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Tax Incentives and Debt-Financing Efficiency in Advanced Manufacturing Enterprises: Evidence from Chinese A-Share Listed Firms

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Abstract

Advanced manufacturing firms face long investment cycles, high technological uncertainty, and limited pledgeable assets, so the efficiency with which they use debt is central to sustained innovation. This study examines the association between tax incentives and debt-financing efficiency among Chinese A-share listed advanced manufacturing firms. Annual efficiency scores are estimated using an input-oriented CCR data envelopment analysis model, and two-limit Tobit regressions are applied to 16,817 firm-year observations from 2015 to 2025. Tax incentives are measured as tax refunds received relative to operating revenue. The fully controlled coefficient is 0.5549 and the average marginal effect is 0.5039, indicating a significant positive association. Financing-constraint relief accounts for approximately 15.09% of the total association. The relationship is significantly stronger for non-state-owned and high-technology firms, whereas regional and firm-size differences are not statistically significant. Lagged and re-winsorized estimates support the baseline result, but alternative definitions of incentives and efficiency reverse the sign, revealing material measurement sensitivity. The findings suggest that timely tax relief can improve debt allocation, although interpretation should remain associational and conditional on the selected measures.

Keywords

tax incentives, advanced manufacturing, debt-financing efficiency, data envelopment analysis, financing constraints

1. Introduction

Advanced manufacturing is distinguished from conventional scale-oriented production by its dependence on specialized equipment, technical knowledge, continuous process improvement, and repeated investment before commercial returns become stable. Debt remains a major source of external capital because bank credit and other debt instruments can be obtained without diluting ownership, but the terms on which debt is supplied may not match the economic life of innovative projects.

Under information asymmetry, lenders may ration credit rather than simply raise the interest rate [1], while firms with valuable projects may avoid external finance when managers believe that outside investors cannot observe project quality [2]. A firm can consequently carry substantial debt while still financing inefficiently if it pays too much, assumes excessive balance-sheet risk, or fails to convert borrowed funds into adequate operating returns.

A refund received during the investment stage retains cash inside the firm and reduces the need for emergency borrowing. A positive effect on financing availability therefore does not necessarily imply a positive effect on financing efficiency.

Capital-structure theory shows that corporate taxation changes the relative cost of debt and equity [3], and recent research links tax relief to financing constraints and investment allocation [4][5]. Yet relatively few studies ask whether tax incentives improve the joint relationship among debt scale, financing cost, leverage capacity, and capital return in advanced manufacturing.

This study uses a two-stage framework and then tests timing, measurement sensitivity, financing-constraint mediation, and heterogeneity across region, size, ownership, and technology groups. It shifts the policy question from whether firms receive more funds to whether debt inputs are matched by financing capacity and capital return.

2. Theoretical Analysis and Hypotheses

2.1 Direct Efficiency Channel

In the classic corporate-tax extension of capital-structure theory, the deductibility of interest affects the relative attraction of debt. A tax refund creates an immediate or near-term cash benefit that can substitute for part of external finance and can alter the timing, size, and maturity of new borrowing. For a firm facing a temporary liquidity gap, this benefit may prevent the use of expensive short-term credit.

Better liquidity may also allow the firm to negotiate longer maturities that correspond to the payoff period of equipment or research projects. In the input-oriented DEA setting used below, such a firm moves closer to the best-practice frontier because it can maintain outputs while proportionally compressing financial inputs.

The signal is supplementary rather than conclusive: public support does not guarantee commercial success, and creditors must still assess repayment capacity. This reasoning yields the first hypothesis: H1. Tax incentives are positively associated with the debt-financing efficiency of advanced manufacturing enterprises.

2.2 Financing-constraint Channel

Financing constraints arise when firms cannot fund all projects with positive expected value at an appropriate price and maturity. When the feasible financing set is narrow, managers may accept high-cost debt, roll over short-term loans repeatedly, postpone productive investment, or combine projects with financing instruments that have incompatible maturities.

Tax relief directly supplies internal liquidity and reduces the funding gap. The firm can then compare more financing alternatives, avoid distress-driven borrowing, and preserve investment with higher expected returns. Governance quality, project selection, and demand conditions still determine the final allocation, so financing-constraint relief should explain only part of the overall association.

Following Hadlock and Pierce [6], a larger ASA value in the coding used here denotes weaker financing constraints. If the direct Tax coefficient remains positive but declines after ASA enters the outcome equation, the results are consistent with partial mediation. H2. Tax incentives are positively associated with debt-financing efficiency partly through the alleviation of financing constraints.

3. Research Design

3.1 Data and Sample

The data combine CSMAR records, annual reports, and stock-exchange disclosures for firms classified as advanced manufacturing enterprises. Observations from 2014 are used only to construct lag-dependent values, including the average-asset and growth measures required for the 2015 observation; the estimation window is therefore 2015-2025. The estimation sample covers Shanghai and Shenzhen A-share firms and excludes Beijing Stock Exchange firms.

The cleaning procedure removes ST and *ST observations, pre-listing years, and firm-years with missing values for the main variables. It also excludes observations with non-positive total assets, operating revenue, or liabilities, as well as insolvent firms whose liabilities exceed assets. Continuous variables are winsorized at the 1st and 99th percentiles. After screening, the unbalanced panel contains 16,817 firm-year observations for 2,699 listed firms.

3.2 Variables and DEA Measurement

The dependent variable, debt-financing efficiency (Eff), is estimated separately for each year with the input-oriented CCR model developed by Charnes, Cooper, and Rhodes [7]. The model assumes constant returns to scale and asks how much the selected inputs could be proportionally reduced while the observed outputs are maintained. A score of one identifies a firm on the estimated annual frontier, whereas a score below one indicates proportional input-reduction potential relative to best-practice observations.

The DEA model uses two inputs and two outputs. The asset-liability ratio represents debt committed to the balance sheet, while debt-financing cost represents its price. Financial leverage and return on invested capital are outputs because they capture financing capacity and the return generated by the debt arrangement. Following related listed-company research [8], Table 1 reports the formulas and economic roles of these indicators. The model evaluates the observed combination relative to peers; it does not assume that greater leverage is unconditionally desirable. Potentially negative indicators are translated within year to satisfy non-negativity without changing their ranking.

Table 1: DEA input-output variable definitions

Category	Indicator	Measurement	Economic role
Input	Asset-liability ratio	Total liabilities / total assets	Debt scale
Input	Debt-financing cost	Interest expense / average short- and long-term interest-bearing debt	Debt price
Output	Financial leverage	EBIT / (EBIT - interest expense)	Debt-financing capacity and risk
Output	Return on invested capital	Net operating profit after tax / invested capital	Capital return

Note: Debt-financing cost uses the average balance of short- and long-term interest-bearing debt. Indicators that can be negative are translated within year before DEA estimation.

Tax equals tax refunds received divided by total operating revenue, which scales realized policy support to the firm's operating base. The baseline controls for Size, ROA, Profit, Growth, Fix, and Indep; Table 2 defines these variables. ASA, the absolute value of the SA index, enters the mediation test, with larger values denoting weaker financing constraints. Year indicators absorb shocks common to all firms, including broad changes in credit conditions and policy. The sensitivity analysis also scales refunds by total assets, but that denominator embeds capital intensity and is not economically equivalent to revenue scaling.

Table 2: Definitions of empirical variables

Category	Variable	Symbol	Definition
Dependent	Debt-financing efficiency	Eff	Annual input-oriented CCR DEA score based on Table 1; range 0-1
Explanatory	Tax incentives	Tax	Tax refunds received / total operating revenue
Mediator	Financing-constraint relief	ASA	Absolute value of the SA index; larger values indicate weaker constraints
Control	Firm size	Size	Natural logarithm of total assets
Control	Return on assets	ROA	Net profit / average total assets
Control	Profitability	Profit	Net profit / total operating revenue
Control	Growth	Growth	(Current-year operating revenue / prior-year operating revenue) - 1
Control	Fixed-asset ratio	Fix	Fixed assets / total assets
Control	Board independence	Indep	Independent directors / total directors x 100%

Note: ASA is used only in the mediation analysis. Indep is reported as a percentage.

For firm o, the program chooses peer weights lambda and an input contraction factor theta. X and Y denote the annual input and output matrices, while x_o and y_o denote the evaluated observation. Theta is minimized subject to the weighted peers producing at least the observed outputs with no more than theta times the inputs. The maintained score lies between zero and one.

$$\min_{\theta,\lambda}\theta \text{s.t.} X\lambda \leq \theta x_0,\ Y\lambda \geq y_0,\ \lambda \geq 0 \tag{1}$$

3.3 Tobit Specification

The second stage relates Eff to Tax and the control variables. Ordinary least squares can predict values outside the feasible interval and does not explicitly accommodate the mass at the frontier. The baseline therefore uses a two-limit Tobit model [9]. The latent equation includes Tax, the control vector, year effects, and an idiosyncratic error. The observed variable equals zero when the latent value is below the lower limit, equals the latent value within the interval, and equals one when the latent value reaches the upper limit. Standard errors are clustered by firm to permit within-firm dependence over time.

Tobit coefficients describe the latent outcome rather than direct changes in observed efficiency, so the fully specified model is accompanied by an average marginal effect. Three models are estimated sequentially: Tax alone, Tax with firm controls, and Tax with controls and year effects. Stability across columns shows whether the result depends on observable composition or common annual shocks. The analysis remains associational because tax support can respond to firm conditions, managerial quality is unobserved, and DEA scores share a frontier estimated from the same sample.

A bounded outcome is not the only statistical issue in a two-stage DEA design. Simar and Wilson show that scores estimated from a common frontier are statistically dependent and recommend bootstrap truncated regression under their maintained assumptions [10]. Tobit is retained for comparability and because the available estimates use this design. Results are therefore interpreted as conditional associations; bootstrap frontier inference and exogenous policy variation remain extensions for future work.

$$\text{Eff}_{it}^{*} = \alpha_0 + \alpha_1 \text{Tax}_{it} + \beta' \text{Controls}_{it} + \gamma_t + \varepsilon_{it} \tag{2}$$

$$\text{Eff}_{it} = \max(0, \min(1, \text{Eff}_{it}^{*})) \tag{3}$$

4. Empirical Results

4.1 Descriptive Evidence and Diagnostic Checks

Table 3 reports the distribution of the estimation variables. Mean Eff is 0.2393 with a standard deviation of 0.1792, and only 40 observations reach the frontier value of one. The low mean does not imply that firms destroy value in an accounting sense; it indicates that, relative to the best performers in the same year and under the chosen inputs and outputs, most firms have substantial room to reduce debt exposure or financing cost while maintaining leverage and capital return. Tax has a mean of 0.0199, so refunds average about 1.99% of operating revenue. Its standard deviation of 0.0220 and range after winsorization show meaningful cross-firm and time variation.

Table 3: Descriptive statistics

Variable	N	Mean	SD	Min	Max
Eff	16,817	0.2393	0.1792	0.0430	1.0000
Tax	16,817	0.0199	0.0220	0.000005	0.1064
Size	16,817	22.2669	1.1685	20.1168	25.9272
ROA	16,817	0.0358	0.0665	-0.2177	0.2244
Profit	16,817	0.0480	0.1794	-0.9415	0.4107
Growth	16,817	0.1303	0.3105	-0.4953	1.6486
Fix	16,817	0.2101	0.1243	0.0142	0.5749
Indep	16,817	37.9842	5.3879	33.3300	57.1400

Note: Continuous variables are winsorized at the 1st and 99th percentiles. Indep is expressed as a percentage.

The controls also display economically plausible dispersion. Negative minima for ROA and Profit indicate that the sample includes loss-making firms rather than only successful policy recipients. Growth is particularly volatile, which is consistent with uneven commercialization and cyclical demand. Fixed assets average 21.01%

of total assets, reflecting the equipment intensity of advanced manufacturing. Pairwise correlations provide preliminary direction but cannot substitute for the multivariate bounded-outcome model. A variance-inflation-factor check based on the baseline covariates and year indicators yields 1.02 for Tax, a maximum of 3.99 among firm-level covariates, and 4.91 on average when year indicators are included. All values remain below 10, so the estimates do not display severe multicollinearity under the conventional diagnostic threshold.

4.2 Baseline Estimates

Table 4 presents the two-limit Tobit estimates. Column (1), which includes only Tax, produces a coefficient of 0.4932 with a standard error of 0.1249. Column (2) adds the six firm controls and increases the coefficient to 0.5213. Column (3) additionally controls for year effects, producing a coefficient of 0.5549 with a standard error of 0.1114. All three coefficients are positive at the 1% level. The sign and significance are therefore not explained by the included differences in size, profitability, growth, fixed-asset intensity, board independence, or common annual shocks. The evidence supports H1 as a robust conditional association within the baseline specification.

Because the reported coefficient belongs to the latent Tobit equation, economic magnitude is evaluated using the average marginal effect on the expected observed score. The estimate is 0.5039. Since Tax is a ratio, a one-percentage-point increase in refunds relative to revenue is associated with an average increase of approximately 0.0050 in expected Eff, holding the other covariates and year effects constant. Relative to the sample mean of 0.2393, this change is not trivial, but it should not be read as a causal policy multiplier. It describes the average model-implied difference associated with the observed support intensity.

Table 4: Baseline two-limit Tobit estimates

Variable	(1) Eff	(2) Eff	(3) Eff
Tax	0.4932***	0.5213***	0.5549***
	(0.1249)	(0.1107)	(0.1114)
Size	-	-0.0498***	-0.0497***
		(0.0019)	(0.0019)
ROA	-	0.4945***	0.5268***
		(0.0803)	(0.0809)
Profit	-	0.1462***	0.1377***
		(0.0353)	(0.0355)
Growth	-	-0.0722***	-0.0769***
		(0.0062)	(0.0065)
Fix	-	-0.1908***	-0.1937***
		(0.0192)	(0.0192)
Indep	-	-0.0003	-0.0002
		(0.0004)	(0.0004)
Firm controls	No	Yes	Yes
Year effects	No	No	Yes
Firm-clustered SE	Yes	Yes	Yes
N	16,817	16,817	16,817

*Note: Firm-clustered robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.*

The controls clarify what the efficiency score captures. ROA and Profit are significantly positive, indicating that stronger asset use and profit conversion are associated with a more favorable relationship between debt inputs and financial outputs. Size is negative in the controlled models. Large firms can obtain more credit, but access alone may create organizational slack, project proliferation, or debt accumulation that is not matched by return. Growth is also negative. Rapid revenue expansion often requires working capital and capacity ahead of realized earnings, so high-growth firms may temporarily appear less efficient when debt rises before output measures adjust.

Fix is negative and significant. Tangible assets can support collateral, yet specialized equipment is costly, illiquid, and subject to long recovery periods. If equipment expansion is debt financed and return on invested capital responds slowly, the contemporaneous input-output relationship deteriorates. Indep is statistically insignificant, suggesting that the percentage of independent directors alone does not capture the quality of monitoring relevant to debt allocation. Overall, the controls reinforce a central interpretation: financing efficiency is not equivalent to financing volume. Debt contributes to efficiency only when cost, scale, maturity, and operating return remain aligned.

4.3 Robustness and Mechanism

Table 5 separates checks that preserve the central measurement design from tests that alter it. When Tax is lagged by one period, the coefficient is 0.5272 with a standard error of 0.1074 and remains significant at 1%. The estimate is close to the baseline value of 0.5549. This result weakens, but does not eliminate, the concern that contemporaneously efficient firms simply receive larger refunds in the same year. It is also consistent with a mechanism that requires time: retained cash can affect refinancing, project continuity, and creditor assessment beyond the period in which the refund is received.

Reapplying the 1st- and 99th-percentile winsorization produces a Tax coefficient of 0.5524, again close to the baseline. This indicates that the main association is not driven by a small number of extreme observations. The exercise is best understood as a consistency check because the original estimation sample was already winsorized. It nevertheless confirms that the reported coefficient is reproducible under the stated treatment of outliers.

The two alternative definitions do not support the expected positive direction: the coefficient is -0.9910 when refunds are scaled by total assets and -0.0773 when Eff2 replaces the DEA score, with both estimates statistically significant. These reversals may arise because the total-assets denominator embeds capital intensity and Eff2 does not preserve the CCR input-output meaning; they are therefore treated as measurement sensitivity, while the lagged and re-winsorized estimates remain the principal robustness evidence supporting H1.

Table 5: Robustness and measurement-sensitivity checks

Specification	Outcome	Tax measure	Coefficient (SE)	N
Baseline full model	Eff	Tax	0.5549*** (0.1114)	16,817
Scaled by total assets	Eff	Tax2	-0.9910*** (0.1428)	16,817
Alternative efficiency measure	Eff2	Tax	-0.0773*** (0.0189)	16,817
One-period lag	Eff	L.Tax	0.5272*** (0.1074)	1.37 x 10^4
Re-winsorized sample	Eff	Tax	0.5524*** (0.1109)	16,817

*Note: Every specification includes firm controls and year effects. *** indicates significance at the 1% level.*

The mediation analysis examines whether financing-constraint relief is one pathway linking tax support to efficiency. Column (1) of Table 6 restates the total Tax coefficient of 0.5549. In column (2), Tax is positively related to ASA: the coefficient is 1.4739 with a standard error of 0.0884. Because larger ASA values denote weaker constraints, the result is consistent with tax refunds widening the feasible financing set. In column (3), ASA is positively associated with Eff at 0.0568, while the Tax coefficient remains positive but falls to 0.4713. The coefficient pattern is consistent with partial, rather than full, mediation.

The product of the Tax-to-ASA and ASA-to-Eff coefficients is 0.0837, which equals approximately 15.09% of the total Tax coefficient. This share is economically plausible because liquidity relief is only one channel. Tax support may also affect efficiency through refinancing timing, creditor signals, profitability, or project continuity, while some funds may not affect debt decisions at all. The result supports H2, subject to two qualifications. The available output does not provide a bootstrap confidence interval for the indirect effect, and the mediator may share unobserved determinants with the outcome. The mediation evidence is therefore mechanism-consistent rather than definitive causal decomposition.

Table 6: Financing-constraint mediation

Variable	(1) Eff	(2) ASA	(3) Eff
Tax	0.5549***	1.4739***	0.4713***
	(0.0556)	(0.0884)	(0.0558)
ASA	-	-	0.0568***
			(0.0048)
Firm controls	Yes	Yes	Yes
Year effects	Yes	Yes	Yes
N	16,817	16,817	16,817
Indirect effect (a x b)	-	-	0.0837
Share of total effect	-	-	15.09%

*Note: Standard errors are in parentheses. ASA is the absolute SA index, so a larger value denotes weaker financing constraints. *** indicates significance at the 1% level.*

4.4 Heterogeneity

Average effects may conceal differences in external finance, implicit guarantees, and technological needs. Table 7 therefore reports subgroup coefficients and independent-sample coefficient-difference z-tests. The difference test is essential because statistical significance in one subgroup and insignificance in another does not by itself establish that the coefficients differ. Every subgroup model retains the firm controls and year effects used in the baseline.

Tax is positive in both the eastern and non-eastern samples, but their coefficient difference is not significant ($p = 0.498$); the same holds for smaller and larger firms ($p = 0.612$), so neither region nor firm size exhibits statistically supported heterogeneity. National policy transmission and revenue scaling may reduce cross-group differences, while the broad regional classification and median size split may conceal finer variation.

Ownership produces a statistically meaningful contrast. The coefficient for state-owned enterprises is -0.0840 and insignificant, whereas the coefficient for non-state-owned enterprises is 0.2600 and significant at 1%. The difference p-value is 0.004. Non-state-owned advanced manufacturers often have weaker implicit guarantees and face stricter collateral and information requirements. A tax refund can therefore have greater marginal value by reducing high-cost borrowing and supporting credit assessment. State-owned firms generally have broader financing access, so additional tax support may be less likely to alter their debt allocation at the margin.

Technology level produces the largest difference. The Tax coefficient is 0.4519 for high-technology firms but -0.0741 and insignificant for the lower-technology group; the p-value for the difference is below 0.001. High-technology firms have greater research intensity, more intangible assets, and longer intervals between expenditure and revenue. Timely tax relief can preserve technical programs and improve the continuity that creditors evaluate. For lower-technology firms, the use of additional funds may depend more on capacity demand and cost control, so the same refund measure does not generate a detectable efficiency association. These results identify ownership and technology, rather than region or scale, as the dimensions with statistically supported heterogeneity.

Table 7: Heterogeneity in the Tax coefficient

Dimension	Group 1: Tax (SE)	Group 2: Tax (SE)	N1 / N2	Difference	p-value
Region	East 0.1877*** (0.0607)	Non-East 0.2662*** (0.0988)	12,403 / 4,414	-0.0785	0.498
Firm size	Small 0.1955*** (0.0539)	Large 0.1448* (0.0841)	8,409 / 8,408	0.0507	0.612
Ownership	State-owned -0.0840 (0.1032)	Non-state-owned 0.2600*** (0.0594)	3,734 / 13,083	-0.3440	0.004
Technology	High-tech 0.4519*** (0.0632)	Lower-tech -0.0741 (0.0806)	9,224 / 7,593	0.5260	<0.001

*Note: p-values are from independent-sample coefficient-difference z-tests. All subgroup models include firm controls and year effects. ***, **, and * indicate significance at the 1%, 5%, and 10% levels.*

5. Conclusion

Using 16,817 observations for Chinese A-share listed advanced manufacturing firms from 2015 to 2025, this study finds that tax refunds relative to operating revenue are positively associated with annual CCR debt-financing efficiency. The association remains positive after firm controls and year effects are included. The average marginal effect indicates that a one-percentage-point increase in Tax corresponds to an approximately 0.0050 increase in expected Eff. Financing-constraint relief accounts for an estimated 15.09% of the total coefficient. The association is significantly stronger for non-state-owned and high-technology firms, while regional and firm-size coefficient differences are not statistically significant.

The findings have several practical implications. Tax authorities can improve the financial value of support by making eligibility, calculation, and receipt more predictable, especially where firms must fund long research and equipment cycles. Policy evaluation should examine not only the amount of relief but also debt cost, maturity alignment, and capital return. Firms should integrate refunds into capital budgeting and prioritize projects with credible technical milestones and cash-flow paths rather than treating tax support as unrestricted surplus. Lenders may use stable and compliant tax-support records as supplementary information, but such records should complement rather than replace project-level cash-flow and repayment analysis.

The conclusions remain bounded by the research design. Tax refunds do not capture every form of income-tax reduction, and alternative scaling changes the result. CCR efficiency depends on selected inputs and outputs, the constant-returns assumption, and the annual comparison set. The two-stage Tobit model does not remove dependence induced by the estimated frontier, unobserved firm heterogeneity, or reverse causality. Future research should compare BCC and slack-based measures, build broader policy indicators, report bootstrap confidence intervals for mediation, implement Simar-Wilson inference, and exploit plausibly exogenous policy changes. Until those extensions are completed, the evidence should be read as a carefully qualified association that is informative for policy design but not a definitive causal estimate.

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Conflicts of Interest

The authors declare no conflict of interest.

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