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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:

$$\ln(edu\_exp_{it})=\alpha+\beta_1 child\_dep_{it}+\beta_2 old\_dep_{it}+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (1)$$

Among them, and t represent provinces and years respectively. is the control variable vector, and $\lambda_t$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

$$\ln(edu_exp_{it})=\alpha+c\cdot old_dep_{it}+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (2)$$

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

Step 2: Mediator Model

$$socialsecurityxp_{it}=\alpha+a\cdot old_d ep_{it}+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (3)$$

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

Step 3: Direct Effect and Mediation

$$\ln(eduxp_{it})=\alpha+c'\cdot old_d ep_{it}+b\cdot socialsecurity_e xp_{it}+\gamma X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (4)$$

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×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 R2 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 R2 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 R2 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 ±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.

References

[1] Lu, J. and Wu, X. Population age structure transformation: Main characteristics, multiple impacts and response strategies. Youth Exploration. 2021(4), pp. 28-40.

[2] Qiao, X. China's population aging: Past, present, and future. Social Policy Research. 2024(1), pp. 47-63+133.

[3] Sparrow, E. P., Swirsky, L. T., Kudus, F. and Spaniol, J. Aging and altruism: A meta-analysis. Psychology and Aging. 2021, 36(1), pp. 49-56.

[4] Xiong, C. and Chen, H. Population change and educational reform: Sociological reflections based on the seventh national population census bulletin. Educational Research. 2021, 42(11), pp. 27-35.

[5] Tao, D. and Zhang, K. Population aging, intergenerational conflict and public education expenditure. Education and Economy. 2015(2), pp. 3-10+24.

[6] Huang, Z. G., Li, X. F. and Chen, X. W. Intergenerational altruists' intertemporal decision making: An analysis based on the change of population structure. Nankai Economic Research. 2019(2), pp. 42-61.

[7] Fan, H. D., Gong, H. L. and Wen, D. X. Population aging, urbanization and expenditure structure of basic public services: An empirical analysis based on provincial panel data. Journal of Jiangxi Normal University (Natural Science Edition). 2022, 446(4), pp. 357-362.

[8] Zhou, Y. Z. Pension burden, social security and family education expenditure. Master's Thesis, Xiangtan: Xiangtan University, 2020.

[9] Wan, B. S. and Min, W. F. An empirical study on the impact of education on the level of Urbanization: Based on China's provincial panel data from 2005 to 2020. Journal of East China Normal University (Education Science Edition). 2023, 41(10), pp. 40-52.

[10] Wang, Y. and Zhang, Z. R. Characteristics of China's population structure, economic efficiency and economic transformation: Based on the analysis of China's Regional Panel Data from 1992 to 2017. Business Research. 2019(12), pp. 126-135.

[11] Pan, j., Xu, t. and Xuan, Y. Aging, human capital and economic growth. Exploration of Economic Issues. 2022(7), pp. 74-89.

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Conflicts of Interest

The authors declare no conflict of interest.

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