source Influence: Complementarity Versus Redundancy

When consumers are exposed to information from multiple sources, persuasive effects are not necessarily additive. Research on informational diagnosticity suggests that when convergent evaluations come from sources that are independent of one another, they increase perceived reliability and improve consumer decision-making under uncertainty [5]. Moreover, multi-endorser research indicates that when different endorsers provide complementary signals, the effect is more pronounced than in single-source designs [6].

However, multi-source exposure can also backfire. Evidence from seeded word-of-mouth campaigns shows that coordinated promotional efforts may generate nonlinear spillover effects and even produce counterproductive outcomes [7]. In other words, when multiple persuasive cues are interpreted by consumers as “strategic coordination” rather than “mutual independence,” adding additional sources does not increase value and may instead have the opposite effect.

Therefore, in influencer marketing contexts, joint KOL–KOC exposure may operate in two ways: it can serve as cross-source corroboration that strengthens informational diagnosticity, or it can be perceived as redundancy or strategic persuasion that attenuates impact. Even though meta-analytic research documents substantial heterogeneity in influencer marketing effectiveness [1], it still cannot fully explain why these opposing outcomes occur. This suggests that the key to understanding whether multi-influencer combinations are complementary or offsetting lies in how consumers interpret them.

3.3 Persuasion Knowledge and Skepticism as Boundary Conditions

The Persuasion Knowledge Model (PKM) proposes that consumers draw on their knowledge of persuasive intent and tactics to interpret influence attempts [8]. When persuasion knowledge is activated, individuals are more likely to attribute commercial motives and discount message claims. In influencer contexts, sponsorship disclosures and commercialization cues significantly shape audience responses [9]. The salience of advertising elements further determines whether persuasion knowledge activation attenuates message effectiveness [10]. In addition, advertising skepticism represents a chronic tendency to doubt promotional claims, reinforcing discounting processes [11].

Thus, the same KOL–KOC combination may be interpreted differently depending on consumers' level of persuasion knowledge. When persuasion knowledge is low, multiple influencer cues are more likely to be construed as independent confirmation; when persuasion knowledge is high, the same combination is more likely to be interpreted as “coordinated persuasion.” This boundary-condition logic explains the contradictory findings in prior influencer research.

3.4 Manipulative Intent and Psychological Reactance

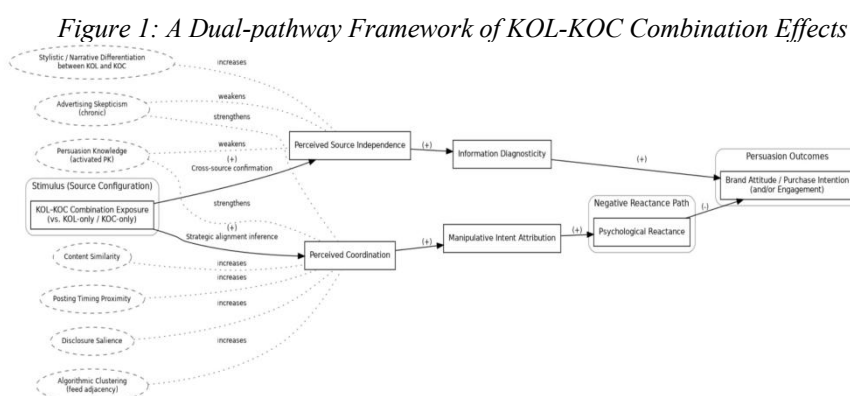
When persuasive attempts are perceived as strategically manipulative, resistance processes may emerge. Reactance theory posits that perceived threats to autonomy trigger motivational states aimed at restoring freedom [12]. Empirical evidence shows that inferences of manipulative intent increase psychological reactance and reduce persuasion effectiveness [13]. In influencer marketing, overt commercial coordination or excessive brand control can strengthen such resistance responses. Research further indicates that some consumer segments, particularly younger audiences, actively avoid influencers and endorsed brands when persuasion attempts appear overly commercialized [14]. Thus, multi-influencer exposure may not only increase informational input but also amplify perceptions of orchestration, activating reactance mechanisms that suppress persuasion.

3.5 Conceptual Integration: A Dual-Pathway Account of KOL–KOC Combinations

Synthesizing the preceding literature, KOL–KOC combinations may either enhance informational diagnosticity and promote purchase intentions when they are perceived as “independent” [5], or weaken persuasion when they are perceived as “strategically coordinated,” thereby eliciting attributions of manipulative intent and psychological reactance [12]. Accordingly, persuasion knowledge determines which interpretation consumers are more likely to adopt, helping explain heterogeneity in outcomes [1, 8].

3.6 Theoretical Structure of the Dual-Pathway Model

Building on the above, we formally conceptualize KOL–KOC combinations as a stimulus configuration that influences persuasion outcomes through two sequential mediation chains. In the positive pathway, KOL–KOC combinations enhance perceptions of source independence, increase perceived informational diagnosticity, and further strengthen brand attitudes and purchase intentions [5]. In the negative pathway, KOL–KOC combinations increase perceived “coordination,” reinforce attributions of “manipulative intent,” trigger psychological reactance, and ultimately weaken persuasion outcomes [12]. Because these two pathways are competing yet may co-occur, the overall persuasive outcome depends on the relative strength of “diagnosticity enhancement” versus “reactance activation.” Persuasion knowledge and advertising skepticism moderate the inference stage, shaping whether consumers construe multi-source exposure as independent confirmation or coordinated persuasion [8].



4. Propositions

P1 (Diagnostic Path)

When consumers perceive KOL and KOC as independent sources, the combination enhances perceived information diagnosticity, which increases purchase intention.

P2 (Reactance Path)

When consumers infer coordination between KOL and KOC, the combination increases perceived manipulative intent, which triggers psychological reactance and reduces purchase intention.

P3 (PK Moderation – Positive Path)

The positive diagnostic pathway is stronger among consumers with low activated persuasion knowledge.

P4 (PK Moderation – Negative Path)

The negative reactance pathway is stronger among consumers with high persuasion knowledge.

P5 (Contextual Moderation – Coordination)

Greater disclosure salience, higher content similarity, and shorter posting intervals increase perceived coordination, thereby strengthening the negative pathway.

P6 (Differentiation Moderation)

Greater stylistic and narrative differentiation between KOL and KOC increases perceived independence and strengthens the positive pathway.

5. Research Implications and Future Directions

5.1 From Influencer Types to Multi-Source Interpretation

Most influencer research compares source types or disclosure formats as isolated variables [1, 2], thereby implicitly treating multi-influencer exposure as an “additive” effect. This review proposes a shift in research focus from “which influencer is more effective” to “how consumers interpret the relationships among multiple sources.”

Future research should conceptualize influencer combinations as cue configurations rather than as cumulative exposure counts. In particular, perceived source independence—central to informational diagnosticity [5]—should be measured directly rather than assumed. Integrating persuasion knowledge theory [8] into multi-source contexts enables scholars to model persuasion as an interpretation-driven process rather than an outcome driven solely by source characteristics.

5.2 Testing Competing Mechanisms

The dual-pathway framework identifies two mechanisms: enhanced informational diagnosticity [5] and psychological reactance triggered by perceived manipulation [12, 13]. Prior influencer research has rarely examined these two processes simultaneously. To determine when complementarity and backlash may co-exist, future research should measure diagnosticity, manipulative intent, and reactance within the same research design. In addition, insights from spillover research suggest that coordination cues may produce nonlinear effects, linking micro-level resistance processes with macro-level campaign diffusion dynamics [7].

5.3 Improving Multi-Source Research Design

Methodologically, multi-influencer research must address recurring confounds. First, exposure duration should be held constant to isolate source effects, because execution characteristics of short-form video can directly influence purchase behavior [15]. Second, differences in production quality across influencer types should be controlled to avoid conflating “professionalism” with “persuasive strength” [3]. Third, combining experiments with platform behavioral data can enhance external validity and help explain the heterogeneity documented in meta-analyses [1, 2].

5.4 Extending the Context: Algorithms and Audience Heterogeneity

Short-video persuasion unfolds within algorithmically curated environments. Recommendation systems shape the order and clustering of exposure, which may influence perceptions of “coordination” and subsequent interpretation. Future research should test how sequencing and presentation structure moderate multi-source persuasion effects. In addition, generational and individual differences also matter. Evidence suggests that younger consumers may be more sensitive to commercial cues and avoidance tendencies [14]. Future research should examine how consumers’ interpretive tendencies dynamically evolve with repeated exposure to influencer ecosystems. To guide future inquiries, we propose a structured research agenda with specific research questions, designs, and expected contributions, as summarized in Table 2.

Table 2: Future Research Agenda and Recommended Designs

Research Question	Core Constructs	Suggested Design	Recommended Context	Expected Contribution
When do KOL–KOC combinations increase perceived source independence versus coordination?	IV: KOL–KOC exposure; Mediator: independence/coordination; DV: attitude/purchase	2×2 experiment manipulating “relationship cues” (independent vs coordinated)	Short-video commerce (TikTok/Douyin)	Directly validates the inference stage in Figure 1
Does disclosure salience shift consumers from diagnosticity to reactance?	Moderator: disclosure salience; Mediators: PK, coordination; DV: purchase/engagement	Experiment: disclosure prominence × KOL–KOC exposure	Sponsored short videos	Links disclosure literature to dual-pathway mechanism
How does content similarity (script, visuals, claims) shape coordination inference?	Moderator: content similarity; Mediator: coordination; DV: persuasion	Stimulus-based experiment with controlled similarity levels	Brand campaigns with multiple creators	Operationalizes “coordination cues” more precisely
Does posting timing proximity (same day vs spaced) intensify perceived orchestration?	Moderator: timing proximity; Mediator: coordination; DV: reactance	Field experiment / quasi-experiment using campaign schedules	Short-video campaigns	Connects campaign planning to consumer inference
Do platform recommender systems amplify coordination perceptions via feed adjacency?	Moderator: algorithmic clustering; Mediator: coordination; DV: reactance/avoidance	Platform simulation / A/B test: feed adjacency vs dispersed exposure	TikTok/Douyin feed	Extends PKM into algorithmic context
How do KOC vs micro-influencer boundaries affect the independence pathway?	Source type operationalization; Mediator: independence; DV: diagnosticity	Multi-cell experiment varying follower counts + “consumer identity” cues	Social commerce	Clarifies conceptual boundary and improves external validity
Which consumer traits make the negative pathway dominant even without clear coordination cues?	Moderator: skepticism/trait reactance; Mediators: manipulative intent/reactance	Survey + experiment (measured traits × manipulated cues)	Gen Z vs older cohorts	Individual-difference boundary conditions
Can narrative differentiation (different evidence types, story style) rescue KOL–KOC synergy under high PK?	Moderator: differentiation; Mediators: independence/coordination; DV: purchase	Experiment: differentiation high/low × PK activation	Sponsored video pairs	Practical design lever to reduce backlash

6. Managerial Implications

The findings synthesized in this review suggest that multi-influencer strategies should be managed as interpretive configurations rather than as simple exposure multipliers. How audiences interpret the relationship between sources determines whether KOL–KOC combinations are effective.

6.1 Designing Influencer Portfolios Strategically

Managers should treat KOLs and KOCs as distinct signaling assets rather than interchangeable promotional tools. For audiences with lower persuasion knowledge or skepticism, combining KOL authority with KOC-style experiential validation can increase informational diagnosticity, reduce decision uncertainty, and improve conversion outcomes. In contrast, for audiences with higher persuasion knowledge, the same mix may be perceived as orchestrated; coordinated posting, highly similar scripts, or uniform disclosure formats can heighten manipulative-intent perceptions. Managers should therefore reduce visible coordination and increase differentiation across influencer voices to preserve perceived source independence.

6.2 Managing Commercial Salience and Platform Execution

In many markets, advertising/sponsorship disclosure is legally required [9], but how it is presented shapes audience interpretation. Compared with highly attention-grabbing cues that emphasize commercial intent, clearer and less “sensational” disclosure formats are more likely to reduce reactance; meanwhile, excessive brand control over content can also heighten perceived “coordination.” Because short-video platforms are algorithmically curated, managers should also coordinate exposure sequencing and presentation structure: dense deployment of multiple influencers within a short period may increase perceived coordination, whereas spacing exposures out and differentiating them across time, content, and context can better preserve perceptions of “independence.”

Accordingly, managers should strike a balance between transparent compliance and creative autonomy, and—considering platform-driven presentation patterns and potential spillover effects [7]—avoid amplifying the salience of persuasive intent; evidence likewise suggests that excessive commercialization increases resistance, especially among younger audiences [14].

6.3 Audience Segmentation and Long-Term Strategy

Finally, influencer-mix effectiveness is contingent on audience heterogeneity. Generational cohorts and digitally sophisticated consumers may be more sensitive to persuasion tactics [14]. Rather than assuming uniform responses, managers should segment audiences based on skepticism levels, platform familiarity, and prior exposure to influencer marketing. Over time, repeated exposure to influencer ecosystems may increase persuasion knowledge. Sustainable strategy thus requires adaptive portfolio management rather than static multi-influencer deployment.

7. Conclusion

This review addresses a central question in influencer marketing: why do KOL–KOC combinations sometimes create synergy and at other times generate backlash? Rather than treating multi-influencer strategies as inherently additive, we propose an interpretation-centered framework that explains heterogeneous outcomes through competing psychological pathways.

We conceptualize joint KOL–KOC exposure as a multi-source cue configuration whose effectiveness depends on how consumers construe relationships between sources. When perceived as independent confirmation, combined exposure enhances informational diagnosticity and strengthens purchase judgments. When perceived as coordinated persuasion, the same configuration increases manipulative intent attributions and psychological reactance, thereby attenuating or even reversing persuasive effects. Persuasion knowledge and skepticism determine which pathway prevails.

By shifting attention from source-type comparisons to consumer interpretation processes, this review offers a theoretically integrated account of multi-source influencer persuasion. Complementarity versus redundancy is not an inherent property of influencer combinations, but a consequence of audience inference. This

perspective helps reconcile conflicting findings in prior research and underscores the importance of examining perceived source relationships rather than exposure counts.

More broadly, in digitally mediated commerce environments, persuasion effectiveness depends increasingly on how audiences interpret networks of influence rather than isolated endorsements. As influencer ecosystems evolve within algorithmically curated platforms, understanding these interpretive dynamics becomes essential for both theory and strategic practice.

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Research on Using Innovation to Address Poverty and Educational Inequality from a Socio-Economic Perspective

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Abstract

Poverty and educational inequality persist as two of the most formidable barriers to global sustainable development, forming a self-perpetuating cycle that undermines both social equity and economic prosperity. Grounded in the theoretical framework of socio-economics, which interrogates the intricate interplay between economic actions and social structures, this paper provides a comprehensive and systematic analysis of the mechanisms through which technological, institutional, and social innovations can effectively disrupt this cycle. The research argues that innovation serves not merely as a tool for incremental improvement but as a transformative force capable of reconfiguring resource allocation, dramatically lowering educational costs, and enhancing long-term social mobility. Through a mixed-methods approach that incorporates theoretical exposition, detailed global case studies, and critical policy evaluation, this study elucidates the pathways of impact and identifies key success factors. The findings robustly demonstrate that multi-stakeholder, integrated innovation strategies yield the most sustainable outcomes. Consequently, the paper proposes a multi-tiered set of actionable solutions and implementation pathways, offering an evidence-based reference for policymakers, private sector actors, and civil society organizations committed to forging inclusive, knowledge-based societies in line with the United Nations Sustainable Development Goals (SDGs).

Keywords

socio-economics, poverty alleviation, educational equity, innovation mechanisms, sustainable development

1. Introduction

The symbiotic relationship between poverty and educational inequality constitutes one of the most persistent and complex challenges of our time. This vicious cycle ensures that poverty limits access to quality education, while a lack of education, in turn, perpetuates poverty across generations. Despite decades of global effort, traditional poverty alleviation models—characterized by direct financial transfers, large-scale infrastructure projects, and standardized educational inputs—have achieved only partial success. While these approaches have alleviated immediate suffering, they have often failed to address the underlying structural and systemic barriers that reproduce inequality.

The socio-economic perspective offers a more nuanced and powerful analytical lens. It moves beyond purely economic metrics to understand how economic behaviors are embedded within, and shaped by, social institutions, norms, and relationships. This perspective recognizes that solving poverty and educational inequality requires interventions that simultaneously alter economic incentives and transform social structures. In this context, innovation emerges as a critical lever for change. This paper posits that targeted innovations—spanning technology, institutions, and social organization—can create disruptive positive shifts in the ecosystem of learning for the marginalized.

This study aims to achieve three primary objectives: first, to delineate the socio-economic linkages between poverty and education with greater theoretical depth; second, to dissect the operational mechanisms of diverse innovations through robust empirical examples; and third, to synthesize a coherent set of policy and practice recommendations that are both visionary and pragmatically grounded. The scope of the paper is global, drawing lessons from contexts as diverse as China, South Asia, Africa, and Latin America, to construct a universally relevant, yet contextually sensitive, framework for action.

2. Socio-Economic Analysis of Poverty and Educational Inequality

2.1 The Multidimensional Nature of Poverty and Its Impacts

The contemporary understanding of poverty, championed by Nobel laureate Amartya Sen, defines it fundamentally as a “capability deprivation.” This paradigm shift from an income-centric to a capability-centric view reveals poverty as a multifaceted phenomenon encompassing the denial of freedoms and opportunities to live a valued life. Its impacts on education are profound and direct:

Educational deprivation poses a severe threat to children in impoverished households, as education is often a luxury they cannot afford [1].

For children in impoverished households, education is often a luxury. Direct costs (tuition, uniforms, books) and massive opportunity costs (foregone child labor or domestic chores) present insurmountable barriers. Even when children are enrolled, the pressure to contribute to family survival can lead to chronic absenteeism and early dropout.

Health risks and impaired cognitive development are inherent consequences of poverty for vulnerable children. Poverty is inextricably linked to food insecurity and inadequate access to healthcare. Chronic malnutrition in early childhood, including micronutrient deficiencies, can cause irreversible damage to brain development, leading to lower IQ, impaired executive functions, and reduced ability to concentrate in school. This creates a biological deficit that even the best schools struggle to overcome [2].

Social capital deficits and lasting psychological scars are often overlooked yet devastating impacts of childhood poverty. Beyond material lack, poverty often entails social exclusion and a lack of supportive networks. Children from poor families may lack role models, mentors, and the social connections that facilitate access to opportunities. Furthermore, the chronic stress of economic precarity can lead to “scarcity mindset,” reducing cognitive bandwidth available for learning and long-term planning [3].

2.2 The Transmission Mechanisms of Educational Inequality

Educational inequality acts as a primary engine for the intergenerational reproduction of social stratification. The mechanisms of this transmission are both powerful and self-reinforcing:

Disparities in human capital accumulation arise because the quality of education for children from low-income backgrounds is typically vastly inferior, featuring overcrowded classrooms, underqualified teachers, a lack of teaching materials, and irrelevant curricula, which results in significant gaps in foundational skills and higher-order competencies and severely hampers employment competitiveness in a knowledge-based global economy [4].

Obstructed social mobility occurs as the education system, when stratified, reinforces existing class divisions by making elite universities—often gatekept by high costs and entrance exams biased towards privileged backgrounds—out of reach, trapping low-income groups in low-skill, low-wage employment and cementing class solidification [5].

Macroeconomic constraints on national development are evident as severe educational inequality, which World Bank (2020) research indicates can reduce a country's annual GDP growth rate by 0.5 to 1.2 percentage points, prevents nations from fully developing human capital potential, leading to a less skilled workforce, lower productivity, reduced innovation, and diminished global competitiveness, thereby creating a vicious cycle of poverty and constrained growth [3].

3. Mechanisms of Innovative Solutions

3.1 Technological Innovation: Democratizing Access and Personalizing Learning

Technology holds the potential to leapfrog traditional infrastructure limitations and deliver quality education at scale and at low cost [1].

Digital Education Platforms: Massive Open Online Course (MOOC) platforms like Coursera, edX, and Khan Academy have made high-quality courses from top universities accessible to millions in impoverished regions. The key innovation is the decoupling of content from physical institutions. However, challenges remain in credentialing, localization, and ensuring completion rates [5].

Mobile Learning Technologies: In regions with high mobile phone penetration but limited internet, SMS-based learning has proven remarkably effective. Africa's "Eneza Education" project delivers quizzes, lessons, and teacher support via SMS, reaching over 6 million students in Kenya, Ghana, and Côte d'Ivoire. This leverages existing technology to bridge the last mile of educational delivery [2].

AI-Assisted and Adaptive Learning: Artificial Intelligence is revolutionizing personalized education. Adaptive learning systems, such as India's "Mindspark" project, use algorithms to diagnose a student's precise learning level and gaps in real-time, then serve up customized exercises and content. Trials have shown dramatic improvements in learning outcomes, effectively replicating the benefits of one-on-one tutoring in a scalable, affordable format [4].

3.2 Institutional Innovation: Re-architecting Support Systems

Institutional innovations rewire the rules, incentives, and financial structures that underpin the education system [3].

Educational Finance Innovations are demonstrated by microfinance for education, Bangladesh's "Grameen Bank" and similar institutions offer education loans to poor families, demonstrating that the poor are bankable. Their high repayment rates (e.g., 98%) challenge conventional banking wisdom and provide a sustainable model for financing education [6].

Mobile money and savings have been innovated through platforms like Kenya's "M-PESA" platform, which has been leveraged to create dedicated education savings plans. The ease and discipline of mobile savings have been shown to increase tuition payment rates by 27%, helping families plan for and prioritize educational expenses [2].

Policy innovations include Conditional Cash Transfers (CCTs): Brazil's "Bolsa Família" program is a landmark policy that provides cash transfers to poor families conditional on their children's school attendance and health check-ups. This directly addresses the opportunity cost of education and has significantly boosted enrollment and attendance rates, particularly for girls.[3]

Targeted vocational training is a key policy innovation, as seen in China's "Rain and Dew Plan", which focuses on providing practical vocational skills to poor youth and adults, aligning training with local labor market demands. This enhances employability and provides a direct pathway out of poverty through skilled employment [7].

3.3 Social Innovation: Harnessing Community and Corporate Capital

Social innovations mobilize and reorganize human and financial resources within and for communities [6].

Resource integration models are exemplified by community volunteer networks like India's "Pratham" initiative, one of the world's largest non-governmental education organizations, which recruits and trains

thousands of community volunteers to deliver accelerated learning programs. Its “Read India” campaign has been instrumental in improving child literacy rates by up to 40% in intervention areas, proving the efficacy of hyper-local, low-cost solutions [3].

Pedagogical Models for Rural Schools have been transformed by Colombia’s “Escuela Nueva” (New School) model transformed rural multigrade schools from teacher-centric lecture halls into interactive, self-directed learning environments. It uses flexible promotion, student government, and tailored learning guides, significantly enhancing educational quality and student retention [1].

Corporate Participation Mechanisms are demonstrated through large-scale digital literacy programs like Microsoft’s “Digital Skills Program” has trained over 80 million people globally in foundational and advanced digital skills. This corporate social responsibility initiative addresses a critical skills gap, enhancing employability and economic participation [4].

Corporate-Facilitated Infrastructure is illustrated by initiatives like Alibaba’s “Rural Education Initiative”, which establishes digital learning centers in remote Chinese villages, providing not just hardware but also curated educational content and teacher training, effectively acting as a catalyst for digital inclusion [7].

4. Case Studies

4.1 China’s “Internet + Education Poverty Alleviation” Model: A Systemic Approach

China’s large-scale, state-led integration of digital technology into its poverty alleviation strategy offers a compelling case study in systemic intervention [7].

Policy Framework and Implementation was demonstrated by the Chinese government’s multi-pronged strategy, which included the “Special Program for Digital Education in Deeply Impoverished Regions” and the comprehensive “Digital Education Resources for All Teaching Sites” project. The strategy was not merely about hardware provision; it involved creating a vast ecosystem of localized digital content, mandatory teacher training on digital pedagogy, and the development of public-private partnerships with tech firms like Tencent and Alibaba [7].

Outcomes and measured impact are evidenced by significant infrastructural achievements. The infrastructural achievement is undeniable: over 98% of impoverished counties achieved high-speed internet coverage, connecting over 40,000 rural schools. Distance learning platforms now benefit approximately 4 million rural students, giving them access to specialized courses (e.g., foreign languages, advanced sciences) that their local schools could never offer. Empirical studies have begun to show a positive correlation between the intensity of these interventions and improvements in standardized test scores in beneficiary areas. However, challenges of teacher readiness, content quality control, and maintaining the technological infrastructure persist [5, 7].

4.2 Innovative Mobile Education Practices in Africa: Leapfrogging with Technology

Africa’s mobile education revolution demonstrates how technological leapfrogging can bypass traditional developmental stages [2].

Diverse technology applications include mobile reading platforms like South Africa’s “FunDza” mobile reading platform, which is designed to foster a culture of reading by providing a library of relatable, locally relevant stories and novels accessible via low-cost mobile phones. It serves over 500,000 users, using data-driven analytics to understand reading habits and preferences [1].

Peer-to-peer learning platforms are exemplified by Nigeria’s “Tuteria” platform is a peer-to-peer marketplace that connects learners with vetted local tutors for in-person or online sessions. It efficiently utilizes underutilized human capital (university students, professionals) within communities, making tutoring affordable and accessible [6].

Supportive institutional environment is crucial for the success of educational technologies. The success of these technologies is not happening in a vacuum. Proactive government policies have been crucial. Rwanda has ambitiously integrated coding and computational thinking into its national basic education curriculum,

preparing its youth for the future of work. Similarly, Ghana has established a comprehensive national digital education policy framework, providing the strategic direction and coordination necessary for scalable and sustainable impact [4].

5. Policy Recommendations and Implementation Pathways

5.1 Government-Led Multidimensional Interventions

Governments must act as strategic facilitators and regulators, creating an enabling environment for innovation to flourish [2].

Infrastructure Development as a Public Utility requires treating educational connectivity as a 21st-century utility. This involves not just achieving full 4G/5G and broadband internet coverage in impoverished regions by 2030 but also ensuring energy access. Furthermore, governments should invest in “education digital twin” monitoring systems—dynamic, data-rich virtual models of the education system—to simulate policy impacts, track resource allocation in real-time, and predict dropout risks [4].

Policy and Funding Innovations should be pioneered by governments through new financing mechanisms. Governments should pioneer new financing mechanisms. Hybrid models like “education vouchers” (giving families choice) combined with “performance-based funding” for schools can drive quality and efficiency. Piloting “Social Impact Bonds” (SIBs) for education poverty alleviation can attract private capital, with investors being repaid by the government only if pre-defined, measurable social outcomes (e.g., improved graduation rates) are achieved [3].

5.2 Market-Driven Innovation Applications

The private sector’s agility, resources, and innovation capacity are indispensable.[6] Context-Appropriate Product Development capitalizes on a significant market opportunity by developing ultra-low-cost, durable smart learning devices (e.g., sub-\$50 tablets) and developing highly effective education apps that are lightweight, operable offline, and consume minimal data. These products must be designed with the user constraints of low-income environments in mind [1].

Sustainable and Impact-Focused Business Models advocate for moving beyond traditional CSR, businesses should adopt “pay-for-success” or “impact sourcing” models. Fostering a vibrant ecosystem of social enterprises in education technology (EdTech) that are driven by a double bottom line—social impact and financial sustainability—can lead to more resilient and scalable solutions [4].

5.3 Collaborative Engagement of Social Forces

Sustainable change requires deep-rooted community ownership and international solidarity [8].

Community Network Building and Capacity Development requires efforts. Efforts must focus on cultivating “local education innovators”—teachers, parents, and youth leaders who can champion change from within. Establishing “parent education cooperatives” can pool resources for shared educational needs, provide a collective voice for advocating better services, and strengthen the home-school connection [3].

Strengthened International Cooperation is necessitated by the complexity of these challenges, which necessitates global collaboration. Forming a “Global Education Innovation Alliance” could facilitate the sharing of open-source educational resources, best practices, and research findings. Establishing a dedicated “South-South Education Cooperation Fund” would provide targeted financial and technical support for pilot projects and scale-up of proven innovations across developing countries [1, 2].

6. Conclusion

This study conclusively affirms that innovation, when understood through a socio-economic lens, is a potent and essential key to breaking the entrenched cycle of poverty and educational inequality. The analysis of technological, institutional, and social innovations reveals a common thread: success hinges on their ability to be context-sensitive, human-centered, and integrated into a broader ecosystem of change. Isolated

technological fixes or top-down policy mandates are insufficient; the future lies in synergistic approaches that leverage the unique strengths of governments, markets, and communities [5, 6].

Looking ahead, four critical areas demand sustained focus and research:

Firstly, systemic policy integration. Future innovation policies must be deliberately woven into national education, economic, and social welfare strategies to ensure coherence and maximize synergistic effects [2].

Secondly, rigorous long-Term impact evaluation. There is an urgent need to move beyond anecdotal evidence and establish robust, longitudinal monitoring and evaluation frameworks to rigorously assess the long-term social and economic returns on innovation investments in education [3].

Thirdly, cultivation of cross-sectoral innovation ecosystems. Fostering physical and virtual spaces where educators, technologists, entrepreneurs, policymakers, and community leaders can collaborate is crucial for generating the next wave of disruptive solutions [4].

Finally, proactively addressing ethical risks is crucial. As technology plays an ever-larger role, society must proactively confront the risks of algorithmic bias, data privacy violations, and the widening of the digital divide. Ethical guidelines and inclusive design principles must be at the forefront of all innovation efforts [1].

The path forward is complex, but the evidence is clear. A deliberate, collaborative, and ethically grounded pursuit of innovation offers the most promising pathway to a more equitable and educated world.

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AI-Driven Consumer Behavior Prediction and Brand Relationship Marketing: Technological Applications and Theoretical Mechanisms

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Abstract

Artificial intelligence (AI) has increasingly been applied in marketing to predict consumer behavior and enhance personalized interactions. While existing research emphasizes technological efficiency and predictive accuracy, limited studies systematically examine how AI-driven consumer behavior prediction influences long-term brand relationship marketing. This study provides a narrative literature review to analyze the theoretical mechanisms connecting AI capability, customer engagement, and brand relationship outcomes. Drawing upon customer journey theory, customer engagement theory, and customer equity theory, this paper proposes that engagement serves as a mediating mechanism between AI-driven personalization and brand performance. Furthermore, trust and data privacy concerns are identified as moderating factors shaping the effectiveness of AI-enabled marketing strategies. By integrating technological and relational perspectives, this study clarifies the theoretical foundation of AI in relationship marketing and identifies future research directions for empirical validation.

Keywords

artificial intelligence, consumer behavior prediction, customer engagement, brand relationship marketing, trust

1. Introduction

The rapid development of artificial intelligence (AI) has significantly transformed marketing practices. Firms increasingly adopt machine learning algorithms and predictive analytic tools to forecast consumer preferences, optimize targeting strategies, and personalize customer experiences. These technologies allow firms to analyze large-scale behavioral data and generate real-time marketing responses. Prior studies highlight AI's ability to enhance marketing efficiency and automation. Davenport and Guha argue that AI reshapes marketing decision-making processes by increasing predictive precision and operational efficiency [1]. Huang and Rust further emphasize AI's role in augmenting service interactions and improving consumer satisfaction [2]. However, these studies primarily focus on technological performance improvement rather than long-term relational outcomes.

Meanwhile, relationship marketing theory suggests that sustainable competitive advantage is rooted in customer engagement, loyalty, and lifetime value accumulation. Customer engagement has been identified as a central mechanism linking marketing activities to financial performance [3]. Customer equity theory further stresses the strategic importance of long-term customer value [4]. Despite these theoretical developments, a clear conceptual explanation of how AI-driven consumer behavior prediction contributes to brand relationship marketing remains insufficient. Most existing research treats AI as a technical tool rather than examining its relational implications.

This study aims to explore how AI-driven consumer behavior prediction influences brand relationship marketing through theoretical mechanisms derived from customer journey and customer engagement frameworks. This study adopts a narrative literature review approach to examine the relationship between artificial intelligence (AI)–driven consumer behavior prediction and brand relationship marketing.

Theoretically, this study contributes by bridging technological innovation research and relationship marketing theory. While prior literature often treats AI as a technical tool, this review emphasizes its relational implications. Practically, understanding the mechanisms through which AI affects engagement and trust provides guidance for firms seeking to implement AI responsibly and strategically. In addition to improving operational efficiency, artificial intelligence also fundamentally changes the way companies interact with consumers in digital environments. Traditional marketing strategies often rely on broad segmentation and mass communication, which limits the ability of firms to address individual consumer needs. In contrast, AI-driven technologies enable companies to process large-scale consumer data and generate highly personalized recommendations in real time. These capabilities allow firms to move from product-centered marketing toward customer-centered marketing strategies.

Furthermore, the increasing digitalization of consumer activities has generated unprecedented volumes of behavioral data. Online shopping platforms, social media interactions, and mobile applications continuously record consumers' preferences and decision-making processes. AI technologies can analyze these datasets to identify patterns that would otherwise remain hidden. As a result, firms are able to anticipate consumer needs and deliver tailored marketing messages at the right time and through the most appropriate channels. Despite these technological advancements, scholars have raised important questions regarding the broader implications of AI-driven marketing. While personalization can improve marketing effectiveness, it may also create challenges related to consumer privacy, data governance, and ethical responsibility. Understanding how AI influences consumer trust and long-term brand relationships therefore represents an important research issue. This study contributes to this discussion by reviewing the existing literature and examining how AI-based consumer behavior prediction can support sustainable brand relationship marketing.

2. Literature Review

2.1 AI in Consumer Behavior Prediction and Customer Journey Management

Existing literature has extensively discussed how artificial intelligence enhances consumer behavior prediction. Machine learning algorithms allow firms to analyze large-scale transactional and behavioral data to forecast purchase intention and customer lifetime value [5]. From a theoretical perspective, customer journey theory suggests that consumers interact with brands through multiple touchpoints across digital and offline channels [4]. AI technologies enable real-time adaptation and personalization at each touchpoint, thereby improving customer experience consistency. However, while these studies highlight efficiency gains, limited research explains how AI-driven personalization translates into long-term relational outcomes.

2.2 AI and Customer Engagement Mechanism

Customer engagement theory provides a crucial theoretical bridge between AI capability and brand relationship performance. Kumar argues that engagement behaviors—such as interaction, feedback, and advocacy—mediate the relationship between marketing actions and financial outcomes [3]. Similarly, customer equity theory proposes that sustained engagement enhances lifetime value and brand equity accumulation [6]. AI systems, through personalized recommendations and predictive analytics, can increase perceived relevance and interaction frequency, thereby strengthening customer engagement. Huang and Rust further suggest that AI augments service interactions and enhances customer satisfaction in marketing

contexts [1]. Nevertheless, most existing studies focus on operational improvement rather than examining engagement as a mediating mechanism.

2.3 Trust and Data Privacy as Moderating Factors

AI-driven marketing relies heavily on consumer data collection and behavioral tracking. While predictive personalization enhances convenience, it simultaneously raises concerns regarding privacy and data security. Dwivedi et al. highlight regulatory and ethical challenges associated with AI adoption [5]. Martin and Murphy argue that perceived data misuse significantly undermines consumer trust and long-term relationship quality [7]. Trust therefore functions as a moderating variable. When consumers perceive transparency and ethical governance, AI-driven personalization strengthens relational bonds. Conversely, when privacy concerns dominate, relational benefits diminish. This moderating mechanism is underexplored in existing AI marketing literature.

Based on the above literature review, several important research gaps remain in the current body of knowledge. First, although numerous studies examine the technological capabilities of artificial intelligence in marketing contexts, limited research integrates these technological developments with relationship marketing theory. Second, while prior studies acknowledge the importance of customer engagement, there is insufficient discussion of engagement as a mediating mechanism linking AI-driven personalization and brand relationship outcomes. Third, existing research tends to focus on short-term operational indicators such as click-through rates and conversion rates, while the long-term brand equity implications of AI-driven marketing remain underexplored. Addressing these gaps is essential for developing a more comprehensive theoretical understanding of how artificial intelligence contributes to sustainable brand relationship marketing.

3. Discussion and Analysis

3.1 Theoretical Integration of AI and Relationship Marketing

The reviewed literature indicates that artificial intelligence technologies significantly improve firms' ability to predict consumer behavior and personalize marketing communications. However, most existing research approaches AI primarily from a technological or operational perspective, emphasizing algorithmic performance, predictive accuracy, and automation efficiency. While these studies provide valuable insights into the technological capabilities of AI, they often overlook the relational dimension of marketing.

From the perspective of relationship marketing theory, the ultimate goal of marketing activities is not merely to generate short-term transactions but to establish and maintain long-term relationships between firms and consumers. Artificial intelligence should therefore be interpreted not only as a technological tool but also as a strategic mechanism that enables firms to deepen customer relationships. By analyzing large volumes of consumer data, AI systems can identify individual preferences, behavioral patterns, and consumption habits. This information allows companies to deliver personalized recommendations, targeted promotions, and tailored service experiences.

Such personalized interactions contribute to creating more meaningful customer experiences across different stages of the customer journey. When consumers perceive that a brand understands their needs and provides relevant solutions, they are more likely to develop emotional connections with the brand. In this sense, AI-driven personalization can strengthen relational bonds between firms and customers, which aligns with the core principles of relationship marketing. Therefore, integrating AI technologies with relationship marketing theory provides a more comprehensive framework for understanding how technological innovation can support long-term brand relationship development.

3.2 Engagement as a Mediating Mechanism

Another important insight emerging from the literature is the role of customer engagement in translating AI-driven marketing activities into long-term brand value. Customer engagement refers to the psychological and behavioral involvement that consumers demonstrate in their interactions with a brand. This may include activities such as sharing brand content, participating in online communities, providing feedback, or

recommending the brand to others. Artificial intelligence plays a critical role in stimulating these engagement behaviors. Through personalized recommendations, intelligent chatbots, and predictive customer service, firms can create more interactive and responsive communication environments. These technologies increase both the frequency and quality of interactions between brands and consumers. As a result, customers may feel more connected to the brand and become more willing to actively participate in brand-related activities.

Despite the importance of engagement, many existing studies still rely heavily on short-term performance indicators such as click-through rates, advertising impressions, or immediate purchase behavior. While these metrics are useful for evaluating marketing efficiency, they do not fully capture the relational processes that drive long-term brand performance. Engagement represents a deeper form of customer involvement that extends beyond simple transactions.

Viewing engagement as a mediating mechanism helps explain how AI-generated insights translate into relational outcomes. AI-based personalization increases consumer interaction and involvement, which subsequently strengthens loyalty, advocacy, and customer lifetime value. Therefore, engagement serves as an important bridge connecting technological capabilities with relational marketing outcomes. Future empirical studies could further test this mediating relationship through quantitative models and longitudinal data analysis.

3.3 The Moderating Role of Trust and Privacy

While artificial intelligence provides powerful tools for enhancing marketing effectiveness, it also raises important concerns regarding consumer privacy, data security, and ethical governance. AI-driven marketing relies heavily on the collection and analysis of personal data, including browsing histories, purchase records, location information, and social media activities. The extensive use of such data may lead to concerns about surveillance, manipulation, or misuse of personal information.

In this context, consumer trust becomes a critical factor determining the effectiveness of AI-enabled marketing strategies. When consumers believe that firms handle their data responsibly and transparently, they are more likely to accept personalized marketing communications and perceive them as beneficial rather than intrusive. Trust can therefore enhance the positive effects of AI-driven personalization by increasing consumer willingness to engage with brand messages and digital services.

However, if consumers perceive that firms collect excessive data or fail to protect their personal information, the effectiveness of AI-based marketing strategies may decline. Concerns about privacy may lead to resistance toward personalized advertising, reduced engagement with digital platforms, and negative perceptions of the brand. Consequently, trust and privacy concerns function as important moderating variables in the relationship between AI-driven marketing practices and brand relationship outcomes.

To address these challenges, firms need to adopt transparent data governance practices and clearly communicate how consumer data is collected, stored, and used. Setting ethical standards for AI use in marketing can also help keep customers' trust and support the long-term growth of AI-driven marketing strategies.

3.4 Future Research Directions

Future research should further develop empirical models to examine the mediating role of customer engagement in AI-driven marketing environments. In particular, scholars could investigate how AI-based personalization influences engagement behaviors such as interaction, participation, and advocacy. In addition, future studies should explore the long-term impact of artificial intelligence implementation on brand equity and customer lifetime value, moving beyond short-term performance indicators. Another promising direction is the examination of cross-cultural differences in consumer acceptance of AI-driven marketing practices, as perceptions of privacy and technology adoption may vary across cultural contexts. Finally, future research should investigate regulatory and ethical frameworks that shape the effectiveness and sustainability of AI-enabled marketing strategies.

3.5 Conceptual Framework

Based on the literature reviewed in this study, a conceptual framework can be proposed to explain how artificial intelligence-driven consumer behavior prediction contributes to brand relationship marketing. The framework highlights the key mechanisms through which AI technologies influence marketing outcomes and emphasizes the importance of relational variables in this process.

At the core of this framework is the role of AI-driven personalization. By analyzing large volumes of consumer data, AI systems are capable of predicting individual preferences, purchase intentions, and behavioral patterns. These predictive capabilities allow firms to deliver more relevant recommendations, customized promotional messages, and personalized service experiences. Such interactions increase the perceived usefulness and relevance of marketing communications, which can enhance customer satisfaction.

Customer engagement plays a central mediating role in this framework. AI-driven personalization encourages consumers to interact more frequently with brands through digital platforms. These interactions may include browsing product information, participating in online communities, sharing brand-related content, or providing feedback about products and services. Higher levels of engagement strengthen the psychological connection between consumers and brands, which can lead to greater loyalty and advocacy behaviors.

At the same time, the effectiveness of AI-driven marketing is influenced by moderating factors such as consumer trust and privacy concerns. Consumers may be willing to accept personalized marketing if they believe that firms use their data responsibly. However, concerns about data misuse or excessive surveillance may weaken the positive effects of AI-based personalization. Therefore, trust and privacy perceptions influence whether AI-driven strategies strengthen or weaken brand relationships.

Overall, this conceptual framework highlights the importance of integrating technological capabilities with relational marketing theories. It suggests that AI-driven consumer behavior prediction influences brand outcomes not only through operational efficiency but also through psychological and relational mechanisms.

3.6 Practical Implications

The increasing adoption of artificial intelligence in marketing also generates several practical implications for businesses seeking to build stronger relationships with their customers. First, companies should recognize that the value of AI lies not only in improving marketing efficiency but also in enhancing customer experience. AI technologies should therefore be designed to support meaningful interactions between firms and consumers rather than merely automating marketing processes.

Second, organizations should focus on developing data-driven personalization strategies that respect consumer preferences while maintaining transparency in data usage. Personalized recommendations and targeted promotions can improve consumer satisfaction when they are perceived as helpful and relevant. However, excessive personalization may create feelings of intrusion if consumers believe that firms are collecting too much personal information. Marketing managers must therefore balance personalization with respect for consumer privacy.

Third, companies should invest in building trust through responsible data governance practices. This includes implementing strong data protection policies, communicating clearly about how consumer data is used, and complying with regulatory frameworks such as data protection laws. Trust is a critical factor that determines whether consumers perceive AI-driven marketing as beneficial or manipulative.

Finally, businesses should use AI technologies to foster long-term customer engagement rather than focusing solely on immediate sales outcomes. Encouraging consumers to participate in brand communities, share feedback, and interact with brand content can strengthen emotional connections and increase customer lifetime value. Firms that successfully integrate AI technologies with relationship marketing strategies are therefore more likely to achieve sustainable competitive advantages in increasingly digital markets, as these strategies enable personalised customer experiences and foster loyalty over time.

4. Conclusion

This study provides a comprehensive literature review on the relationship between artificial intelligence-driven consumer behavior prediction and brand relationship marketing. By synthesizing prior research on AI technologies, customer engagement theory, and relationship marketing frameworks, this study proposes a conceptual explanation of how AI contributes to long-term brand performance. The findings suggest that AI enhances marketing effectiveness not only through predictive accuracy and operational efficiency but also through relational mechanisms. In particular, customer engagement plays a key mediating role linking AI-driven personalization and brand relationship outcomes, while consumer trust and data privacy concerns function as important moderating factors that influence the effectiveness of AI-enabled marketing strategies. From a theoretical perspective, this study contributes to the literature by integrating technology-oriented AI research with relationship marketing theory. It highlights the importance of examining AI not merely as a technological tool but as a relational mechanism that influences customer engagement and brand equity. From a managerial perspective, the findings suggest that firms should focus not only on technological implementation but also on building consumer trust and maintaining ethical data governance practices. Despite these contributions, several limitations remain. This study is based on a narrative literature review and does not include empirical testing of the proposed conceptual relationships. Future studies could employ quantitative methods or experimental designs to validate the mediating role of engagement and the moderating role of trust. Additionally, future research could examine industry-specific differences and cross-cultural variations in AI adoption.

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A Literature Review of Audit Issues and Improvement Paths in the Context of ESG Information Disclosure

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Abstract

In the context of the global push for sustainable development, Environmental, Social, and Governance information disclosure has emerged as a crucial link between enterprises and the capital market, witnessing rapid growth worldwide. The implementation of the EU's Corporate Sustainability Reporting Directive (CSRD) and the enhanced disclosure requirements under China's dual - carbon goal are clear indicators of this trend. ESG information differs significantly from traditional financial information. It is non-financial, multi-dimensional, and highly subjective. These characteristics pose new challenges to the traditional audit model centered around financial data, especially in terms of the scope of verification, evidence collection, and professional judgment. Although the importance of ESG audit and assurance is increasingly recognized, existing research on ESG assurance is fragmented. There are inconsistencies in research conclusions regarding standardization, professional practices, and economic consequences. A systematic review and integration of these studies is urgently needed to meet the practical demands of the growing ESG disclosure landscape. This review consolidates fragmented ESG audit research and proposes actionable improvement paths to advance ESG assurance practice.

Keywords

ESG information disclosure, ESG auditing, non-financial information assurance

1. Introduction

This paper adopts a literature review method to systematically sort out domestic and foreign studies on Environmental, Social, and Governance (ESG) information disclosure audits, summarizes and comments on them from the perspectives of research themes, research methods and research conclusions, and on this basis, summarizes the deficiencies of existing studies and proposes future research directions. The purpose of this review is to systematically sort out relevant literature, summarize the main academic viewpoints on the impact mechanism of ESG information disclosure on audit processes, methods and audit quality; induce discussions on the impact of industry characteristics and enterprise scale differences on ESG audits in different studies; and generalize the ESG audit improvement ideas proposed in existing studies to form an analytical framework centered on systems, technology and personnel capabilities. Specifically, the research objectives include three aspects: first, to systematically analyze the impact mechanism of ESG information disclosure on audit processes, methods and audit quality, clarifying how ESG information transparency affects audit planning, evidence collection and risk assessment; second, to accurately identify the

differentiated problems of ESG audits in enterprises of different industries and scales, such as the difficulty in unified measurement of ESG indicators in high-pollution industries and the lack of professional capabilities in small and medium-sized enterprises; third, to construct a system-technology-personnel trinity ESG audit improvement framework. Meanwhile, this review also sorts out the main problems existing in current ESG information disclosure audits, including inconsistent audit standards, backward audit technologies and insufficient professional talents, [1] and explores feasible paths for improvement. The research has important theoretical and practical significance. In terms of theoretical significance, it enriches the theoretical system of non-financial information auditing, improves the theoretical basis of ESG assurance, and fills the research gap in the connection between ESG audit standards and practice. In terms of practical significance, it provides scientific reference for regulators to formulate unified and operable ESG audit rules, offers targeted practical guidance for accounting firms to expand ESG audit businesses and improve audit quality, and also helps enterprises standardize ESG information disclosure and enhance their sustainable development capabilities. Overall, this review is expected to sort out the research context of ESG information disclosure audits and provide a foundation for the in-depth development of subsequent related research [2]. In terms of practical significance, it provides a reference for regulators to formulate ESG audit rules, and offers practical guidance for accounting firms to expand ESG businesses and improve audit quality.

2. Literature Review

2.1 Research on ESG Information Disclosure

As an important bridge for enterprises to communicate with stakeholders, research on ESG information disclosure has always centered on two core issues, namely disclosure motivation and economic consequences [3]. Enterprises engage in ESG information disclosure under the combined drive of external institutional constraints and internal strategic needs, with the purpose of conveying signals of sound corporate governance and long-term development value to the market. High-quality ESG information disclosure can effectively reduce the degree of information asymmetry in the capital market, enhance investor confidence in enterprises, further reduce corporate financing costs, and continuously improve enterprises' sustainable operational capabilities and overall risk resistance [4]. Disclosure quality serves as a key premise for ESG information to exert its inherent value, which is mainly reflected in the authenticity, completeness and comparability of the disclosed information. At present, there are obvious deficiencies in the quality of corporate ESG information disclosure, including overly formalistic qualitative descriptions, insufficient quantitative data support, information omissions, false disclosure behaviors and inconsistent disclosure standards among different entities, all of which significantly weaken the practical usefulness of ESG information [5]. The quality of ESG information disclosure is jointly determined by external and internal factors, and this interaction mechanism also provides clear directions for subsequent in-depth research on improving disclosure quality.

2.2 The Role of Auditing in Non-Financial Information Disclosure

Existing literature mainly focuses on the governance role of auditing in non-financial information disclosure, with an emphasis on the audit of social responsibility reports and the assurance of sustainability reports. The core content is to explore how third-party assurance improves the reliability and credibility of non-financial information, restrains corporate greenwashing and selective disclosure, and analyzes its economic consequences from the perspectives of information quality, corporate governance, and capital market reactions. At the same time, it compares assurance standards, implementation subjects, and institutional environments to improve the non-financial information assurance system. Abdifatah Ahmed Haji, Paul Coram and Indrit Troshani argue that social responsibility report assurance can constrain managerial opportunism, reduce greenwashing behavior, and improve disclosure quality [6]. Pengwen Zhang found that auditors' industry expertise can enhance the reliability of social responsibility information and reduce corporate financing costs. Velte points out that high-quality sustainability assurance can enhance the credibility of reports and the decision-making value of information [7]; Hirsch & Heichl further confirm that assurance helps improve the recognition of corporate sustainability information by investors and stakeholders [8]. Research methods are mainly divided into three categories: normative research focuses on constructing the theoretical framework and standard system of assurance; empirical research is the

mainstream, mostly using methods such as regression, DID (Difference-in-Differences), and PSM (Propensity Score Matching) to test the economic consequences of assurance; case and content analysis focus on specific industries to analyze problems in the implementation of assurance. In addition, some studies adopt an international comparison perspective to compare the differences in non-financial information disclosure and assurance systems among different countries. Current research has obvious limitations: non-financial assurance standards are not unified, leading to insufficient information comparability; the problem of formalization is prominent under voluntary assurance; non-financial indicators are difficult to quantify, the acquisition of audit evidence is challenging, and auditors lack comprehensive capabilities. Controversies mainly focus on issues such as whether assurance should be mandatory or voluntary, whether to adopt reasonable assurance or limited assurance, and the division of qualifications of assurance subjects. At the same time, existing studies mostly focus on short-term market effects, and the discussion on long-term governance effects and industry differences is still insufficient.

2.3 Research on ESG Assurance and Auditors' Competence

The core value of third-party ESG assurance lies in independence [9]. If enterprises evaluate their own environmental, social and other performance, it is easy for them to conceal problems or exaggerate achievements in an attempt to polish their image, and such information is hard to convince investors, regulatory authorities and the public. An independent third-party institution has no interest ties with the enterprise and can objectively and neutrally inspect the authenticity and completeness of the enterprise's ESG information in accordance with unified professional standards. This not only provides a credible reference for all parties but also urges enterprises to effectively manage their ESG work, which is a key guarantee for making ESG information more transparent and reliable. The comprehensive requirements of ESG assurance are also driving auditors to develop their capabilities from a single dimension to a comprehensive one. In the past, auditors mainly focused on the verification of financial data, but ESG involves multiple non-financial fields such as environmental protection, employee rights and interests, and corporate governance. This requires them to learn relevant knowledge of environmental and social management on the basis of their original financial expertise, be familiar with the inspection norms related to ESG, improve their ability to analyze and verify non-financial data, and at the same time learn to communicate efficiently with different departments of the enterprise. Ultimately, they need to grow into compound talents who are competent for both traditional financial auditing and ESG assurance work.

2.4 Theoretical Basis and Analytical Perspective

2.4.1 Information Asymmetry Theory

This theory forms the foundation for analyzing ESG auditing issues. A significant information gap exists between enterprises and external stakeholders in terms of ESG information, with enterprises holding an information advantage that may easily lead to false or selective disclosure. Third-party ESG audit assurance can effectively bridge this information gap and reduce the level of information asymmetry in the market through professional verification. On the one hand, in the environmental dimension, enterprises may overstate emission reduction efforts or underreport resource consumption to meet regulatory thresholds; on the other hand, in the social dimension, they might exaggerate stakeholder engagement initiatives while obscuring potential labor rights controversies. In the governance dimension, information asymmetry often manifests as opaque disclosure of internal control deficiencies or related-party transactions. Effectively, third-party ESG audit assurance serves as a critical mechanism to bridge this information gap. Through independent verification and professional evaluation, third-party audits can quantify the authenticity and comparability of ESG data, thereby systematically reducing information asymmetry in the market and enhancing the credibility of corporate ESG disclosures.

2.4.2 Principal-Agent Theory

Based on the principal-agent relationship arising from the separation of enterprise ownership and management rights, managers may neglect the long-term ESG development of enterprises for short-term interests and even whitewash ESG information. Notably, the sensitivity of such agency issues varies across different types of enterprises: large enterprises tend to face higher agency costs due to complex governance hierarchies, while small and medium-sized enterprises (SMEs) are more prone to ESG information gaps due

to weak internal controls. As an external supervision mechanism, ESG auditing can effectively restrain managers' opportunistic behaviors and alleviate interest conflicts between the two parties in the ESG field, with differentiated effects tailored to the governance characteristics of large enterprises and SMEs respectively.

2.4.3 Signaling Theory

Against the backdrop of information asymmetry in the market, enterprises' active acceptance of third-party ESG assurance serves as a positive signal to the capital market. It can enhance the credibility of ESG information, boost the confidence of investors and other stakeholders, and help enterprises build a good market image.

2.4.4 Enlightenments of the Theoretical Framework for This Study

These three classic theories constitute the core theoretical support for this study. They clarify the practical necessity and core value of third-party ESG audit assurance, and provide a clear analytical perspective and research direction for this paper to analyze the existing problems of ESG information disclosure auditing, explore their causes and put forward improvement paths.

2.5 Main Problems Faced by ESG Information Disclosure Audits

This strand of literature primarily identifies the practical challenges encountered in ESG information disclosure audits. Scholars generally agree that such audits are currently plagued by common issues including the lack of specific auditing standards and norms [10], great difficulties in obtaining and evaluating audit evidence, hurdles in verifying the authenticity of ESG information, and insufficient professional competence of auditors. Most studies adopt normative research methods, with some combining case analysis to explore these problems. However, existing research lacks in-depth exploration of the internal connections between various issues and has not yet formed a unified analytical framework for studying the heterogeneous manifestations of these problems across different industries.

2.6 Analysis of the Causes of ESG Information Disclosure Audit Issues

The emergence of various issues in ESG information disclosure audits results from the interplay of multiple factors, mainly influenced by the inherent characteristics of ESG information, external institutional supervision, and the internal development status of the audit industry. ESG information is non-financial and subjective, which easily interferes with professional audit judgments; meanwhile, its scattered data sources and non-unified measurement methods leave the audit work without a standardized verification basis. In alignment with the Global Reporting Standards, [11] the current regulatory system for ESG information disclosure is still immature, and the supporting audit standards and relevant guidelines are lagging behind, failing to provide a sound institutional underpinning for audit practice. There are also obvious shortcomings within the audit industry: accounting firms generally lack practical experience in ESG-related businesses, and the application of applicable audit technical tools and methods is limited. This makes it hard to meet the professional requirements of ESG audits, becoming a key internal factor restricting the effective advancement of ESG information disclosure audit work.

3. Discussion

3.1 Common Audit Issues

Acknowledged by Academia, Academia has reached a broad consensus on the core dilemmas confronting ESG information disclosure audits. First, the absence of unified and detailed audit standards remains the most prominent constraint. Unlike mature financial audit criteria, ESG audit norms lack global consistency and operable implementation guidelines, resulting in significant disparities in audit scope, procedures, and assurance levels across different institutions and regions, which severely impairs the comparability of audit outcomes. Second, the acquisition and verification of audit evidence are exceptionally challenging. ESG information is non-financial, multi-dimensional, and highly subjective, with scattered data sources, ambiguous quantification criteria, and difficulties in tracing and verifying information authenticity, thereby increasing audit risks and uncertainty. Third, auditors' professional competence is insufficient. Traditional

auditors predominantly possess financial expertise, yet ESG audits demand interdisciplinary knowledge in environmental science, social governance, and law. The shortage of compound talents directly restricts the depth and quality of ESG audit practices. Additionally, issues such as the formalization of voluntary assurance, prevalent corporate greenwashing, and inadequate regulatory oversight further exacerbate the practical difficulties of ESG audits.

3.2 Policy Implications and Future Research Directions of Existing Studies

Existing research provides clear implications for practice and directions for theoretical exploration. In terms of policy implications, first, accelerate the construction of a third-party assurance mechanism for ESG information. Clarify the legal status and professional responsibilities of assurance subjects, strengthen the independence of third-party audits, and restrain greenwashing and selective disclosure through mandatory assurance policies for key industries. Second, improve the supporting systems for ESG information disclosure and auditing. Promote the unification of global or regional ESG audit standards, formulate operable technical guidelines and indicator systems, and enhance the standardization and comparability of audit practices. Third, promote the transformation of the auditors' competency structure. Establish interdisciplinary training systems covering finance, environment, and governance, encourage the integration of industry expertise, and cultivate compound talents adapted to ESG audit needs. In terms of future research, scholars should focus on the heterogeneity of ESG audits in different industries and enterprise scales, explore targeted audit models and improvement paths; strengthen the research on long-term governance effects of ESG audits rather than being limited to short-term market reactions; and combine digital technologies such as big data and artificial intelligence to explore technological empowerment paths for ESG audits to enrich the theoretical system and practical solutions of ESG audits.

4. Conclusion

This paper systematically reviews domestic and foreign literature on ESG information disclosure audits, combs the research context from the dimensions of ESG information disclosure, the governance role of non-financial information audits, ESG assurance and auditor competence, and summarizes the core issues, causes, and improvement paths of current ESG audits. The study finds that ESG information disclosure audits are currently plagued by problems such as imperfect standards, difficult evidence collection, and insufficient professional talent, which are jointly caused by the inherent attributes of ESG information, external institutional supervision, and the internal development of the audit industry. Theories such as information asymmetry, principal-agent, and signaling provide important theoretical support for explaining the value and necessity of ESG third-party assurance. This review also has certain limitations. It mainly focuses on the collation and induction of existing research, lacking empirical test and case verification of the improvement path; the research on the heterogeneous performance of ESG audit issues in different scenarios is not in-depth enough, and the analytical framework needs to be further tested and improved in combination with practice. In the future, with the continuous improvement of global sustainable development requirements and the deepening of ESG information disclosure, ESG audit research will develop in the direction of standardization, digitalization, and interdisciplinary integration. Subsequent research can focus on the design and effect testing of unified ESG audit standards, the application of digital technology in audit evidence collection and risk control, the competency model of ESG auditors, and the heterogeneous effects of ESG audits in emerging markets, so as to provide a more solid theoretical support and practical reference for the high-quality development of ESG information disclosure and audit practices.

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The Impact of Digital Transformation on Supply Chain Efficiency: A Case Study of JD Logistics

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Abstract

This paper investigates the mechanisms of digital transformation in enhancing supply chain efficiency, focusing on JD Logistics. The study reveals that the integration of the “Hyper-Brain 2.0” decision system and “Wolfpack” robotic execution has established a synergistic hardware-software architecture. Empirical data indicate that digital intelligence improved frontline operational efficiency by 20.24%, achieved a sorting accuracy of 99.98%, and shortened site selection cycles by 80%. Furthermore, the application of digital twin technology effectively mitigates the “bullwhip effect” by facilitating the logical convergence of order variance toward actual demand variance. Additionally, the externalization of digital capabilities contributed to a 14.1% counter-cyclical revenue growth. This research validates the transition of digital transformation from micro-operational efficiency to macro-value empowerment, providing a strategic paradigm for the industry.

Keywords

digital transformation, supply chain efficiency, JD logistics, digital twin, variance convergence

1. Introduction

Driven jointly by the industry 4.0 strategy and the global wave of the digital economy, the traditional logistics industry is undergoing a fundamental transformation from a labor-intensive model to a technology-driven one [1]. Digital transformation is no longer merely an external tool for firms to respond to market competition; instead, it has evolved into a core endogenous force driving changes in internal operational efficiency [2]. However, despite the widespread adoption of digital technologies, most logistics enterprises continue to face structural challenges, including high operating costs, delayed information transmission, and insufficient supply chain responsiveness [3]. How digital technologies can be leveraged to restructure business processes and achieve end-to-end supply chain coordination in complex environments has therefore become a critical issue that warrants further academic investigation [4].

As a benchmark provider of technology-driven supply chain services, JD Logistics’ integrated supply chain model offers an ideal closed-loop case for examining digital transformation. JD not only achieves hardware-level automation through intelligent warehousing systems such as the JD Asia No. 1 warehouse network [5], but also realizes a strategic shift from a push-based to a pull-based supply chain by leveraging artificial intelligence and big data-based predictive technologies [6]. The selection of this case for in-depth analysis is motivated not only by its benchmark status, but also by the deep coupling between technology and business

operations, which facilitates the extraction of generalizable mechanisms through which digitalization influences efficiency [7].

This study aims to examine the specific pathways through which digitalization affects supply chain efficiency by conducting a micro-level analysis of JD Logistics. It seeks to address the gap in existing research concerning closed-loop analysis across the entire “procurement–warehousing–distribution” chain [7], and to provide a logically grounded and practically relevant reference for achieving dual optimization of cost and efficiency in the logistics industry [8].

2. Literature Review

2.1 Digital Transformation: Conceptual Foundations and Industry Applicability in Logistics

Digital transformation is generally understood as a systematic process in which digital technologies are used to reshape business processes and modes of value creation [2]. Under the Industry 4.0 framework, digital supply chains (DSC) enhance the integration of physical and information flows by enabling real-time transparency and vertical integration [1]. Prior research suggests that, for logistics firms, the essence of digital transformation lies in incorporating big data, artificial intelligence, and the Physical Internet into core operational activities, thereby promoting the transition toward “intelligent digitalization” [4].

2.2 Mechanisms Through Digitalization Influences Supply Chain Efficiency

The academic literature has reached three main points of consensus regarding the pathways through which digitalization enhances efficiency. First, standardized support plays a foundational role, as digitalization relies on unified operational norms to ensure the accuracy of automated execution [10]. Second, decision optimization is achieved through the application of AI-based predictive technologies, which help reduce inventory redundancy and improve the precision of resource allocation [6]. Finally, collaborative effects emerge as digital platforms break down organizational boundaries and strengthen the stability of inter-firm relationships, thereby significantly lowering external transaction costs [9].

2.3 Assessment of the Current State of Digitalization at JD Logistics

Empirical studies focusing on JD indicate that digital transformation has made a significant positive contribution to its asset management efficiency and corporate value creation [10]. By leveraging its integrated warehousing and distribution network, JD has applied intelligent decision-making systems to achieve more precise control over supply chain costs, thereby completing a transition from experience-based management to data-driven management [8].

2.4 Research Gaps and Analytical Focus

Although existing literature has generally affirmed the macro-level effectiveness of digitalization, two key limitations remain. First, there is a lack of detailed analysis of closed-loop efficiency across the entire “procurement–warehousing–distribution” chain. Second, the micro-level mechanisms through which digitalization reshapes specific operational logics—such as the shift from a push-based to a pull-based supply chain—have not been sufficiently explored [7]. This study therefore adopts these gaps as its analytical entry point and conducts a case-based investigation.

3. Methodology

3.1 Research Design and Strategy

This study uses a case study method, taking JD Logistics as a typical example to analyze how digital transformation affects supply chain efficiency and its internal mechanisms. As a leading technology-driven logistics company, JD Logistics' 'integrated supply chain' model provides an ideal case to observe the deep integration between technology and business operations [7].

The research design is structured into three interconnected dimensions:

At the theoretical level, this study establishes an analytical framework using a Narrative Review. By systematically reviewing 26 core academic papers published between 2018 and 2025, I have defined the critical nodes of digital transformation in procurement, warehousing, and distribution. This process also identifies existing research gaps in micro-efficiency evaluation, ensuring that the case analysis remains theoretically continuous and critical [1].

Second, at the data level, this study utilizes Data Triangulation. To ensure the timeliness and rigor of the business analysis, I relied not only on secondary academic literature but also on primary operational data from JD Logistics' 2025 Interim Report [11]. By analyzing quantitative indicators—such as the application of the 'Wolfpack' automated warehousing system and the revenue share from external customers (67.1%)—I have aligned abstract transformation theories with actual financial performance.

Finally, at the evaluation level, a benchmark analysis is introduced. To scientifically quantify the excess efficiency generated by digital transformation, this study adopts the “2025 Postal Industry Operation Report” [12] issued by the State Post Bureau as a reference. By using the industry-wide revenue growth rate of 12.0% as a baseline, the research compares the differentiated performance of JD Logistics under digital empowerment. This approach enables an accurate assessment of the case study's validity and the universal value of its conclusions within a macro-economic context.

Table 1: Data Triangulation for the Study.

Dimensions	Data Sources	Core Contributions / Analytical Value
Theoretical dimension	26 core academic articles	Constructs a conceptual framework illustrating the impact pathways of digital transformation and identifies gaps in existing literature.
Empirical dimension	JD Logistics 2025 Interim Report	Provides up-to-date empirical evidence through key financial indicators (e.g., 67.1% external revenue share) and technological applications (such as the Intelligent Wolf System)
Industry dimension	State Post Bureau of China, 2025 Operational Report	Establishes an industry growth benchmark (12.0% revenue growth rate) and enables the quantification of JD Logistics' excess efficiency relative to the industry.

3.2 Data Sources and Selection Procedures

Data collection for this study follows rigorous systematic principles, aiming to enhance the objectivity of business analysis through the mutual verification of multi-dimensional data. Specifically, the data sources are categorized into the following three modules:

(1) Systematic Screening of Academic Literature (Secondary Data)

Following the standardized procedure of a Narrative Review, this study selected 26 core academic papers published between 2018 and 2025 from CNKI and Google Scholar. The search was conducted using “JD Logistics”, “Digital Transformation”, and “Supply Chain Efficiency” as primary keywords. The inclusion criteria were defined as follows:

- case studies centered on JD Logistics;
- research containing concrete efficiency metrics, such as inventory turnover days and cost structures;
- publications in peer-reviewed journals or high-quality dissertations.

Through qualitative analysis of these sources, this study extracted historical evolution data regarding intelligent logistics systems, such as “Asia No. 1”.

(2) Official Disclosures and Primary Empirical Data (Primary Data)

To mitigate the time-lag inherent in academic literature, this study independently retrieved the latest primary materials disclosed by JD Logistics. The analysis focuses on key operational data from the “2025 Interim Report” [11], including but not limited to: the revenue share from external customers (67.1%) as of June 30, 2025, the Non-IFRS profit (RMB 3.34 billion), and the large-scale application parameters of the self-developed “Wolfpack” automated warehousing system. Such real-time data provide the most direct empirical support for validating the economic consequences of digital transformation.

(3) Industry Benchmarks and Macro-statistical Data

The “2025 Postal Industry Operation Report” [12], issued by the National Post Bureau, is introduced as a comparative reference. By incorporating industry-wide benchmarks—such as the 14.3% growth in express delivery volume and the 12.0% revenue growth rate—this study situates JD Logistics’ individual performance within a macro-industry context. This benchmarking design helps isolate general industry growth factors, thereby accurately identifying the excess efficiency premium generated by digital transformation.

3.3 Research Quality, Reliability, and Validity

To ensure the integrity of the findings, the following quality control measures were implemented during the design and execution phases of this study:

(1) Validity Assurance

Internal validity is ensured through Data Triangulation. Rather than relying on a single descriptive source, the findings are derived by cross-referencing three distinct layers: the theoretical mechanisms from 26 academic papers, the financial evidence disclosed in JD Logistics’ 2025 financial report, and the industry benchmarks provided by the State Post Bureau. This ‘theory-empirical-benchmark’ closed-loop validation effectively mitigates potential subjective bias from any single information source. Furthermore, by selecting JD Logistics—a benchmark in “Integrated Supply Chain”—as the primary sample, the study ensures the representativeness and external validity of its findings within the field of smart logistics.

(2) Reliability Consistency

This study provides a detailed documentation of the entire research trajectory, spanning from literature retrieval and metric extraction to data benchmarking. By clearly defining the search terms, the screening timeframe (2018-2026), and the extraction logic for core operational indicators—such as the external revenue share and fulfillment expense ratio—the transparency of the research process is ensured. Such structured procedural design allows other researchers to yield consistent analytical results when applying the same data retrieval standards and logical frameworks.

(3) Objectivity and Ethics

All data utilized in this study are sourced from publicly available channels, including peer-reviewed academic journals, compliant financial disclosures from listed companies, and official government statistical bulletins. The research involves no non-public commercial secrets and adheres strictly to academic ethical standards. Throughout the analytical process, a neutral stance is maintained. By benchmarking JD Logistics’ performance against industry average growth rates, the study objectively evaluates efficiency, ensuring the impartiality of its conclusions.

4. Evaluating the Impact of Digital Transformation on Supply Chain Efficiency

4.1 Intelligent Execution and Human-Machine Collaboration

Within JD Logistics’ native intelligent framework, digital transformation has evolved beyond “decision support” into a “co-evolution of spatial and embodied intelligence” [13]. This section focuses on how the synergy between the “Superbrain Large Model 2.0” and the “Wolfpack” hardware system reconstructs warehousing execution processes and enhances operational efficiency.

(1) Standardizing Operational Workflows Driven by Embodied AI

JD Logistics has addressed flexibility challenges at the logistics execution layer by integrating large model capabilities into frontline operations. Leveraging embodied AI technology, the company introduced AR-guided sorting in various operational stages. By utilizing vision-based large models for automatic cargo localization and voice assistants for real-time guidance, the system has achieved a transition from experience-driven manual labor to algorithm-guided operations.

Technical assessments indicate that this human-machine collaboration model has increased frontline operational standardization by 15% and overall productivity by 20%. This efficiency gain stems not only from hardware upgrades but also from the optimization of human-machine trust. According to research by Liu et al. (2025), establishing effective trust evaluation models in warehouse picking scenarios can significantly reduce

workers' cognitive load. Their findings demonstrate that optimized collaborative models can improve overall efficiency by 20.24% and reduce worker fatigue by 59.40% [14]. These empirical results provide a theoretical explanation for the underlying drivers of JD Logistics' frontline efficiency improvements.

Table 2: Digitalized Workflow of Warehouse Execution Processes.

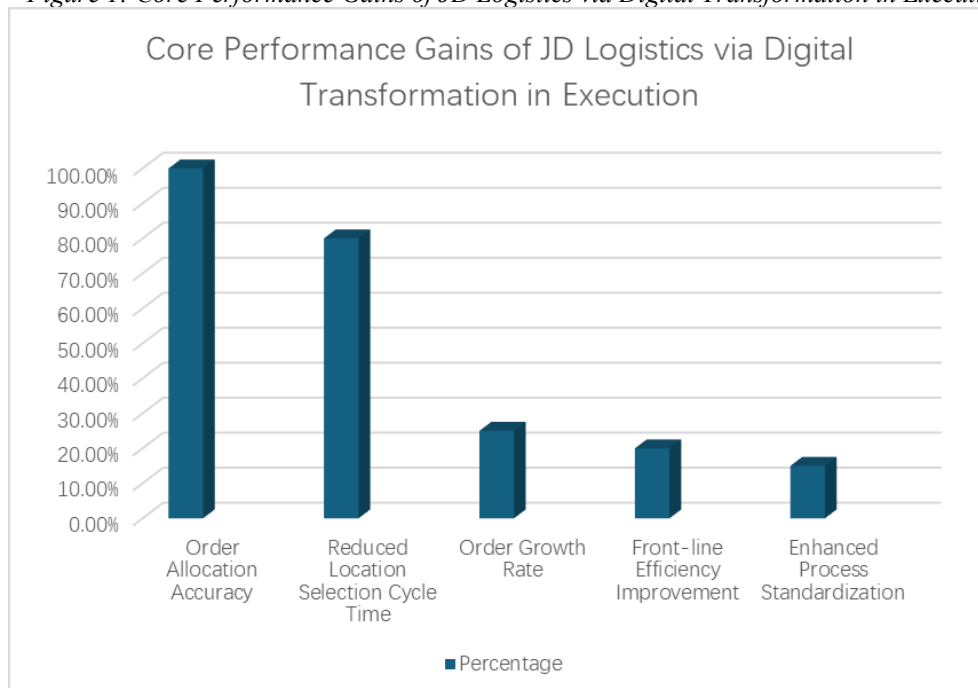
Process Stage	Traditional Mode (Experience-Based)	Digital Mode	Efficiency / Quality Gain
Task Allocation	Manual assignment of storage locations based on work orders	<i>Super Brain 2.0</i> automatically predicts demand and optimizes picking paths	Eliminates non-value-added walking time
Picking Operations	Visual identification with manual verification	AR-enabled vision large model for item localization with voice guidance	Standardization of operations improves efficiency by 15%
Human–Machine Interaction	Basic obstacle avoidance, independent operation	Game-theoretic collaboration based on a trust model (ISTSG)	Front-line operational efficiency increases by 20%
Fatigue Management	Continuous high-intensity work with no early warning	Algorithm-based optimization reduces cognitive load	Fatigue level reduced by 59.4% ([31])

(2) Swarm Collaboration and Precision Control of the “Wolfpack” Hardware System

Another manifestation of digital execution efficiency lies in the seamless interconnectivity between hardware components. Acting as the central hub, Superbrain 2.0 has established a multi-agent interaction mechanism, enabling robust interoperability across the “Wolfpack” series, including the “Lone Wolf” AGV, “Flying Wolf” drone, and “X-Wolf” robotic arm [13]. This swarm intelligence collaboration significantly enhances the flexibility of the supply chain system.

Leveraging the “Yutu” Digital-Intelligent Spatial-Temporal Platform, JD Logistics has achieved highly precise delivery even within complex geographical scenarios. Data indicates that the platform’s geocoding accuracy exceeds 98%, while its order-sorting accuracy reaches an exceptional 99.98%. Such high-precision performance directly reduces operational re-routing and resource waste caused by mis-sorting, thereby optimizing overall fulfillment efficiency.

Figure 1: Core Performance Gains of JD Logistics via Digital Transformation in Execution



(3) Business Value Conversion at the Execution Layer

Site Selection and Deployment Efficiency: Leveraging JD's massive "People-Business-Location" database, the digital system has assisted retail enterprises in shortening the store site selection cycle by 80% while increasing the store survival rate by 50%. In precision deployment scenarios, order growth reached 25% [13]. This demonstrates that the digital upgrading of the execution layer directly delivers commercial value to external customers by reducing costs and enhancing efficiency.

4.2 Upgrading Intelligent Decision-Making: An Efficiency Shift from Passive Response to Proactive Prediction

In the advanced stages of supply chain digital transformation, enhancing decision-making efficiency has become pivotal to eliminating systemic redundancy. By deeply integrating the "Superbrain Large Model 2.0" with digital twin technology, JD Logistics has achieved a generational leap in decision-making logic, transitioning from experience-driven heuristics to algorithm-based predictive modeling.

(1) Digital Twin-Driven Transportation Management and Real-Time Dispatching Optimization

Traditional logistics transportation systems exhibit significant decision-making latency when navigating dynamic environments due to data fragmentation and insufficient monitoring capabilities [15]. JD Logistics addresses this by constructing a digital twin network with a 1:1 mapping of the physical world, achieving real-time synchronization across the entire warehousing, transportation, and delivery chain [13]. This digital twin-driven management strategy integrates multi-source heterogeneous data and utilizes time-series forecasting algorithms (such as LSTM) to enable dynamic monitoring and risk anticipation of transportation behaviors.

Leveraging this technology, JD Logistics has achieved "second-level optimization" of routing instructions and can simulate optimal path solutions for millions of orders in high-concurrency scenarios, such as major promotion events. This rapid response—on a scale of minutes or even seconds—validates the core value of digital twin technology in overcoming system integration challenges and enhancing real-time monitoring capabilities.

(2) Information Transparency as a Root-Cause Mitigation of the "Bullwhip Effect"

The distortion of information flow within supply chains is the primary cause of inventory accumulation, transportation inefficiency, and declining fulfillment timeliness—a phenomenon known as the "Bullwhip Effect" [16]. According to Lee et al. (1997), demand forecast updating, order batching, and environmental fluctuations are key factors that amplify demand volatility. In traditional push-based supply chains, the tiered transmission of information inevitably causes order fluctuations to far exceed actual consumption levels.

JD Logistics utilizes the robust training capabilities of Superbrain 2.0 to conduct model simulations based on the real-flow data of hundreds of millions of users and tens of millions of SKUs [13]. Through pre-simulations of extreme scenarios within its digital twin system, JD achieves more precise demand forecasting and order-sorting decisions. This mechanism has enabled an order-sorting accuracy of 99.98%. By enhancing information transparency and predictive precision, the system mitigates ineffective inventory investment and transportation resource waste caused by information distortion at their source, facilitating a strategic transition toward a demand-driven pull-based supply chain.

(3) Decision Capitalization and External Business Value Conversion

The premium effect of intelligent decision-making capabilities is reflected not only in the reduction of internal costs but also in the digital empowerment of external business scenarios [13]. Aligning with prior theoretical research, digital capability has emerged as a critical source of competitive advantage [18]. Through its "Yutu" Digital-Intelligent Spatial-Temporal Platform, JD Logistics exports sophisticated geocoding and precision addressing technologies, achieving a geocoding accuracy exceeding 98% [13]. Such high-precision decision support has enabled retail enterprises to shorten store site selection cycles by 80% and significantly boost order growth rates in precision deployment scenarios. Compared to the industry average growth rate of 6.1% [12], JD Logistics' revenue growth of 14.1% in the first half of 2025 [11] provides a quantitative validation of the superior performance of "proactive predictive" decision-making models in enhancing asset efficiency and market responsiveness.

4.3 Quantification of Financial Returns and Business Value

Based on the preceding analysis of execution and decision-making dimensions, the empowerment of digital transformation within JD Logistics is ultimately manifested in its financial resilience and market expansion capabilities. This section will integrate financial data from the first half of 2025 to analyze how technology dividends are translated into comprehensive corporate performance.

(1) Profitability Leap Driven by Cost Reduction and Efficiency Enhancement

According to supply chain performance evaluation theory [17], cost savings serve as the most intuitive indicator of digital effectiveness [18]. In the first half of 2025, JD Logistics achieved a profit of 3.34 billion RMB, representing a significant year-on-year increase [11]. This growth was not driven solely by scale expansion but stemmed from the reduction in fulfillment cost per order. The “20% increase in frontline operational efficiency” mentioned in Section 4.1 and the “second-level routing optimization” in Section 4.2 directly reduced labor input and fuel consumption. This technology-driven improvement in gross margin validates that digital transformation can effectively offset pricing pressures resulting from intensifying industry competition.

(2) Market Premium Derived from the Conversion of Response Speed

In the logistics industry, responsiveness is the core competitive advantage. Leveraging the predictive capabilities of Superbrain 2.0, JD Logistics achieved a 25% increase in orders within precision deployment scenarios [13]. This implies that faster decision-making (evidenced by an 80% reduction in site selection cycles) has been effectively converted into higher customer acquisition rates. Against the backdrop of a 6.1% average industry revenue growth rate in 2025 [12], JD Logistics leveraged the agility of its pull-based supply chain to achieve a 14.1% revenue increase. This demonstrates that the “time-based competitiveness” generated by digital transformation has been translated into substantial incremental market share.

(3) Asset Utilization and Long-term Sustainability

Digital transformation has fundamentally reshaped the asset structure of logistics enterprises. By leveraging digital twin simulations of physical assets [15] and mitigating the “Bullwhip Effect” [16], JD Logistics has significantly optimized its asset turnover efficiency. High-precision order sorting and warehouse-distribution coordination have further improved inventory turnover days. This asset-light operational model, combined with high-precision fulfillment (evidenced by a 99.98% order-sorting accuracy), collectively establishes a formidable industrial moat.

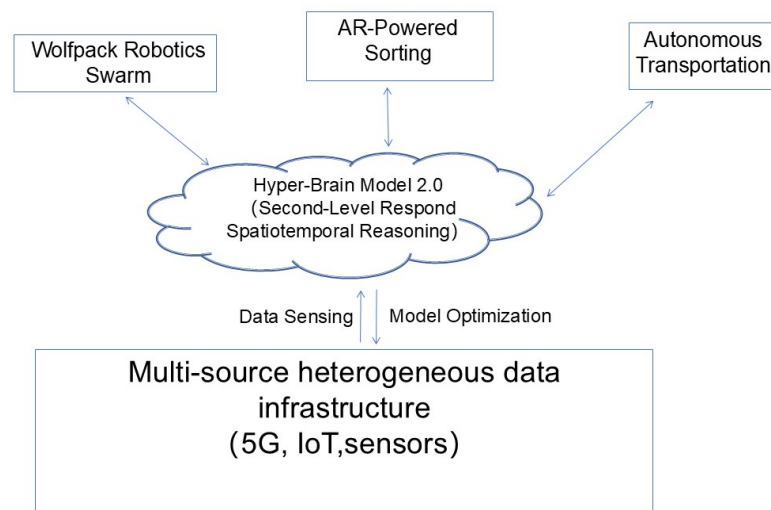
5. The Efficiency Evolution Path and Industrial Paradigm Extraction of JD Logistics’ Digital-Intelligent Transformation

In the case of JD Logistics’ digital transformation, the enhancement of supply chain efficiency through technology is not a simple non-linear accumulation; rather, it is achieved through the reconstruction of the underlying logic. Based on the preceding empirical analysis, logistics enterprises should focus on the following core dimensions in their subsequent transformation phases.

5.1 Software-Hardware Co-evolution: Transitioning from Equipment Automation to Algorithmic Intelligence

The focus of digital transformation should shift from early-stage, standalone hardware automation investments toward the perception and scheduling of the entire process by an “algorithmic brain.” Much of JD Logistics’ success can be attributed to the deep coupling of its “Superbrain 2.0” decision-making system with its “Wolf” execution system [13]. This implies that enterprises must move away from “siloes” hardware upgrades and instead construct a unified digital foundation, ensuring that bottom-layer sensor data provides real-time feedback to the decision-making layer. By introducing Embodied AI technologies to achieve standardized operations—such as AR visual sorting—enterprises can reduce dependence on manual experience while improving operational standardization levels by 15%. This approach effectively addresses the long-standing challenges of system integration difficulties and data fragmentation within traditional logistics systems [15].

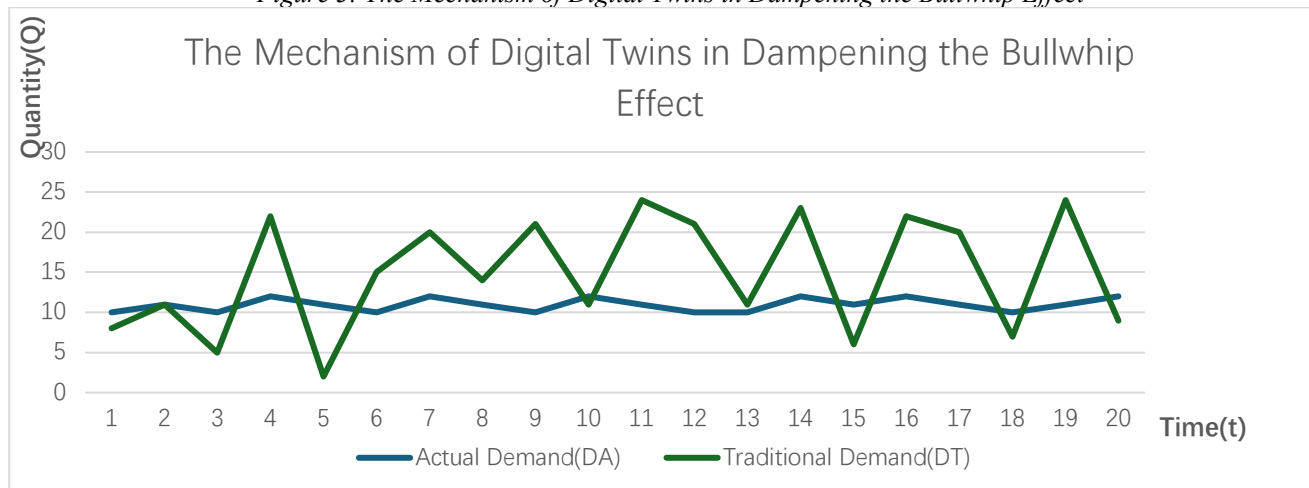
Figure 2: Brain–Execution Integrated Architecture for Digital-Intelligent Supply Chain



5.2 Transparent Governance: Utilizing Digital Twin Mechanisms to Dampen the “Bullwhip Effect”

Information transparency and symmetry are the core levers for mitigating the “Bullwhip Effect” in supply chains [16]. Enterprises should construct 1:1 physical mapping models that integrate multi-source heterogeneous data and perform time-series forecasting [15]. This logical shift from “reactive response” to “proactive anticipation” enables enterprises to achieve second-level routing optimization and high-frequency demand simulations [13], effectively dampening order fluctuations triggered by demand forecast updates. This transition toward a “demand-driven pull-based supply chain” not only pushes order-sorting accuracy to a marginal limit of 99.98% but also achieves the optimal allocation of logistics resources by eliminating dead stock and redundant transportation.

Figure 3: The Mechanism of Digital Twins in Dampening the Bullwhip Effect



5.3 Embodied AI Collaboration: Reshaping the Boundaries of Trust and Efficiency in Human-Machine Interaction

The depth of digital processes should be bounded by a “people-centered” philosophy, leveraging technology to enhance human creativity rather than merely replacing it. The case of JD Logistics demonstrates that the release of technology dividends depends on the trust calibration between algorithmic decisions and frontline employees [14]. When advancing automated processes, managers should establish collaboration mechanisms based on game theory to dynamically assess employees' cognitive loads. Evidence suggests that

by optimizing human-machine interfaces and operational logic, enterprises can achieve a synergistic efficiency gain of approximately 20.24% while significantly reducing worker fatigue by 59.4%. This implies that enterprises should organically integrate the “rigidity” of algorithms with the “flexibility” of human operations.

5.4 Value Transformation Path: Extending from Internal Efficiency Enhancement to External Commercial Empowerment

Logistics enterprises should actively explore pathways for the “value spillover” of digital capabilities, achieving a leap from being a cost center to a value center. Against the backdrop of a stabilizing industry revenue growth rate of 6.1% in 2025 [12], JD Logistics leveraged its internalized assets—such as its address database and spatial-temporal large models—to provide external services, achieving a revenue growth of 14.1%, which far exceeds the industry average [11].

The core competitiveness of this empowerment lies in exporting a standardized “variance control capability.” For external partners, the fundamental pain point of supply chain management is the inability to overcome the uncertainty caused by information distortion. The mathematical objective of digital transformation is to realize the following logical conversion:

$$\sigma_{\{order\}}^2 > \sigma_{\{demand\}}^2 \Rightarrow \sigma_{\{order\}}^2 \rightarrow \sigma_{\{demand\}}^2 \quad (1)$$

In this context, $\sigma_{\{order\}}^2$ represents the variance of a partner's order fluctuations, while $\sigma_{\{demand\}}^2$ denotes the variance of actual terminal demand. This formula reveals how JD Logistics utilizes digital-intelligent means to transform “uncertainty” into “certainty”: by productizing its mature internal algorithmic models, the company helps clients achieve precise alignment between order fluctuations and actual demand.

Evidence shows that this business empowerment, rooted in mathematical certainty, can significantly shorten clients' site selection cycles by 80% and directly drive a 25% increase in order [13], thereby constructing a deep competitive moat based on data assets. This model innovation—transitioning from an “internal tool” to an “industry standard”—forcefully validates the immense potential of digital assets in external commercial empowerment.

6. Conclusion and Future Outlook

This study systematically elucidates the mechanisms by which digital transformation drives supply chain efficiency, using JD Logistics as a quintessential case. The research demonstrates that digitalization has evolved from an auxiliary tool into a core endogenous drive, achieving a “leapfrog improvement” in operational efficiency through the synergy of “Superbrain” algorithms and Digital Twin systems. Specifically, by realizing the logical convergence of order variance toward actual demand, enterprises can effectively dampen the “Bullwhip Effect” and establish a sustainable competitive barrier rooted in human-machine collaboration and “value spillover.” For managers, the key to success lies in constructing an integrated “brain + execution” architecture and prioritizing a “people-centered” trust calibration. While this study is limited by its focus on a heavy-asset benchmark and the time-lag effect of organizational change, it provides a foundational paradigm for the industry's digital evolution. Future research should further explore the integration of Generative AI (LLMs) with embodied intelligence in complex logistics scenarios, as well as the contractual governance of data assets in multi-party collaborative ecosystems.

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Conflicts of Interest

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The Economic Impacts of Automation in the Port Industry

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Abstract

The rapid digitalization of global maritime logistics has positioned port automation as a transformative force, but the theoretical understanding of its systemic economic implications is still insufficient. This study investigates the welfare consequences of automation-induced market restructuring across multiple economic agents within oligopolistic port governance frameworks. Through comparative case analysis of Shanghai's Yangshan Deep-Water Port, Qingdao Automated Terminal, and the Port of Rotterdam, the research synthesizes operational data, labor statistics, and cybersecurity incident reports to evaluate distributional effects. The findings reveal three interrelated pathologies: natural monopoly consolidation wherein the top decile of automated ports commands 40% of global container throughput; labor market polarization reducing traditional dockworker complements by approximately 70% while generating substantial skill premiums; and negative externalities manifesting as systemic cyber-vulnerability, with documented disruptions demonstrating cascading supply chain contagion and unpriced social costs. These findings challenge efficiency-centric narratives by demonstrating that automation amplifies market concentration, exacerbates income stratification, and externalizes digital risk. The study contributes to transportation economics literature by formalizing the efficiency-resilience-equity trilemma inherent in port digitalization and provides an evidence base for regulatory interventions including cybersecurity subsidies and just-transition labor frameworks.

Keywords

port automation, intelligent economy, cybersecurity vulnerability, supply chain resilience

1. Introduction

In an era of rapidly expanding international trade, ports, as the backbone of maritime transportation, are under increasing pressure to enhance production efficiency in order to survive intense global competition. The rise of port automation, referring to the integration of advanced technologies and artificial intelligence into port systems, has brought about a profound transformation in the port infrastructure market. Shanghai's Yangshan Deep-Water Port, the world's largest automated container terminal, exemplifies this transformation by handling 51% of Shanghai's total container throughput and achieving over 90% of its operational efficiency through AI-driven systems. However, this efficiency-driven transformation comes with substantial social and economic risks that are rarely fully addressed. Such as natural monopoly, negative externalities and factor income polarization.

Forty percent of global container throughput is concentrated in the top 10% of ports, all of which are pioneers in automation [1]. Yangshan Port handles approximately 26 million TEUs of container throughput, accounting for about 51% of Shanghai Port's total cargo volume. Over half of Shanghai Port's cargo throughput is located at Yangshan Port, situated in the outer sea, and Yangshan Port contributes more than 90% of Shanghai Port's container throughput [2]. It captured the majority of the market share, subsequently forming a natural monopoly trend.

These smart ports rely heavily on digital systems due to their high level of automation, even with over 90% of tasks performed by computer systems. As port systems become increasingly digitized and automated, cyberattacks could paralyze servers, cause automated equipment to malfunction, or compromise data integrity, ultimately disrupting logistics operations. In recent years, cyberattacks have disrupted infrastructures at the ports of Antwerp [3]. The most impactful cyberattack on the maritime sector to date was NotPetya in 2017, when the Danish logistics and transports company Maersk suffered significant business disruption and 76 port terminals were affected [4, 5]. Navigating cyber resilience in seaports: challenges of preparing for cyberattacks at the Port of Rotterdam.

Port automation is often accompanied by significant job opportunities losses, particularly in traditional manual labor positions. In the UK alone, automation caused the number of port workers to decline from 140,000 in the early 1960s to 30,000 by 2000 [6]. Furthermore, taking Qingdao Port in China as an example, as one of the world's most automated container terminals, its automation system has reduced labor costs by 70%, leading to a sharp decline in demand for traditional labor [7]. Moreover, Automation will result in a reduction of \$476.32 million to \$743.89 million in local traditional port worker expenditures and a decrease of 2,445 to 3,818 jobs [8]. But in Prince Rupert, some highly skilled dockworker positions command annual salaries exceeding \$100,000 [9]. This has only served to widen the wealth gap between different workers.

2. Economic Mechanism

2.1 Market Power

Oligopoly refers to a market structure in which a small number of firms dominate a large share of the market and exercise substantial control over pricing and output levels. In the port infrastructure market, geographical location creates high barriers to entry, allowing a limited number of ports—such as Shanghai's Yangshan Deep-Water Port and the Port of Rotterdam—to gain significant market power due to their uniquely advantageous locations. However, oligopolistic markets are often subject to the prisoner's dilemma, a game-theoretic concept in which firms acting to maximize individual utility ultimately fail to achieve collective welfare optimization. Each port strives to outperform its competitors by enhancing efficiency and profitability, which incentivizes all firms to continuously increase their level of automation. This competitive dynamic encourages excessive investment in automation, potentially leading to an unreasonably high level of technological adoption without corresponding welfare gains.

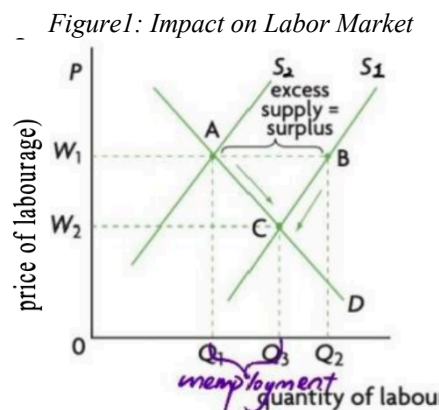
2.2 Unemployment & Labor Market

Furthermore, port automation is frequently accompanied by substantial job losses, particularly in traditional manual labor positions. Automated machinery allows ports to operate continuously, 24 hours a day, without incurring additional wage costs, leading ports to increasingly substitute capital for labor, as discussed previously. This shift directly results in the reduction in traditional port worker expenditures, along with a substantial cut in job vacancies; these consequences are directly associated with port automation to some extent [10]. According to Figure 2.2, low-income groups may experience further wage reductions, leading to an overall decline in living standards. Moreover, demand-pull inflation may emerge in low-income countries, resulting in lower national output and rising price levels, which further depress living standards.

2.3 Externalities

Heavy reliance of smart ports on digital systems increases the vulnerability and volatility of the marine supply chain, which amplifies the impact of cyber threats, as the breakdown of a single subsystem may trigger cascading failures across the entire port. As global supply chains become increasingly interconnected,

with over 90% of operational tasks performed by computer-based systems, successful cyberattacks have the potential to generate widespread disruption on a global scale. Such cyberattacks often involve actions that paralyze servers, cause automated equipment to malfunction, or compromise data integrity, thereby directly disrupting port logistics operations. Empirical evidence demonstrates the severity of this risk. Consequently, both directly target identities, such as terminal operators, and downstream stakeholders, including logistics companies and cargo owners, are exposed to significant operational risks.



3. Case & Data Analysis

3.1 Qingdao Port

As a leader in smart maritime operations, Qingdao Port has transitioned from “Made in China” to “Created in China” [11]. The fully automated terminal marks a strategic shift toward a high-tech operational paradigm. Its single-crane efficiency reaches 42.23 containers per hour with a world-record peak of 60.2 [12], significantly exceeding the global conventional average of 25-28 containers per hour. This efficiency reduces marginal costs and serves as the core competitiveness for attracting cargo flow. In the Bohai Rim, this technological edge has consolidated Qingdao's market power, with annual throughput exceeding 700 million tons [13]. Within the Shandong port cluster, Qingdao Port accounts for approximately 36% of total cargo throughput and a dominant 71% of container volume [14], establishing it as the region's primary container hub. Studies confirm that such high efficiency accelerates the concentration of cargo toward top-tier hubs [15]. Furthermore, the deployed Port Center ICT System enhances port community synergy, while BIM-based smart construction [16] secures a long-term, resilient supply chain advantage.

Qingdao Port's highly digitized ecosystem—with 90% of its operational tasks relying on digital systems—exemplifies the “single point of failure” risk inherent in over-automation [11]. While BIM and Smart Worksite technologies enable a record 60.2 TEU/hour efficiency, this dependency ensures that any cyber-interference triggers cascading effects. Disruptions discussed by Baixun [17] export operational risks to downstream providers as uncompensated negative externalities. As annual throughput exceeds 700 million tons, localized paralysis causes a cyber-contagion. According to Ma et al. [18], these disruptions impose unpriced social costs, such as inventory spoilage for local manufacturers. Given Qingdao Port handles 25-30% of China-Japan-South Korea trade (valued at 150-180 billion euros annually) and over 700 million tons of annual throughput, even a temporary localized paralysis could spark a “cyber-contagion” across East Asian supply chains.

Qingdao Port's automation has triggered a radical structural shift in labor demand. The transition to fully automated terminals has achieved a 70% reduction in labor costs, leading to a sharp decline in demand for traditional manual roles [19]. While the port sets global benchmarks for Intelligent Manufacturing, “this progress masks significant job losses. Historically, port automation has decimated worker counts as seen in the UK where workforce numbers fell from 140,000 to 30,000 and Qingdao mirrors this through capital-labor substitution for quay crane operators and drivers [20]. The shift has institutionalized a stark wage stratification. The market now aggressively favors a technical elite, creating a substantial skill premium. While high-skill dockworkers in automated hubs can command salaries exceeding \$100,000, displaced manual workers face income erosion. This disparity reflects a polarized distribution where the financial

rewards of innovation are concentrated among technical insiders, while the marginalized manual workforce bears the brunt of structural unemployment [21].

3.2 Port of Rotterdam

Another concrete real-life case is the Port of Rotterdam. Container throughput at the Port of Rotterdam stood at 6.28 million TEUs in 2000, prior to large-scale automation, and rose to 13.8 million TEUs by 2024 following automation, with further productivity improvements expected as technology continues to evolve. However, despite awareness of the potential welfare losses associated with automation, the Port of Rotterdam faces a classic prisoner's dilemma, as do other major European ports. If competing ports such as Hamburg adopt automated systems, Rotterdam must do the same to avoid profit losses. Conversely, even if competitors refrain from automation, Rotterdam still has an incentive to automate in order to increase profits. Consequently, the dominant strategy for each port is to expand automation, resulting in similar profit levels across ports while imposing welfare losses on third parties within the economy.

Figure 2: Prisoner dilemma between ports

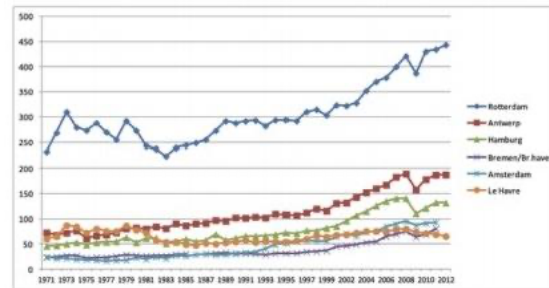
		Port A	
Port B	use automated systems	Port A receives same profit Port B receives same profit	Port A receives lower profit Port B receives higher profit
	do not use automated systems	Port A receives higher profit Port B receives lower profit	Port A receives same profit Port B receives same profit

To increase its level of automation, the Port of Rotterdam has allocated a substantial proportion of its budget to acquiring and developing advanced technologies. Estimates suggest that developing an automated crane system alone requires approximately USD 80-120 million. Investment in AI software alone can exceed USD 6.5 million, excluding additional integration and operational costs

such as data infrastructure development. Reports indicate that the Port of Rotterdam has invested approximately EUR 200 million in automation and AI infrastructure. Despite rapid technological progress, the cost of automation has declined only gradually. As a result, the initial investment required for automated ports is expected to remain high in the foreseeable future, with average payback periods estimated at approximately six years.

High financial costs have prevented smaller ports in the region from adopting automation technologies. Even prior to widespread automation, the European port sector already exhibited a high concentration ratio, with container throughput dominated by a small number of leading ports. In 2008, the Port of Rotterdam accounted for 26.8% of total container volume in the Hamburg-Le Havre range. Over time, superior efficiency and lower unit handling costs at major ports have attracted shipping lines and cargo owners, further intensifying market concentration. Ports handling fewer than 0.5 million TEUs annually typically operate with profit margins of only 15% to 25%, which are insufficient to finance large-scale automation investments.

As illustrated in Figure 3, container throughput increased from 2 million TEUs in 1980 to 12 million TEUs in 2010, while employment levels declined sharply. Container throughput increased from 2 million TEUs in 1980 to 12 million TEUs in 2010, while employment levels declined sharply. Historically, the port employed approximately 180,000 workers, accounting for 19% of total employment in the Rotterdam-Rijnmond region. Automation is projected to reduce employment in the Dutch maritime sector by 25%, implying that around 45,000 workers associated with the Port of Rotterdam may face displacement. By the end of 2024, only 1,392 employees and 185 external contractors remained directly employed by the Port Authority.

Figure 3: Total cargo output in main NW-European ports [22]

Finally, excessive reliance on digital systems increases vulnerability across the European supply chain. Cyberattacks may paralyse servers, disrupt automated equipment, or compromise data integrity. Despite investing approximately EUR 50 million in cybersecurity, the Port of Rotterdam has experienced cyber incidents that temporarily shut down internet and website services. Estimates suggest that a large-scale cyberattack could generate losses of up to USD 110 million if disruptions spread to other ports simultaneously.

4. Practical Proposal

4.1 Policy I: Government Subsidies for Data Security

Cyber threats targeting the Port of Rotterdam have become increasingly frequent in recent years. Given the port's critical role in national trade and essential supply chains, prolonged shutdowns could severely disrupt the Dutch economy. As the development of advanced cybersecurity systems can cost hundreds of millions of euros, government subsidies could support ports in strengthening digital defences. This policy would ensure continuity in international trade and prevent large-scale economic losses arising from cyberattacks. Without adequate protection, supply chain disruptions could undermine firm profitability and investor confidence, reducing aggregate demand and national output in the long run.

4.2 Policy II: Re-training program

One good policy to address the problem of structural unemployment is the agreement on the duration of employment contracts, providing job security and offering the re-training programs. Aim to ensure the employment of labour by legal protection, thus the workers will not be laid off after the introduction of automation. Taking Port of Rotterdam as an example, in 2016, the employment guarantee agreement reached between the port authority, the trade union [23], and the terminal operator provided job security and re-employment mobility measures for employees who had obtained permanent contracts before 2015 during the agreement period, including early retirement support and internal job reallocation mechanisms, thereby alleviating the impact of automation on the employment of port workers [24]. Moreover, the Port of Rotterdam region has made up for the shortcomings of a single agreement through multi-party cooperation such as the "Port of Energy" project and other re-training and labour market support programs, that are supported by Just Transition Fund, to improve cooperation between the education system and the labour market, aimed at motivating, training and re-educating the necessary human resources, by the end of 2024, 370 job seekers have successfully found employment in port enterprises, indicating that such policies have achieved concrete results in attracting talents and promoting employment [25].

5. Conclusion

Port automation represents a paradoxical paradigm in global maritime logistics, simultaneously enhancing operational efficiency while exacerbating systemic vulnerabilities. This study demonstrates that automated terminals, exemplified by Qingdao Port and Port of Rotterdam, achieve unprecedented throughput rates yet concentrate market power, creating natural monopolies that marginalize smaller competitors. Furthermore, digitalization introduces critical supply chain fragilities through cyber-vulnerability and cascading disruption risks. The socioeconomic consequences manifest as structural unemployment and widening wage

disparities, with manual laborers displaced while technical elites capture disproportionate economic rents. Effective policy interventions—including transparent pricing protocols, employment security agreements, and workforce retraining programs—remain essential to balance technological advancement with equitable labor transitions and supply chain resilience. However, such subsidies would place pressure on government budgets, potentially limiting funding for welfare or infrastructure development. In addition to the subsidies, the plan of offering re-training program has obvious limitations: the employment guarantee has a time limit and does not cover all types of workers. During the subsequent negotiations regarding the implementation of automation, conflicts still arose between the unions and the port authority. This indicates that the social dialogue mechanism needs to be more institutionalized and long-term.

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International Marketing Strategy Adaptation: A Driver of Global Value Chain Embedding: A Review of Chinese Firms

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Abstract

This study examines how international marketing strategy adaptation supports progressive embedding and upgrading of Chinese firms within global value chains (GVCs). A stage-based conceptual framework was developed by integrating network embeddedness theory and resource orchestration theory. A qualitative review approach was adopted, and comparative case analysis was conducted on Huawei and Lenovo to illustrate how firms navigate distinct challenges, opportunities and upgrading paths at different stages of GVC embedding. The findings reveal that marketing strategies play various roles across stages: facilitating market legitimacy at early stages, enabling relational integration at intermediate stages, and supporting strategic governance at advanced stages. Such marketing adaptation contributes to GVC upgrading primarily by mediating firms' network embeddedness. This study contributes to international business and GVC literature by clarifying the contingent effect of marketing capabilities in value chain upgrading. It also offers managerial and policy implications by highlighting how downstream capabilities and relational strategies can support sustainable internationalization.

Keywords

internationalization, marketing strategies, global value chain embedding, network embeddedness, resource orchestration

1. Introduction

Internationalization has become a central strategy for firms seeking sustained growth in an increasingly fragmented yet interconnected global economy. In recent years, Chinese firms have expanded rapidly within global value chains (GVCs). In the first ten months of 2024, China's goods exports reached 20.8 trillion yuan, increasing by 6.7% year-on-year. This expansion reflects not only rising export scale but also firms' ambition to move toward higher value-added positions. There is a significant positive impact of global risk management capability on GVC capability, which eventually impacted MNE performance [1]. Therefore, as competition intensifies and institutional environments diversify, the ability to dynamically adapt international marketing strategies has become a critical determinant of global competitiveness.

Existing studies provide substantial insights into the international marketing strategies of emerging market firms, particularly their adaptive behavior under institutional constraints. Meanwhile, GVC research has examined governance structures and value capture across fragmented production networks. However, these two streams remain insufficiently integrated. International marketing studies typically focus on market performance and legitimacy, whereas GVC research emphasizes production capabilities and governance structures. Limited attention has been paid to how marketing strategies shape firms' evolving positions within GVCs.

To address this gap, this study asks: How do Chinese firms dynamically adapt international marketing strategies across stages of global expansion, and how do these adaptations facilitate progressive GVC embedding? Drawing on network embeddedness theory and resource orchestration theory, this study develops a stage-based analytical framework conceptualizing marketing strategies as evolving mechanisms. Rather than viewing marketing adaptation as a one-time localization decision, the framework highlights how its role shifts from legitimacy building to relational embedding and ultimately to governance influence.

As for methodology, the study adopts a review approach and develops a conceptual framework grounded in two theories. Comparative case analysis of two Chinese firms is used to illustrate how firms navigate stage-specific challenges and opportunities. By integrating international marketing and GVC perspectives, this research clarifies how marketing adaptation contributes to sustainable upgrading rather than mere market expansion, offering implications for managers and policymakers.

2. Literature Review

2.1 International Marketing Strategies

Research on international marketing strategies have traditionally focused on how firms adapt product, branding, and channel decisions to heterogeneous institutional and cultural environments. They highlighted trade-offs between global integration and local responsiveness. More recent research shift attention toward dynamic adaptation under institutional uncertainty, particularly for emerging market firms expanding into advanced economies. International marketing is increasingly viewed not merely as a functional activity, but as a strategic capability. However, much of this literature evaluates outcomes in terms of market performance and brand success, with limited attention to how marketing strategies influence firms' structural positions within global production networks.

2.2 Global Value Chain (GVC)

Global value chain research examine how value creation, coordination and governance are distributed across fragmented international production networks. Foundational studies distinguish between different governance structures to emphasize how firms move from low-value manufacturing to higher value-added functions such as design, branding, and coordination. Recent work highlights relational embeddedness and capability accumulation as key determinants of upgrading outcomes. Nevertheless, GVC scholarship has traditionally prioritized production capabilities and governance configurations, so it often underplays the role of market-facing strategies. The interaction between international marketing adaptation and GVC positioning therefore remains a gap.

3. Stage-Based Analysis of International Marketing Strategies and GVC Embedding

This study demonstrates the internationalization of marketing strategies and global value chain embedding as a dynamic and stage-based process. Building on resource orchestration theory and network embedding theory, the study proposes a three-stage framework to illustrate how firms adapt marketing strategies to overcome constraints, leverage opportunities and progressively enhance their positions. According to network embedding theory, corporate internationalization is a process of continuous integration and connection into host country networks [2]. During this process, firms need to obtain, organize, and then utilize resources which are in line with resource orchestration theory [3].

3.1 Stage 1: Peripheral Market Entry and Production-Oriented Embedding

3.1.1 Challenges

At the initial stage of GVC embedding, firms enter international markets from peripheral positions. Marketing strategies are primarily used to reduce uncertainty rather than capture high-value activities [4]. Companies primarily face liabilities of limited brand recognition and restricted access to key actors. It is also difficult to align with the shared values and cultural needs of global consumers. Firms find ways to combine local cultural expression with global value resonance, thereby standing out on the multicultural international stage [5]. Institutional distance and liability of foreignness further constrain their abilities to control marketing channels or influence value distribution. As a result, firms often depend on intermediaries and lead firms, which limits their bargaining power and strategic autonomy.

3.1.2 Opportunities

Despite these constraints, early international participation creates opportunities to establish foundational market presence. Exposure to foreign markets allows firms to accumulate experiential knowledge and build initial network ties with distributors and platform intermediaries. Even peripheral participation may trigger upgrading processes over time [6]. At this stage, firms begin bundling basic marketing resources, such as market knowledge and localized distribution capabilities, laying the groundwork for deeper embedding.

3.1.3 Optimal path

The strategic focus at this stage lies in resource structuring and standardized marketing to achieve cost efficiency and stable participation. Network embeddedness remains transactional, yet it serves as a critical entry point for accumulating market knowledge. The optimal path involves leveraging standardized marketing capabilities to secure stable GVC participation while selectively investing in relational learning. Different industries choose different ways to participate in reconstruction of GVCs due to their different levels of competitiveness, such as constructing National Value Chains and indigenous innovation [7]. Marketing adaptation supports repeated transactions and gradual legitimacy building, but its contribution to GVC upgrading is indirect. Firms secure stable participation first before pursuing higher-value positioning.

3.2 Stage 2: Relational Market Embedding and Value Chain Integration

3.2.1 Challenges

As firms move beyond initial entry, the central challenge shifts from market access to relational integration. International marketing strategies increasingly operate as deepening network embeddedness within global value chains [8]. Therefore, standardized marketing strategies become insufficient as firms confront heterogeneous consumer demands and intensified competition. Coordination costs increase and technological constraints may limit firms' ability to deliver credible value propositions [9].

Studies show that diversity in governance relationships helps enhance overall resilience, which requires relational aspects to be considered alongside economic aspects of the GVC [10]. Marketing adaptation alone cannot sustain upgrading unless supported by stronger relational and technological capabilities.

3.2.2 Opportunities

This stage creates opportunities for functional upgrading through deeper integration with local partners and enhanced innovation capabilities. Technological knowledge flows contribute to firms' improved GVC positioning [11]. Firms establish authoritative and highly recognized technological proprietary which helps to differentiate themselves from other companies in the international market, thereby occupying an irreplaceable position in GVC. Marketing adaptation facilitates this shift by aligning branding and value propositions with local market expectations.

3.2.3 Optimal path

Firms engage in resource bundling to reconfigure marketing capabilities, balancing global integration and local responsiveness. Localization in branding and pricing becomes more pronounced. Simultaneously, firms deepen network embeddedness through strategic partnerships and relational learning [12]. The optimal path involves aligning adaptive marketing capabilities with relational upgrading to facilitate functional GVC

embedding and solving problems of technical bottlenecks. Marketing adaptation contributes to upgrading not through scale expansion alone, but by reinforcing relational integration that enables firms to reposition themselves within production and distribution networks [13].

3.3 Stage 3: Strategic Embeddedness and GVC Position Upgrading

3.3.1 Challenges

At advanced stages of GVC embedding, the central challenge lies in transforming accumulated relational assets into strategic influence and governance power [14]. Companies face intensified competition from incumbent multinationals and structural power asymmetries within global value chains, so it is necessary to form transmission mechanisms and arena of actors to yield power in GVC governance [15]. Moving into high-value activities such as brand leadership and ecosystem coordination requires substantial strategic commitment and capability integration.

3.3.2 Opportunities

Firms that successfully orchestrate marketing capabilities can transition from GVC participants to controllers, which influence standards, consumer preferences and network governance. International marketing strategies increasingly serve as strategic tools for ecosystem construction and brand-based value capture. The internal governance of GVC is a dynamic phenomenon that is subject to continuous adjustments and changes. Different integration and utilization of information or resources affect co-evolution [16].

3.3.3 Optimal Path

This stage emphasizes resource leveraging at the ecosystem level, where firms integrate marketing, innovation, and relational capabilities to build global brand equity. Deep network embeddedness enables firms to occupy more central positions within GVCs. Then firms enhance both their bargaining power and long-term competitiveness through improved coordination and governance of market-facing activities [17, 18]. The optimal path involves continuous reconfiguration of marketing strategies as dynamic capabilities, supporting sustained high-level GVC embedding. Accordingly, marketing strategies at this stage play a role in supporting firms to shape downstream activities and exert greater control over value distribution.

4. Discussion: Implications for GVC Upgrading and Internationalization Strategy

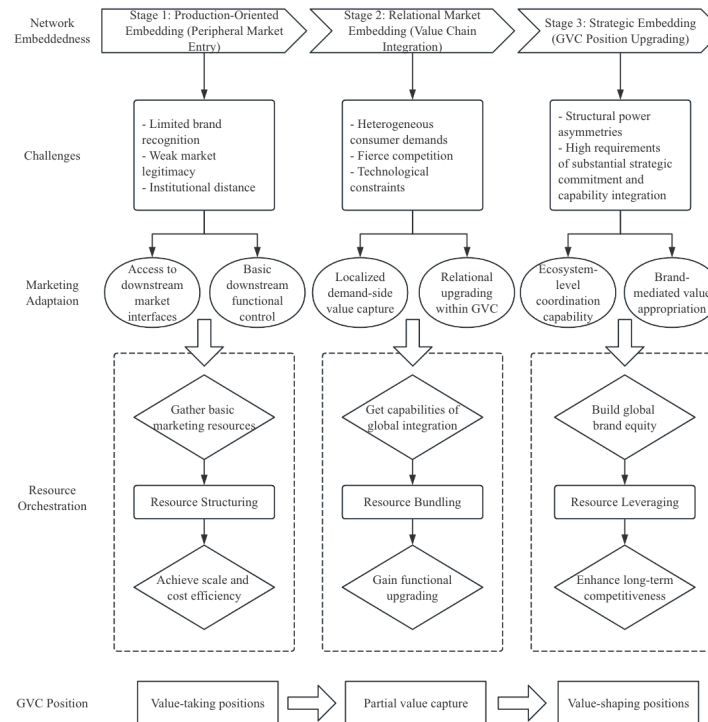
4.1 Framework Explanation

Figure 1 present a stage-based framework illustrating how international marketing strategy adaptation facilitates firms' progressive embedding within global value chains. Internationalization is conceptualized as a dynamic process comprising three stages of network embeddedness, during which firms reconfigure marketing resources and gradually shift from value-taking to value-shaping roles. Transitions across stages are not driven by market expansion alone, but by changes in firms' control over downstream activities, relational positioning, and value appropriation within GVCs.

4.2 Case Analyses of Representative Firms in China

Orchestrating firms can enhance efficiency outcomes of the GVC using social mechanisms, such as relational capital, multilateral feedback and so on. Deployed in an integrative fashion, these mechanisms facilitate coordination and foster innovation or new capability development [19]. International marketing functions as a key mechanism through which firms bundle and leverage different types of resources to overcome capability constraints and achieve higher-value GVC participation [20]. Collectively, marketing strategy operates as a conduit linking resource configurations with dynamic shifts of positions in GVC.

To illustrate how the proposed framework operates in practice, the following section applies the stage-based model to two representative Chinese firms—Huawei and Lenovo, and then makes comparative analysis. These representative cases are selected to capture distinct variation in several aspects such as technological capabilities, strategy changes and so on.

Figure 1: Framework of International Marketing Strategy Adaptation

4.2.1 Huawei: From Peripheral Participation to Strategic Embeddedness

Huawei's internationalization reflects a transition from peripheral participation to strategic embeddedness within global value chains. In its early stage, the firm entered foreign markets through cost-based competition and arrangements for original equipment manufacturer (OEM), occupying low value-added positions with limited control over branding and downstream activities. As technological capabilities and market knowledge accumulated, Huawei shifted toward localized solutions and relationship-based market development. This strategic reorientation strengthened its integration within host-country networks. In the advanced stage, Huawei leveraged its technological base and global partnerships to move into higher value-added segments, despite growing geopolitical and regulatory constraints.

Although institutional distance and weak initial legitimacy posed significant barriers, learning and continuous capability upgrading enabled the firm to reposition itself within global networks. Huawei's trajectory illustrates that marketing localization alone is insufficient for upgrading if without technological credibility. Sustainable strategic embeddedness depends on the interaction between technological credibility and relational integration within GVC structures.

4.2.2 Lenovo: From Peripheral Manufacturing to Brand-Oriented Embeddedness

Lenovo's international expansion reflects a transition from production-oriented participation to brand-driven embeddedness within global value chains. In its early stage, Lenovo operated primarily as an OEM, relying on cost efficiency and standardized products. While this strategy enabled market access and scale expansion, it offered limited downstream control and minimal value capture beyond manufacturing. A major turning point was the acquisition of personal computer (PC) business arm of international business machines (IBM), which provided access to established global brands, distribution networks and customer relationships. This strategic shift transformed Lenovo's international marketing orientation from cost-based competition to brand-centered positioning.

However, upgrading through brand acquisition also introduced integration challenges and governance complexity. Successfully managing these trade-offs allowed Lenovo to convert marketing capabilities into a strategic lever for higher-value positioning. The case demonstrates how brand control enhances downstream influence but requires effective organizational integration to sustain GVC upgrading.

4.3 Conceptual Refinement of the Framework

The comparative case analysis refines this framework by demonstrating that marketing-led upgrading is inherently stage-contingent. In early phases, marketing adaptation supports market access and legitimacy building under limited downstream control. As firms accumulate technological capabilities and deepen relational integration, marketing increasingly functions as a mechanism that mediates network embeddedness and enables governance influence. GVC upgrading therefore depends on how firms align marketing adaptation with evolving resource configurations and network positions. Rather than generating direct value capture, international marketing strategy shapes firms' upgrading trajectories through its interaction with relational and organizational capabilities.

5. Conclusion

This study examines how Chinese firms adapt international marketing strategies to achieve deeper embedding within global value chains. Drawing on a stage-based framework and two case analyses, it shows that marketing-driven upgrading is dynamic and contingent rather than linear. International marketing strategies evolve from facilitating market access and legitimacy building to enabling relational integration and governance influence. Marketing adaptation contributes to upgrading primarily through its interaction with firms' network positions and resource orchestration [21].

The study advances a stage-based perspective on GVC embedding, clarifying how the role of marketing capabilities shifts across phases of internationalization. It highlights network embeddedness as a mediating mechanism and integrates resource orchestration into GVC analysis [22]. Rather than treating marketing localization as a universal upgrading strategy, the findings demonstrate how firms translate marketing initiatives into sustained development and upgrading heterogeneity [8].

Several limitations warrant attention. First, the study relies on qualitative evidence from two large Chinese firms, which may limit the generalization of the findings to smaller firms or other emerging economies. Second, broader institutional and geopolitical dynamics are not fully examined. Future research could adopt mixed methods or cross-industry datasets to test the framework across diverse contexts [23, 24].

From a managerial perspective, the findings suggest that firms should combine marketing adaptation with evolving network positions and resource configurations rather than treating localization as an isolated tactic. For policymakers, maintaining institutional openness promotes value chain advancement by reducing institutional transaction costs and augmenting technological innovation [25]. So, capabilities like branding and channel development can enhance firms' resilience and facilitate sustainable GVC upgrading.

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ESG Factors and Asset Pricing Efficiency from the Perspective of Information Asymmetry: A Narrative Review

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Abstract

This narrative review systematically investigates the connection between the aspects of ESG and asset pricing efficiency with regard to the view of information asymmetry. As the analysis reveals, ESG has two impacts on prices: a signaling channel, whereby credible disclosures such as ratings and certifications address the information asymmetry in the stock market, and a trust channel, whereby the investors, because of their value congruence, reduce the risks associated with transactions. A central contribution is the development of a contingency framework demonstrating that the relative efficacy of these pathways depends on the information environment—signaling dominates in high-asymmetry contexts, while trust gains prominence as information becomes more abundant. The analysis further reveals that the moderating role of information asymmetry is shaped by heterogeneous conditions at the firm, market, and institutional levels. For instance, ESG signals exert stronger pricing effects in opaque environments, while trust mechanisms dominate in contexts with abundant information. The review constructs a contingency, which incorporates signaling and trust pathways. It concludes conflicting results in the literature and provides viable information to investors and regulators in improving the efficiency of the markets through prescribing a combination of measures that can be adopted in both opaque and transparent markets.

Keywords

ESG disclosure, ESG rating adjustment, asset pricing, CAPM model, information asymmetry

1. Introduction

In recent years, Environmental, Social, and Governance (ESG) factors have increasingly become a central component of global investment strategies, driven by regulatory frameworks such as the European Union's Sustainable Finance Disclosure Regulation (SFDR) and China's "dual-carbon" goals [1, 2]. In addition, at the market response level, the rapid development of green bonds and ESG-themed wealth management products indicates that capital is actively being channeled toward sustainability objectives [3]. For instance, on the back of the sustainable finance market achieving several significant milestones in 2025, Climate Bonds Initiative has identified six trends for 2026 [4], reflecting the significant trend of sustainable and green low-carbon development in the financial market. Against this backdrop, ESG factors have become critical in shaping asset valuation and pricing efficiency.

Existing research has come up with a basic consensus that ESG performance is related to the corporate value and stock returns, usually through alleviating the information asymmetry. Other studies like Pedersen et al. [5] suggest an ESG-efficient frontier, whereby when ESG activities exist, high ESG ratings have the potential to decrease capital costs and increase efficiency in prices. Similarly, Shi and Wang [6] find that ESG risks are priced in the Chinese market and the higher the ESG performance the lower the cost of capital of firms. Nevertheless, despite the growing body of literature focusing on the investigations of the relationship between ESG and asset pricing, there are still major disputes relating to the direction, mechanism, and contextual limits of these effects [7,8]. There are major concerns that are involved in the debate. To start with, whereas there are scholars who claim that ESG performance impact mispricing through a homogenous effect on disclosure quality across the markets [9], other scholars point to a heterogeneity of markets and firms [10]. Second, the lack of consistency in the prices across different studies on ESG has been caused by the variation in methodologies, including different ESG rating criteria, biases in sample selection, and models [11].

This review aims to synthesize the literature related to ESG factors, and asset pricing efficiency with respect to the role of information asymmetry. Explaining the theoretical channels through which ESG influences the price, discussing the discrepancy in results across studies concerning the matter and understanding the contextual aspect, this review details future research potentials. It contributes to a deeper understanding of the mechanisms by which ESG affects asset pricing, provides practical insights for investors in evaluating ESG-related risks and opportunities, and informs regulators to develop more standardized disclosure regulations to increase market efficiency.

2. Theoretical Background

2.1 Asset Pricing Theory and the Role of Information

Contemporary asset pricing theory dates back to Capital Asset Pricing Model which formalizes the relationship between expected return and systematic risk (Beta). One of the additional assumption is that every publicly available information is fully socialized in the prices, the Efficient Market Hypothesis [12]. Subsequent multi-factor models also add more dimensions of risk but do not modify rational information processing [13]. The asymmetry of information in such a tradition refers to skewed information that is not shared equally among market participants as a primary cause of market friction that may cause prices to be below the intrinsic value.

The emergence of ESG investing introduces a new layer. The ESG data representing such aspects of non-financial performance as carbon emissions, employee welfare, and board independence is a unique category of non-financial performance data [5], which provide an insight not only into the risk exposure of a specific firm but also into its long-term sustainability possibilities.

2.2 Signaling Theory and Trust Theory

With ESG investing, there is a high level of information asymmetry between firms and investors. Companies have comprehensive information about what they are doing, including ESG practices, and investors can hardly observe and verify those. There are two primary explanatory channels in the literature on the topic of ESG information regarding bridging this gap [11].

Signaling theory assumes that high-quality firms have credible and costly signals to make distinction [14]. Sustainability reports, third-party ratings, and certified green bonds are some of the examples of sustainability signals in ESG. These signals reduce investors' information processing costs, enabling more accurate firm valuation.

Trust theory changes to the internal psychology of the investors. Trust which is a psychological condition depending on a positive anticipation towards the good will and honesty of another person is a complex part of cooperation and expands simplicity [15]. When company values align with investor values, affective trust develops, influencing behavior beyond risk-return calculations [16]. This mechanism is especially crucial where information is ambiguous.

2.3 Theoretical Synthesis

Signaling Theory lays stress on objective, verifiable external mechanisms used to diminish information asymmetry, while Trust Theory highlights subjective, internal psychological mechanisms for building investor relationships. This composite lens frames the further discussion of ESG's pricing effects, how information asymmetry moderates such impact, and rate at which they change in heterogeneous conditions.

Table 1: Signaling Theory vs. Trust Theory: A Comparative Framework

Dimension	Signaling Theory	Trust Theory
Core	The sender's strategy and signal effectiveness	The receiver's psychological perception and value identification
Concepts	Information asymmetry, adverse selection, signal cost, credibility	Psychological contract, perceived responsibility, affective trust, value alignment
Role of ESG	Serves as a differentiating signal to reduce information asymmetry	Serve as a relationship bond that evokes investors' emotions and value resonance
Primary Mechanism	Reduces uncertainty through external validation (e.g., ratings)	Build psychological security through internal identification (e.g., sense of responsibility)

3. Literature Review

3.1 The Asset Pricing Efficacy of ESG Factors

Based on the theoretical backgrounds of signaling theory and trust theory, increasing literature is involved in exploring if and how ESG factors are priced in financial markets. Empirical studies that have been carried out so far provide substantial evidence that ESG factors have a large impact on asset pricing, though the direction and mechanisms of this impact remain under discussion. The fundamental topic of the discussion consists of whether ESG performance is a risk enhancing factor, a quality indicator of firms, or a non-pecuniary investor utility source.

Mainstream research based on the ESG Effective Frontier theoretical framework holds that the capital cost of a company is reducing and results in superior ESG performance in the case where the investor possesses non-pecuniary preferences towards sustainability [5]. This is mainly owed to the fact that ESG helps to alleviate risks which are being the most commonly priced in like regulatory, reputational, and litigation risks. As an example, research on the cost of debt and equity results in a view that companies scoring highly on ESG enjoy low financing cost [8, 17]. Similarly, Shi and Wang [6] provide evidence from the Chinese market that ESG risks are systematically priced, with superior ESG performance associated with reduced cost of capital.

However, the empirical evidences not very conclusive. Conversely, another perspective suggests that ESG factors, particularly controversies, can themselves be a source of systematic risk that demands a risk premium. Crifo et al. [3] the asymmetric effect is uncovered: the effect of the disclosure of irresponsible ESG practices has a stronger negative effect on firm valuation than the effect of responsible practices. This brings out the defensive incentive of making firms consider entering into ESG disclosure in order to shield their valuation. Similarly, Bang et al. [7] construct an ESG controversy risk factor and find that negative ESG events can have asymmetric pricing effects compared to positive ESG performance. This aligns with the risk-based explanation, where poor ESG performance is associated with higher future cash flow volatility and commands higher expected returns. The model proposed by Avramov et al. [18] is a dynamic equilibrium model whereby it is shown that ESG uncertainty has a major impact in the asset prices, and the attribute of impacts differs considerably under varying market condition.

To sum up, despite a trend towards agreeing that ESG factors are relevant to the pricing of assets, there are still considerable controversies about the direction, the strength, and the mechanism of these impacts. Other literature focuses on the risk reduction channel as it states that good ESG performance decreases firm specific risk and consequently lowers required returns. Others mention the channel of investor preference, indicating ESG is getting a special group of investors who are ready to get reduced returns in non-pecuniary gains. Although these two mechanisms are not mutually exclusive but may co-exist, the role of either could depend on a specific firm, industry, and market environment. Conventionally, the literature suggests that the

ESG-pricing relationship is conditional by a few moderating factors such as information asymmetry, rating disagreement, and government structure.

3.2 The Moderating Role of Information Asymmetry

While the preceding section establishes that ESG factors influence asset pricing, the magnitude and direction of this influence are not consistent. Information asymmetry is regarded as a paramount modifying variable in the connection between ESG and asset pricing. In this section, the differing degrees of information asymmetry will be analyzed in terms of exacerbating or mitigating the information effects of ESG factors basing on the two theoretical prisms: the signaling theory and the trust theory.

From signaling theory perspective [14], information asymmetry creates the very condition that makes ESG signals valuable. High-quality ESG disclosure acts as a credible signal to the market. It reduces the information gap between managers and outside investors, leading to more accurate valuation. When investors face high uncertainty about firm quality, credible ESG signals become more diagnostic and exert stronger influence on asset prices. Ruan et al. [10] demonstrate that ESG rating adjustments have greater pricing impact in information-opaque environments, where external validation serves as a crucial substitute for direct observation. This finding aligns with Christensen et al.'s [11] observation that rating divergence is most pronounced when underlying firm information is scarce, suggesting that signals matter most precisely when they are needed most. Conversely, ESG signals will have lower value of marginal value when in an information-rich environment. Avramov et al. [18] indicate that ESG uncertainty carries mutual characteristics with the information transparency, and market and firm pricing effects are concentrated in firms and markets where the alternative sources of information are scarce. It would mean that the ESG factors serve as an alternative information asymmetry mechanism which means the more other information sources are scarce the better is the pricing effectiveness.

Information asymmetry not only amplifies signals but also creates space for trust-based mechanisms to operate. Trust Theory presents a complimentary psychological process. An informal institution such as social trust has the ability to minimize perceived risks and transaction costs. Investors follow affective trust and value alignment to make decisions when the information necessary is not objective. Li et al. [8] discover that CEO power moderates the ESG-firm value relationship, suggesting that leadership credibility becomes more important when information is ambiguous. Subsequently, social trust has the potential to further increase the effect of ESG factors on asset pricing. Fan et al. [16] demonstrate that in regions with higher social trust, corporate ESG performance is significantly better. They argue that social trust fosters an environment where public environmental concern is heightened and corporate compliance is improved, thereby facilitating ESG engagement. The study by Crifo et al. [3] indirectly supports this, as the negative reaction to bad ESG news can be interpreted as a rapid erosion of trust, which is more damaging than the positive build-up from good news.

The combination of these results holds that information asymmetry would not linearly moderate the relationship between ESG-pricing. Rather, it acts through two channels, one which is the signal channel where high asymmetry enhances the diagnostic value of external signals; other is the trust channel where high asymmetry enhances the reliance on emotional trust, and amplifies the susceptibility to trust violation.

3.3 Information Asymmetry under Heterogeneous Boundary Conditions

The moderating effect of information asymmetry on the ESG-asset pricing association shows significant heterogeneity under different boundary conditions. These differences can be categorized into firm-level, market-level, and institutional-level factors.

Firm-level heterogeneity can be found in terms of scale, visibility and asset structure. Given the analyst coverage and media attention, the extent of information asymmetry is reduced in the case of large and visible firms. In the case of these types of firms, ESG indicators might have the role of differentiation other than information substitutes [10]. Small and medium enterprises, in turn, work rather in obscurity; in their case ESG ratings and certifications are the critical visibility-boosting signals that can dramatically alter investor perceptions [24]. Similarly, Fan et al. [16] show that the positive effect of social trust on ESG performance is stronger for firms with low internal control quality, indicating that external institutional pressures (like social trust) can compensate for weak internal governance mechanisms.

Market-level conditions, such as industry competition and market development, also shape the role of information asymmetry. Due to their high impact on the economy, energy, mining, and manufacturing sectors are characterized by inherent information asymmetry. Bang et al. [7] indicate that ESG scandals in such industries cause escalated market responses since investors are not able to observe these scandals directly and have to depend on the external indicators. Lin et al. [19] find that the relationship between state ownership and innovation is moderated by ESG practices and is more pronounced in periods of high economic policy uncertainty. In highly competitive industries, the signaling value of ESG might be heightened as firms strive to differentiate themselves. In low-impact industries, ESG information may be less material, and trust-based mechanisms may predominate. Moreover, the effects of ESG pricing also vary in the developed and emerging markets. Pedersen et al. [5] find that ESG-efficient frontiers are most clearly defined in markets where sustainability data is reliable and comparable.

Institutional-level factors, particularly the interplay between formal and informal institutions, are paramount in shaping the effectiveness of ESG strategies and their acceptance in different markets. The European Union's SFDR represents a fundamental shift, mandating standardized ESG disclosures that directly reduce information asymmetry [1]. The effectiveness of ESG signals and trust mechanisms also depends heavily on the broader institutional environment. Fan et al. [16] discover a complementary relationship between informal institution (social trust) and formal institution (legal environment) in promoting ESG performance. This suggests that a strong legal framework enhances the credibility and enforcement of ESG disclosures, thereby strengthening the signaling effect.

4. Discussion

4.1 The Dual-Channel Framework: Signaling and Trust Mechanisms

Our analysis demonstrates that the optimal ESG strategy for firms is determined by their information sphere. Information asymmetry manages the ESG-pricing relationship via two different and complementary ways. The signaling channel predominates when information asymmetry is high. In these environments, external validation, certifications, and standardized disclosures acts as a crucial alternative to direct observation, enabling investors to distinguish firm quality more precisely. They cut down on investors' information acquisition costs and enable more accurate risk assessment, ultimately enhancing pricing efficiency. Simultaneously, in low-asymmetry contexts, building trust mechanism through affective bonds and value alignment may prove more effective. When objective data is plentiful but its interpretation remains uncertain, investors increasingly rely on subjective assessments. Leadership credibility, demonstrated through consistent value alignment, can shape investor perceptions. High ESG performance fosters effective trust, which reduces perceived risk and transaction costs, while ESG controversies can trigger rapid trust dissolution with disproportionate pricing consequences. Critically, these mechanisms are jointly related. By repeated validation, signals can build trust as time goes on, and trust affects how signals are judged. The interaction of these channels brings into being a dynamic equilibrium. In the early stages of ESG markets or in settings with little information, trust mechanisms may be the main factor as investors lack strong verification signals. As the market ripens and standardized disclosure shows up, signaling mechanisms gain prominence. Still, in information - rich environments, trust remains relevant for sorting out ambiguity in ESG data interpretation, especially when different stakeholders may have different understandings of the same data due to their different priorities or values.

4.2 The Influence of ESG Factors from a Contingency Perspective

From this perspective, the ESG-pricing relationship is best understood as context-dependent, with information asymmetry serving as the master moderator, which itself varies across boundary conditions. The reviewed literature further reveals that the relative effectiveness of information asymmetry depends on boundary conditions at multiple levels.

Firm-level factors such as size, visibility, and governance quality determine the baseline information environment. For large, well-endowed firms with good governance, there might be limited value creation on ESG cues, and trust mechanisms might therefore be more relevant to the differentiation. For small, opaque firms, credible ESG signals provide more benefits by addressing fundamental information gaps. Market-level

conditions including industry characteristics and market development stage create natural variation in information asymmetry. The observation that the ESG controversies elicit exaggerated responses in high-impact sectors is the feature of both an increased signal value as it is important and the heightened sensitivity of trust because of the expectations of stakeholders [10]. The arrangements at the institutional level influence who takes the upper channel. Effective signaling can be promoted by strong legal systems that can guarantee the credibility and advanced social trust systems that can boost the mechanisms of trust [16].

5. Conclusion

This review has conducted a review of literature on the ESG factors and asset pricing efficiency in terms of information asymmetry. It has been shown in the analysis the two different, but complementary, effects of the ESG information on the asset prices; signaling pathway, which is dependent on the credible external validation, and trust pathway, which depends on the affective bonds and value alignment. The comparative effectiveness of these pathways depends on the information environment, where in high-asymmetry environments, signaling prevails and in environments characterized by increased information, trust prevails.

The main contribution of this review lies in advancing a contingency perspective that moves beyond universal claims about ESG's pricing effect. This framework defines the circumstances in which each of the mechanisms works, in the interaction of their mechanisms and the contexts of the subsequent relative contributions of the firms, markets and institutions. This collective knowledge resolves ostensibly conflicting results in the body of literature and gives a consistent base to further research. For practitioners, the framework provides a strategic direction. The companies ought to diagnose their information environment to find the best compromise between the signaling aspects as the third-party certifications and expanded disclosures and trust booster activities as the stakeholder involvement and continued demonstration of value. For policymakers, the key findings are the need to have both formal institutions such as standardized reporting structures to enhance signaling channels. At the same time, the informal institutions, like the trust-building programs and rules of ethics, ought to be elaborated in order to promote the significance of the trust-resources.

While this review synthesizes current evidence, several limitations warrant attention. The literature is dominated by the studies of public equity markets and a weak insight in the ESG pricing mechanisms on the private markets or fixed income. Problems in measuring information asymmetry and separating signaling and trust effects are methodological issues that are still significant. Policy Longitudinal studies of the changing relative significance of these mechanisms with market development, designs that better isolate workings of causation and cross market studies on how institutional structures determine the dynamics of ESG pricing can be undertaken in future research.

In conclusion, information asymmetry operating through dual channels fundamentally shapes the relationship between ESG factors and asset pricing efficiency. Recognizing this complexity moves us toward a more sophisticated understanding that accounts for contextual variation and provides actionable insights for market participants seeking to navigate the evolving ESG landscape.

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Audit of the New Economic Model: A Study on Revenue Recognition, Value Measurement and Audit Challenges in the Platform Economy

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Abstract

As the core form of the new economic model, the platform economy encompasses diverse business types including the sharing economy and the gig economy. Its traits of virtualized transactions, diversified participants and intricate revenue models have exerted a profound impact on the traditional accounting systems for revenue recognition and value measurement, as well as on practical auditing work. This paper starts with the business characteristics of the platform economy to analyze the core difficulties in judging the timing and amount of revenue recognition, as well as in measuring virtual assets and platform value. Combined with current accounting and auditing standards, it explores the unique challenges faced by audit procedures, risk identification and evidence acquisition under the new economic model. Finally, it puts forward optimized ideas for revenue recognition and value measurement that adapt to the characteristics of the platform economy, along with practical paths for innovating audit methods and preventing and controlling audit risks. The research is intended to provide theoretical reference and practical guidance for standardizing the accounting treatment of the platform economy and improving the quality and efficiency of auditing.

Keywords

platform economy, revenue recognition, value measurement, audit challenges, new economic model

1. Introduction

Research into platform economy auditing within the new economic model is grounded in the integration of three theoretical frameworks: the traditional theory of accounting recognition and measurement, modern audit theory, and the development theory of the digital economy. This integration lays a multi-dimensional theoretical foundation for investigating revenue recognition, value measurement and audit challenges in the platform economy. The value measurement theory, which is based on such measurement attributes as historical cost and fair value, also provides a standardized measurement framework for the recognition of physical assets and traditional intangible assets, and serves as the basic theoretical support for the accounting treatment of economic activities.

Modern audit theory centers on risk-oriented auditing, with risk identification, assessment and response as its core. With the rise of the digital economy, the development theory of the digital economy—based on network effects, resource integration and digital transformation—has broken the operational boundaries of the traditional economy. Its core viewpoints, including the virtualization of transaction forms, diversification of subject relationships and intellectualization of resource allocation, have laid a theoretical foundation for understanding the business characteristics and operational logic of the platform economy, sharing economy and gig economy.

Against the backdrop of the deep integration of the digital economy and the real economy, the application of traditional accounting and audit theories in the platform economy is facing a process of reconstruction. On the one hand, the virtualization of transaction scenarios, fragmentation of transaction behaviors and ambiguity of revenue attribution in the platform economy make it difficult for traditional revenue recognition criteria to accurately judge the timing and amount of revenue recognition. Meanwhile, traditional value measurement attributes fail to fully reflect the value of the platform's virtual assets, data assets and network effects. On the other hand, the digitalization of audit evidence, complexity of audit objects and concealment of audit risks mean that risk-oriented audit theory needs to be innovated in terms of audit procedure design, evidence acquisition methods and risk assessment models when applied to platform economy auditing.

Scholars have carried out preliminary theoretical explorations on integrating traditional accounting and audit theories with the characteristics of the platform economy, and put forward theoretical insights on optimizing revenue recognition models and innovating value measurement methods for the platform economy. These theoretical explorations have laid a preliminary research foundation for this paper, and also pointed out a clear research direction: combining theoretical innovation with practical needs more closely, and systematically exploring the adaptation paths of accounting and audit theories in the field of the platform economy.

Grounded in the integration of the traditional theory of accounting recognition and measurement, modern audit theory and the development theory of the digital economy, research on platform economy auditing has gradually become a research hotspot in the accounting and audit field amid the deep integration of the digital economy and the real economy. As the core form of the new economic model, the platform economy—including the sharing economy and gig economy—has broken the operational logic of the traditional economic model, and its unique business characteristics have brought profound challenges to the traditional accounting and audit system.

This paper systematically sorts out and reviews existing research findings from three core dimensions: revenue recognition, value measurement and audit challenges in the platform economy. It summarizes the theoretical disputes and practical dilemmas in current research, and points out the research gaps and future development directions, thus providing a theoretical basis for improving the accounting and audit system of the new economic model.

2. Literature Review and Theoretical Basis

2.1 Research Status of Revenue Recognition in the Platform Economy

Revenue recognition judgment is the core of accounting treatment for the platform economy, and the most prominent theoretical and practical dispute in current research focuses on defining the platform's role in transactions—that is, whether the platform acts as a principal or an agent [1]. Both International Financial Reporting Standard 15 and China's Accounting Standard for Business Enterprises 14 [2] take the transfer of control as the core basis for judging revenue recognition. However, the virtualization of platform economy transactions and diversification of transaction subjects have made the identification of control highly ambiguous. Forde & Wood [3] pointed out in their research on the sharing economy that platforms only provide information matching services in shared travel and shared accommodation transactions, and should therefore be identified as agents, with revenue recognized based on commission fees. In contrast, Huang [4] argued that some platform enterprises participate in the entire process of transaction pricing, settlement and after-sales service, and exercise substantive control over the traded goods or services, so they should be identified as principals and recognize revenue based on the total transaction amount. Ge & Zhang [5] further found through an empirical study on Chinese platform enterprises that there are obvious differences in

revenue recognition methods among different types of platform enterprises. The lack of detailed judgment criteria for principal-agent relationships has led to a loss of comparability in the accounting information of enterprises in the same industry. In research on the gig economy, Kalleberg & Dunn [6] proposed that the fragmentation of gig economy transactions and flexibility of income forms have made the judgment of revenue recognition timing a new difficulty. The traditional point-in-time recognition method is difficult to adapt to the continuous and fragmented transaction characteristics of the gig economy. To address this problem, some scholars have proposed combining point-in-time and over-time recognition methods, and taking the completion of service segments as the basis for judging revenue recognition [7].

2.2 Research Status of Value Measurement in the Platform Economy

The measurement of platform economy value is another core difficulty in current research, mainly reflected in the challenges of measuring the platform's specific assets and the overall value of platform enterprises. The traditional value measurement theory takes historical cost and fair value as its core measurement attributes, which is suitable for measuring physical assets and traditional intangible assets, but fails to reflect the value connotation of platform-specific assets such as data assets and network effects [8]. Ball [9] pointed out that data assets are the core intangible assets of platform enterprises, but due to their non-exclusivity and the difficulty of measuring their costs, current accounting standards have not yet formed a unified measurement and recognition standard. Ge [10] proposed in his research on digital asset accounting that fair value should be the primary measurement attribute for platform data assets, and the income approach should be used to measure the future economic benefits brought by data assets. In terms of measuring the overall value of platform enterprises, Zeff [11] argued that the traditional enterprise value measurement method based on financial indicators ignores the value of the platform's user resources and network effects, leading to a significant deviation between the measured value and the actual value. Zhang & Liu [12] further improved the enterprise value measurement model by introducing non-financial indicators such as user scale and user stickiness, and verified the rationality of the improved model through an empirical study on e-commerce platform enterprises. Chen et al. [13] applied the real option method to the value measurement of sharing economy platform enterprises, pointing out that this method can better reflect the potential value of platform enterprises in an uncertain market environment. However, most current research on platform value measurement is limited to a single type of platform enterprise, and there is a lack of a unified value measurement system applicable to different types of platform economies such as the sharing economy and the gig economy [12].

2.3 Research Status of Audit Challenges in the Platform Economy

Research on the audit challenges of the platform economy is closely integrated with modern risk-oriented audit theory, and existing research mainly focuses on the difficulties of audit practice and the innovation of audit methods. Simnett et al. [14] pointed out in their research on digital economy auditing that the virtualization of platform economy transaction data has transformed audit evidence from tangible paper evidence to intangible electronic evidence, and the authenticity, integrity and traceability of electronic evidence have become the core challenges of auditing work. Zhou & Li [15] further found through a case study of platform enterprise auditing that off-balance sheet transactions and hidden related transactions of platform enterprises have increased the difficulty of audit risk identification, and traditional audit risk assessment models are unable to accurately identify the potential audit risks of platform enterprises. In response to these challenges, scholars at home and abroad have put forward various ideas for innovating audit methods. Wang & Zhang [16] proposed applying big data audit technology to the audit practice of sharing economy platform enterprises, and collecting and analyzing audit data through data mining and cloud computing technologies to improve the efficiency of audit evidence acquisition and risk identification. Wu & Qiu [17] pointed out that the internal control system of platform enterprises is quite different from that of traditional enterprises, and platform economy auditing should focus on auditing the platform's information system and internal control over financial reporting to ensure the reliability of the platform's transaction data. In research on gig economy auditing, Liu et al. [18] proposed expanding the audit scope to include the platform's cooperative individuals and third-party institutions, and constructing a multi-party joint audit mechanism to solve the problem of difficult audit evidence acquisition in the gig economy. In addition, some scholars have proposed building a digital audit platform based on blockchain technology, which can realize

real-time supervision and traceability of platform economy transactions and fundamentally solve the problem of difficult verification of transaction authenticity [19].

3. Core Dilemmas of Accounting and Auditing in the Platform Economy

3.1 Inadaptability of Traditional Accounting Systems to the Platform Economy

A systematic review of existing research shows that the academic community has conducted in-depth research on revenue recognition, value measurement and audit challenges in the platform economy, and achieved rich research results, which provides a preliminary theoretical basis for the accounting and audit practice of the platform economy. However, there are still obvious research gaps in current research: first, research on platform economy revenue recognition is mostly limited to theoretical discussions on principal-agent relationships, and lacks detailed and operable judgment criteria combined with the different business types of the platform economy; second, research on platform value measurement is mostly scattered in the study of a single asset or a single type of platform enterprise, and there is a lack of a systematic and unified value measurement system adapted to the overall characteristics of the platform economy; third, research on audit method innovation mostly focuses on the application of digital technology, and lacks in-depth research on the integration of audit technology and the actual business of platform enterprises, meaning the practicality of the proposed audit methods needs to be further verified. In the future, research on platform economy auditing should be closely combined with the practical development of the new economic model, focus on the above research gaps, and conduct in-depth research on the refinement of accounting and audit standards, the construction of a unified value measurement system, and the deep integration of digital audit technology and platform business. This will continuously improve the accounting and audit system of the new economic model and promote the standardized and sustainable development of the platform economy.

This paper systematically reviews existing research on revenue recognition, value measurement and audit challenges in the platform economy, and finds that the core contradiction in the accounting and audit practice of the platform economy lies in the inadaptability of the traditional accounting and audit system to the new economic business forms. Driven by digital technology, the platform economy has broken the transaction logic of the traditional economy, and its characteristics of virtualization, diversification and fragmentation render principle-based accounting and audit standards hard to apply directly. This is the fundamental cause of the theoretical disputes and practical dilemmas in current research.

3.2 Specific Difficulties in Revenue Recognition of the Platform Economy

In terms of revenue recognition, the core dispute over principal-agent identification is essentially due to the lack of detailed judgment criteria for the transfer of control in current standards [1]. Existing standards only put forward core judgment principles, but fail to formulate differentiated identification rules for different platform economy forms such as the sharing economy and the gig economy. This leads to the arbitrary selection of revenue recognition methods by platform enterprises, resulting in the loss of comparability of accounting information among enterprises in the same industry [5]. The difficulty in judging the revenue recognition timing of the gig economy is further caused by the fragmentation of its transaction behaviors, which makes the traditional point-in-time recognition method unable to reflect the economic substance of transactions [6]. Although scholars have proposed combining point-in-time and over-time recognition methods [7], there is still a lack of operable judgment criteria for dividing service segments.

3.3 Specific Difficulties in Value Measurement of the Platform Economy

In terms of value measurement, the current research dilemma is mainly reflected in the absence of a unified measurement system for platform-specific assets and the overall value of enterprises. As the core value drivers of platform enterprises, data assets and network effects have not been clearly defined in current accounting standards, and their measurement attributes and methods are still in the exploratory stage [9]. Although scholars have tried to apply fair value and real option methods to the measurement of platform assets and enterprise value [13], most research is limited to a single type of platform enterprise, and there is a lack of a measurement system applicable to the platform economy as a whole. The traditional enterprise

value measurement method based on financial indicators ignores non-financial value drivers such as user resources, leading to a deviation between the measured value and the actual value [11].

3.4 Specific Audit Challenges Faced by the Platform Economy

In terms of audit challenges, the digitalization of audit evidence and the concealment of audit risks have made the traditional risk-oriented audit model face severe challenges in its application to the platform economy [14]. Although scholars have proposed innovative ideas such as big data auditing and blockchain-based digital auditing [16][19], current research is mostly limited to theoretical discussions on technology application. The lack of in-depth research on the integration of digital audit technology and the actual business of platform enterprises results in the poor practicality of the proposed methods. In addition, the internal control system of platform enterprises is quite different from that of traditional enterprises, and the lack of targeted internal control audit standards further increases the difficulty of audit practice [17].

4. Conclusion

It should be noted that this review study also has certain limitations. The existing research reviewed is mostly focused on mature platform economy forms such as shared travel and e-commerce, while research on the accounting and audit issues of emerging platform forms such as live-streaming e-commerce and community group buying is relatively scarce. In the future, the research scope can be further expanded to form a more comprehensive research framework for the accounting and auditing of the platform economy.

As the core form of the new economic model, the platform economy has become an important driving force for economic development, and its accounting and audit issues have attracted extensive attention from the academic community. This paper sorts out and reviews domestic and foreign research on revenue recognition, value measurement and audit challenges in the platform economy, and draws the following core conclusions: the academic community has conducted in-depth research on the accounting and audit issues of the platform economy, and put forward a variety of theoretical viewpoints and practical solutions for principal-agent identification in revenue recognition, the measurement of platform-specific assets and the innovation of audit methods. This has laid a solid theoretical foundation for the standardization of accounting and audit practice in the platform economy.

However, current research still has obvious research gaps, and the core problems in the accounting and audit practice of the platform economy have not been fundamentally solved: the traditional accounting and audit system cannot fully adapt to the development characteristics of the platform economy; the lack of detailed accounting standards leads to confusion in accounting treatment; the absence of a unified value measurement system results in inaccurate reflection of platform value; and the disconnection between digital audit technology and practical business leads to low efficiency in audit risk identification and evidence acquisition.

In response to the above problems, future research on the accounting and auditing of the platform economy should focus on the integration of theory and practice, standards and business forms, and technology and industry. On the one hand, it is necessary to refine accounting and audit standards in combination with the characteristics of different platform economy forms, formulate differentiated judgment rules for revenue recognition, and establish a unified value measurement system that includes platform-specific assets and non-financial indicators. On the other hand, it is necessary to strengthen in-depth research on the integration of digital audit technology and platform business, improve the practicality of audit methods, and construct a multi-party joint audit mechanism adapted to the platform economy. At the same time, regulatory authorities should accelerate the improvement of supporting systems to form a joint force of standard formulation, theoretical research and practical application, so as to promote the healthy and sustainable development of the platform economy and even the entire new economic model.

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