Original Paper

Research on the Impact of Executive Innovation Awareness on Innovation Efficiency

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Abstract

Based on panel data from A-share listed companies in Shenzhen and Shanghai from 2008 to 2023, this paper constructs an indicator of executive innovation awareness from a textual quantitative perspective and examines its impact on firm innovation efficiency. Executive innovation awareness significantly improves firm innovation efficiency. Further robustness tests and endogeneity tests maintain consistent direction and significance, supporting the main conclusion that is independent of specific metrics or sample years. In terms of mediating mechanisms, management shareholding ratio partially mediates the "executive innovation awareness → innovation efficiency" effect chain. Heterogeneity analysis shows that this positive relationship is stronger in firms with low competition and high employee density, suggesting that resource redundancy and human capital conditions can enhance the transformation from awareness to efficiency. The research conclusions provide a basis for firms to enhance executive innovation awareness from a strategic and governance perspective, optimize equity incentives, and improve organizational configuration to improve innovation efficiency.

Keywords

executive innovation awareness, innovation efficiency, management shareholding ratio

1. Introduction

With the deepening development of globalization and the knowledge economy, corporate innovation capabilities have become a key factor in determining their competitiveness. Against this backdrop, executive innovation awareness, as a core element in corporate innovation decision-making, has increasingly attracted attention from both academic and practical circles regarding its impact on corporate innovation efficiency. In recent years, the Chinese government has placed significant emphasis on the innovation-driven development strategy and has introduced a series of policies and regulations, such as the "Outline of the National Innovation-Driven Development Strategy" and the

"13th Five-Year Plan for National Science and Technology Innovation", aiming to stimulate corporate innovation and enhance the country's overall innovation capabilities. Currently, enterprises face numerous challenges in the innovation process, including insufficient innovation resources, a shortage of innovative talent, and imperfect innovation mechanisms. Against this backdrop, studying the impact of executive innovation awareness on corporate innovation efficiency is of great practical significance. On the one hand, it can help enterprises gain a deeper understanding of the role of executive innovation awareness in the innovation process, thereby optimizing innovation management mechanisms and improving innovation efficiency. On the other hand, it can help the government formulate more targeted policies to promote the improvement of corporate innovation capabilities.

Research level of executive background: Multi-dimensional exploration of the key factors for improving corporate innovation performance. First, focus on executive incentives and team stability to solve the problem of corporate innovation performance. Zhang et al. (2023) proposed that there is a significant positive correlation between executive incentive mechanisms and corporate technological innovation performance. Executive incentive mechanisms have a partial mediating effect on innovation through team stability, and different incentive methods have different innovation effects on different patent types (Zhang & Zhang, 2023). Jing et al. (2021) proposed that both long-term and short-term executive pay gaps have a significant promoting effect on innovation investment, but the long-term impact is more significant, and the background of the board of directors' human capital and the short-term pay gap have a complementary effect on the promotion of innovation investment. This shows that the impact mechanism of executive pay gaps and board capital on corporate innovation investment is complex, which has important implications for formulating effective pay incentive mechanisms and optimizing board governance mechanisms (Jing, Jiang, Zhao, & Lin, 2021). Second, focus on the effectiveness of corporate innovation management and solve the problem of the interactive influence of executive background and internal and external environment. Yue et al. (2015) proposed that in an increasingly turbulent environment, corporate executives should regard business innovation as one of the core functions of the company, because their emphasis on innovation awareness and the creation of a good innovation atmosphere have a significant positive correlation, which in turn strengthens innovation activities from the perspective of product innovation and technology, thereby promoting enterprises to support innovation activities from multiple aspects, building flexible systems, empowering innovation, optimizing innovation processes, cultivating a supportive culture, expanding external partners, and identifying strategic frontiers for innovation growth, which have become key issues for corporate executives to form innovation-driven (Yue, Zhu, Zhang, & Zhu, 2015). Wang Huifang et al. (2024) showed that executives with a scientific research background can significantly promote corporate innovation investment and innovation quality, while executives with an R&D background can improve innovation output. Optimizing the business environment and equity incentives play a key role in promoting executive innovation decisions, so that enterprises can more effectively implement innovation decisions when considering "physical", "rational" and "human" factors (Wang &

Chen, 2024). The third is to focus on the research of executive backgrounds to solve the problem of corporate innovation. Zhu et al. (2017) proposed that highly educated executives have a significant positive impact on the innovation intensity of entrepreneurial companies, and risk preference plays a partial mediating role in this process. At the same time, the age of the executives has a negative moderating effect on the mediating effect (Zhu, Zhang, BE, Kuek M, Zhang, & Zhao, 2017). Cao et al. (2025) proposed that the IT background of corporate executives significantly enhances the company's digital technology innovation, especially in the field of digital technology invention patents. The effect is particularly significant and leads to improved corporate financial performance, which highlights the importance of executive IT human capital and provides inspiration for government and corporate talent recruitment policies (Cao & Wu, 2025).

Innovation efficiency research level : Explore the path to improve innovation efficiency, optimize the supply chain knowledge sharing mechanism, and the efficiency and risk balance strategy in enterprise innovation. First, focus on innovation efficiency research and solve the problem of supply chain knowledge sharing. Chen Xueying et al. (2025) proposed that the supply chain intellectual property relationship between listed companies and important transaction partners significantly improves enterprise innovation efficiency by reducing innovation risks, communication costs and improving market bargaining power, thereby revealing the key role of knowledge sharing in innovation collaboration and industrial upgrading (Chen, Ye, & Liu, 2025). Wei Qinwen et al. (2025) proposed that the development of the technology market has significantly improved the innovation efficiency of high-tech enterprises by promoting enterprises to absorb external knowledge, innovate specialized division of labor and coordinate investment of innovation factors, especially in areas with advantageous economic development locations and developed technology markets. This improvement effect is more significant (Wei & Sun, 2025). Second, focus on innovation efficiency research and solve the problem of digital transformation and policy combination optimization. Tian Gaoliang et al. (Unknown) proposed that digital transformation can significantly improve the innovation efficiency of enterprises, and by improving the quality of innovation, it can double the improvement of the innovation momentum and efficiency of enterprises. This impact has a positive regulatory effect on the quality of internal control, salary gap, and the digital level of regional governments and peer enterprises. In particular, this promotion effect is more significant in industries and regions with strong market power, a high proportion of executives with R&D backgrounds, high educational levels of employees, capital and technology intensiveness, fierce competition, high financing costs, and high levels of marketization and intellectual property protection. Zhu Xiangyu et al. (2025) proposed that the innovation policy combination has a positive impact on the innovation efficiency of high-tech industries, and has a significant promotion effect through mechanisms such as improving industrial agglomeration, talent and technology agglomeration, and enterprise innovation investment. At the same time, its impact has a threshold effect, making the effect more significant when the policy combination is below the threshold value. (Zhu & Zhang, 2025) The third is to focus on enterprise innovation research and solve efficiency

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and risk problems. Wang Tao et al. (2025) emphasized that the impact of financing constraints on corporate innovation efficiency presents a significant inverted U-shaped threshold effect, and is negatively regulated by the development of digital finance and corporate internal control. As a result, the advancement of digital finance and the strengthening of internal control can significantly alleviate the inhibitory effect of financing constraints on corporate innovation, thereby promoting the improvement of corporate innovation efficiency (Wang & Liu, 2025). Huang et al. (2017) proposed that the improvement of executives' innovation awareness can significantly promote corporate innovation investment and innovation performance, and revealed the mediating role of corporate innovation investment in the relationship between executives' innovation awareness and corporate innovation performance, thus making corporate executives' innovation awareness a key factor in improving corporate innovation performance (Huang & Shao, 2017).

on executives' influence on enterprises reveals that innovation incentives, executive background, innovation efficiency, and corporate knowledge sharing have become research hotspots, providing important insights for improving innovation performance and optimizing enterprise management. However, unresolved issues include the following: 1. Incomplete research on incentive mechanisms. Existing research has largely focused on executive compensation incentives, while insufficient exploration of other internal incentive mechanisms has failed to fully reveal the full impact of incentive mechanisms on innovation performance. 2. The influencing mechanisms of executive background are complex. While research has revealed the impact of executive background on enterprise innovation, the analysis of these influencing mechanisms is insufficient, failing to fully reveal how executives from different backgrounds influence enterprise innovation through different pathways. 3. The paths to improving innovation efficiency are unclear. Although research has proposed multiple paths to improve innovation efficiency, a lack of in-depth exploration of the interrelationships and mechanisms between these paths leads to ambiguity in the selection and implementation of these paths. To address these three issues, this paper conducts an in-depth analysis of the relationship between executive innovation awareness and enterprise innovation efficiency, drawing on data from A-share listed companies in Shenzhen and Shanghai, to reveal the mechanisms by which executive innovation awareness influences the innovation process.

2. Research Design

2.1 Sample Data and Sources

This paper examines the impact of executive innovation awareness on innovation efficiency using panel data from Shenzhen and Shanghai-listed companies from 2008 to 2023. The company data are sourced from the China Securities Regulatory Commission (CSMAR) database. The sample data undergoes the following processing: excluding companies with ST or *ST status; excluding companies in the financial sector; eliminating missing values; and winsoring continuous variables at the 1% and 99% levels.

2.2 Variable Definition

Explained variable: Innovation efficiency (InnoEff1). Based on existing literature references, the measurement method of innovation efficiency (InnoEff1) is as follows:

Ln (total number of applications for invention patents, utility model patents, and design patents + 1)/ln(1 + R&D expenditure)

Explanatory variable: Executive Innovation Mindset (TMI). This measure of executive innovation mindset is conducted by analyzing the text of the board report section of the annual reports of GEM-listed companies, which reflects the core values of the company's senior management team. The specific steps are as follows: I collected all the annual reports of the listed companies in my study, converted them from PDF files into plain text files, and used a shell script programming language to calculate the keyword share in batches using computer calculations. This paper selected ten words that reflect executive innovation mindset, including "innovation", "independence", "research and development", "scientific research", "new products", "new technologies", "development", "scientific research", "research", and "patents". The proportion of these words in the total word count of the board report was calculated to represent the strength of executive innovation mindset. Specifically, the strength of executive innovation mindset = the total word count of keywords reflecting executive innovation mindset / the total word count of the board report section in the annual report.

Control variables. See Table 1 for reference to existing literature.

Table 1. Variable Definition Table

Variable Type	variable name	variable symbols	Variable Definition
Explained variable	Executive innovation awareness	InnoEff1	Innovation Efficiency Index
Explanatory variables	Executive innovation awareness	TMI	Intensity of executives' innovation awareness
	Enterprise scale	Size	Logarithm of total corporate assets
	debt-to-asset ratio	Lev	debt-to-asset ratio
	Net profit on assets	ROA	Net profit margin of total assets
Control variables	Management expense ratio	Mfee	Ratio of management expenses
	Institutional Investment	INSP	Proportion of

		institutional investment
Equity checks and balances	Balance	Equity Index
Two jobs in one	Dual	Whether two positions are combined into one
Company age	Age	Years of establishment

2.3 Model Construction

This paper uses the panel data of A-share listed companies in Shenzhen and Shanghai to study the impact of executive innovation awareness on innovation efficiency. This paper selects a fixed effect model. The specific model settings are as follows

$$\text{InnoEff1}_{it}=\alpha_0+\alpha_1 \text{TMI}_{it}+\delta X_{it}+\lambda_j+\mu_t+\varepsilon_{it} \tag{3}$$

In the above model, i and t represent the enterprise and year, respectively; X is the control variable; λ_j is the industry fixed effect, where j is the industry to which enterprise i belongs; μ_t is the year fixed effect; ε_{it} is the random disturbance term, and robust standard errors are used to address heteroskedasticity.

3. Empirical Analysis

3.1 Descriptive Analysis

This study has a large sample size of 35,586, which helps ensure the reliability of subsequent statistical inferences. The distribution characteristics of the core variables are as follows: First, the mean of executive innovation awareness (TMI) is 0.0130, with a standard deviation of 0.00613. This relatively low mean indicates that, across the sample, management generally allocates little attention to innovation strategy, and innovation may not yet occupy a central position in their overall strategic agenda. Furthermore, the standard deviation of this variable is relatively small compared to its mean, reflecting that while executive innovation awareness varies across companies, the absolute differences are not significant, with the majority of observations concentrated around the mean. Its value range is 0 to 0.0876, indicating that some companies' executives place a high priority on innovation (TMI = 0), while others show no focus at all (TMI = 0). This provides the necessary basis for variation in the variable's impact on corporate innovation efficiency.

Secondly, the mean of firms' innovation efficiency (InnoEff1) is 0.161, with a standard deviation of 0.0824. This value indicates that, on average, firms are moderately efficient in converting innovation inputs into outputs. The standard deviation reveals significant differentiation in innovation efficiency across firms, suggesting that some firms are able to efficiently utilize innovation resources, while others may experience significant resource waste or inefficient management in their innovation processes. The range of values, from 0 to 0.441, further confirms the significant heterogeneity in

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innovation efficiency across firms. This significant variation provides a sound data foundation for empirical research on the role of executive innovation awareness.

In summary, the descriptive statistics indicate that the core variables exhibit significant variation within the sample, meeting the basic criteria for further regression analysis. While executive innovation awareness is generally low, there is variation, while corporate innovation efficiency exhibits significant differentiation, initially suggesting a possible correlation between the two.

Table 2. Descriptive Analysis

Variable	Obs	Mean	Std.	Min	Max
TMI	35,586	0.0130	0.00613	0	0.0876
InnoEffl	35,586	0.161	0.0824	0	0.441
ROA	35,586	0.0349	0.0892	-4.946	0.786
Lev	35,586	0.398	0.206	0.00752	3,919
Size	35,586	8,313	1.267	4,009	14.79
Age	35,586	1.912	0.955	0	3.526
Mfee	35,586	0.188	15.15	-0.111	2825
INSP	35,586	41.25	25.10	0	101.1
Balance	35,586	0.797	0.633	0.00450	4
Dual	35,586	0.332	0.471	0	1
Boardsize	35,586	8.412	1.645	4	18

3.2 Regression Analysis

Table 1 reports the regression results of executive innovation awareness (TMI) on firm innovation efficiency (InnoEffl). Columns (1) and (2) use a baseline regression approach, with the sample containing all firm-year observations. Column (1) excludes control variables and fixed effects, while column (2) adds fixed effects. To verify that the conclusions are not due to differences in model specifications, column (3) adds control variables but excludes fixed effects while maintaining the sample size. Column (4) includes both control variables and fixed effects. The regression results show that the regression coefficient of TMI is significantly positive in all four specifications: 1.002 (t=13.563) for column (1), 0.231 (t=2.814) for column (2), 1.788 (t=24.365) for column (3), and 1.248 (t=16.667) for column (4), all of which are significant at the 1% level; the corresponding adjusted R^2 is 0.006, 0.198, 0.132, and 0.347. This shows that regardless of whether control variables and fixed effects are included, the stronger the executive's innovation awareness, the higher the enterprise's innovation efficiency, and the conclusion direction is consistent and the statistical strength is high.

After adding fixed effects (columns (1) → (2)), the coefficient shrinks from 1.002 to 0.231, and the fit is significantly improved, indicating that the fixed effects effectively absorb unobserved

time-invariant/slow-variant heterogeneity; when only control variables are added (columns (2) → (3)), the coefficient rises to 1.788, indicating that the main effect is stronger after the observable confounding is eliminated; under the most stringent simultaneous control setting (column (4)), the coefficient of 1.248 is still highly significant and the model fit is the highest (adj.$R^2=0.347 R^{2}=0.347 R2=0.347$), which can be used as the benchmark specification for the main conclusion. Since the table does not provide the standard deviation and mean of the variables, this paper does not perform a specific "standard deviation-economic magnitude" conversion here, but the estimated size and significance in column (4) show that the effect has statistical significance and potential economic significance.

Table 3. Regression Analysis

	(1)	(2)	(3)	(4)
	InnoEff1	InnoEff1	InnoEff1	InnoEff1
TMI	1.002***	0.231***	1.788***	1.248***
	(13.563)	(2.814)	(24.365)	(16.667)
ROA			0.061***	0.037***
			(9.411)	(6.193)
Lev			0.023***	0.002
			(8.799)	(1.039)
Size			0.023***	0.027***
			(51.175)	(65.686)
Age			-0.002***	0.003***
			(-4.560)	(5.237)
Mfee			-0.000***	-0.000***
			(-12.398)	(-13.791)
INSP			-0.000***	-0.000
			(-7.561)	(-0.662)
Balance			0.001*	-0.001**
			(1.827)	(-2.061)
Dual			0.001	0.001
			(0.604)	(0.862)
Boardsize			-0.000	0.001***
			(-1.373)	(3.927)
_cons	0.148***	0.158***	-0.054***	-0.098***
	(134.604)	(136.194)	(-14.506)	(-28.916)
N	35586	35586	35586	35586

| adj. R^2 | 0.007 | 0.194 | 0.131 | 0.131 |

t statistics in parentheses * p < 0.1, ** p < 0.05, *** p < 0.01.

3.3 Robustness Analysis

This paper conducts three types of robustness tests to determine whether improving executive innovation awareness (TMI) robustly improves firm innovation efficiency. The conclusions are all consistent with the baseline regression and statistically significant: 1. Substituting the dependent variable. Replacing the innovation efficiency measure from InnoEff1 to InnoEff2, the regression results show that the coefficient of TMI is 1.657 (t=17.246), which is significant at the 1% level, indicating that the main conclusion is not dependent on a single measure of innovation efficiency. The corresponding adjusted R² is 0.315. 2. Adding control variables. Further adding staff density (StaffInt), financing constraints (SA), and supervisory board size (SupSize) to the baseline, the coefficient of TMI is 1.301 (t=15.587), which remains significant at the 1% level. The adjusted R² increases to 0.341, indicating that the positive relationship between TMI and innovation efficiency remains robust after controlling for more observable confounding. 3. Excluding special years. Taking into account the interference of abnormal macroeconomic shocks, after excluding 2015 and 2020, which were affected by the financial market and the epidemic, the coefficient of executive innovation awareness (TMI) was 1.303 (t=15.619), which was also significant at the 1% level; the adjusted R² was 0.340, which was almost consistent with the result after expanded control, indicating that the main conclusion was not driven by abnormal years.

Based on the above three robustness tests (the sample size is N=30,329), regardless of replacing the dependent variable measurement, expanding the control variables, or excluding special years, the impact of TMI on innovation efficiency is always significantly positive, which further enhances the credibility and extrapolation robustness of the core conclusions of this article.

Table 4. Robustness Analysis

	(1)	(2)	(3)
	InnoEff2	InnoEff1	InnoEff1
TMI	1.565***	1.245***	1.266***
	(18.302)	(16.588)	(15.661)
ROA	0.040***	0.038***	0.037***
	(5.741)	(6.315)	(5.573)
Lev	0.002	0.003	0.004
	(0.693)	(1.171)	(1.449)
Size	0.029***	0.027***	0.027***
	(59.573)	(63.461)	(60.263)

Age	0.003***	0.003***	0.003***
	(4.992)	(6.111)	(4.821)
Sorry.	-0.000***	-0.000***	-0.000***
	(-15.171)	(-3.088)	(-23.616)
INSP	-0.000	-0.000	-0.000
	(-1.059)	(-0.674)	(-0.277)
Balance	-0.001*	-0.001**	-0.001*
	(-1.740)	(-2.057)	(-1.846)
Dual	0.000	0.001	0.001
	(0.136)	(0.743)	(0.756)
Boardsize	0.001***	0.001***	0.001***
	(4.575)	(4.092)	(3.242)
SupSize		-0.000	
		(-0.493)	
StaffInt		0.000**	
		(1.971)	
SA		0.005***	
		(3.267)	
_cons	-0.075***	-0.078***	-0.099***
	(-19.412)	(-10.956)	(-27.074)
N	35586	35586	30329
adj. R^2	1.565***	1.245***	1.266***

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

3.4 Endogeneity Analysis

This paper conducts endogeneity tests to determine whether improving executive innovation awareness (TMI) significantly improves innovation efficiency (InnoEff1). The results are consistent with the baseline conclusion and statistically robust: 1. Individual fixed-effect tests. After controlling for year and industry fixed effects and adding individual fixed effects, the current coefficient of TMI is 0.505 (t=5.884), which is significant at the 1% level. This indicates that the positive impact of TMI persists even after accounting for time-invariant firm heterogeneity, mitigating the upward/downward bias caused by omitted time-invariant factors (N=35,252; adj. R^2=0.661). 2. Time series lead-in (first-order lag) tests. When replacing the current TMI with the one-period lagged TMI, the coefficient is 1.234 (t=15.152), which is significant at the 1% level (N=29,050; adj. R^2=0.354). The results show that even when only the previous period's executive innovation awareness explains the current period's innovation efficiency (InnoEff1), the main effect remains significant and positive, helping to alleviate concerns about reverse causality caused by performance negatively influencing management intentions.

(3) Time-series lead-in (two-order lag) test. Using the second-order lagged executive innovation awareness (TMI) as the core explanatory variable, the coefficient is 1.240 (t=13.553), which is significant at the 1% level (N=24,653; adj. R²=0.358). This result suggests that the impact of executive innovation awareness (TMI) on innovation efficiency (InnoEff1) is persistent and not limited to a short-term, current effect. (4) Time-series lead-in (three-order lag) test. Using the third-order lagged executive innovation awareness (TMI) as the core explanatory variable, the coefficient is 1.234 (t=12.669), which is significant at the 1% level (N=20,906; adj. R²=0.363). As the lag period increases, the sample size decreases as expected, but the direction and significance of the main effects remain stable, further supporting the lagged and persistent impact of TMI on innovation efficiency (InnoEff1).

In summary, under stronger fixed effect constraints and multi-period time series pre-settings, the positive impact of executive innovation awareness (TMI) on innovation efficiency (InnoEff1) is always significant. The conclusion does not depend on the specific current period setting and is temporally leading and robust.

Table 5. Endogeneity Analysis

	(1)	(2)	(3)	(4)
	InnoEff1	InnoEff1	InnoEff1	InnoEff1
TMI	0.505***			
	(5.884)			
L.TMI		1.234***		
		(15.152)		
L2.TMI			1.240***	
			(13.553)	
L3.TMI				1.234***
				(12.669)
ROA	0.004	0.027***	0.023***	0.027***
	(0.936)	(4.466)	(3.862)	(4.297)
Lev	-0.013***	-0.001	-0.003	-0.006*
	(-3.746)	(-0.501)	(-0.915)	(-1.829)
Size	0.023***	0.028***	0.028***	0.028***
	(24.910)	(61.639)	(58.333)	(54.524)
Age	0.008***	-0.000	-0.001	-0.001
	(7.720)	(-0.170)	(-0.983)	(-1.275)
Sorry.	-0.000**	-0.010**	-0.014***	-0.022***
	(-2.093)	(-2.042)	(-3.835)	(-3.222)
INSP	0.000	-0.000	-0.000	-0.000

	(0.553)	(-0.060)	(-0.454)	(-0.443)
Balance	0.001	-0.001*	-0.001**	-0.001*
	(0.619)	(-1.712)	(-2.079)	(-1.680)
Dual	0.001	0.000	-0.000	-0.001
	(0.931)	(0.012)	(-0.471)	(-0.778)
Boardsize	0.001**	0.001***	0.001***	0.001***
	(2.062)	(4.194)	(4.006)	(4.678)
_cons	-0.058***	-0.092***	-0.090***	-0.088***
	(-7.448)	(-24.464)	(-22.278)	(-19.593)
N	35252	29050	24653	20906
adj. R^2	0.661	0.354	0.358	0.363

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

3.5 Mediation Analysis

This paper uses a three-step approach to examine the mediating mechanism by which executive innovation awareness (TMI) influences innovation efficiency (InnoEff1) through management ownership (MH). Results are presented only for the core variable. Using innovation efficiency (InnoEff1) as the explained variable, the regression coefficient for TMI is 1.248 (t=16.667, p<0.01), with an adjusted $R^2 = 0.347$, indicating a significant positive correlation between TMI and innovation efficiency (InnoEff1). Using management ownership (MH) as the explained variable, the coefficient for TMI is 0.354 (t=2.438, p<0.05), indicating that TMI significantly increases management ownership (MH), confirming the necessary prerequisite for conducting a mediation analysis. The adjusted $R^2 = 0.636$. Based on the first-step model, the management shareholding ratio (MH) was added. The coefficient of management shareholding ratio (MH) was 0.028 (t=9.678, p<0.01), which had a significant positive impact on innovation efficiency (InnoEff1). The innovation consciousness of executives (TMI) was still significantly positive (1.239, t=16.533, p<0.01), and its point estimate was only slightly lower than that of the first step (1.248). The adjusted $R2 = 0.349$.

The results of the three-step approach consistently show that while top management innovation awareness (TMI) directly improves firm innovation efficiency (InnoEff1), it also has a significant, though smaller, indirect promoting effect through increased management ownership (MH). This suggests that MH plays a partial mediating role in the mechanism by which TMI affects innovation efficiency. This mediation path is clear and statistically valid, but its economic magnitude relative to the main effect is limited.

Table 6. Mediation Analysis

	(1)	(2)	(3)
	InnoEff1	MH	InnoEff1
TMI	1.248***	0.354**	1.239***
	(16.667)	(2.438)	(16.533)
MH			0.028***
			(9.678)
ROA	0.037***	0.190***	0.031***
	(6.193)	(7.858)	(5.618)
Lev	0.002	-0.066***	0.004*
	(1.039)	(-14.319)	(1.804)
Size	0.027***	0.022***	0.027***
	(65.686)	(30.048)	(63.427)
Age	0.003***	-0.098***	0.005***
	(5.237)	(-97.396)	(9.344)
Sorry.	-0.000***	-0.000	-0.000***
	(-13.791)	(-0.489)	(-12.294)
INSP	-0.000	-0.005***	0.000***
	(-0.662)	(-139.278)	(5.912)
Balance	-0.001**	0.001	-0.001**
	(-2.061)	(0.807)	(-2.107)
Dual	0.001	0.011***	0.000
	(0.862)	(6.969)	(0.469)
Boardsize	0.001***	-0.003***	0.001***
	(3.927)	(-7.679)	(4.303)
_cons	-0.098***	0.425***	-0.110***
	(-28.916)	(70.700)	(-30.508)
N	35586	35586	35586
adj. R^2	0.347	0.636	0.349

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

3.6 Heterogeneity Analysis

By market competition level, the coefficient for executive innovation awareness (TMI) in the low-competition group (column 1) is 1.498, t=12.436, and significant at the 1% level. For the high-competition group (column 2), the coefficient for executive innovation awareness (TMI) is 1.085, t=11.520, and significant at the 1% level. Regardless of competitive strength, TMI has a significant

positive impact on innovation efficiency (InnoEff1). The coefficient is even greater in low-competition (high market share) environments, indicating that when a firm has a high market share, resource slack, and greater absorptive capacity, TMI is more likely to translate into process improvements and output efficiency gains. In highly competitive environments, despite the external driving force of "competitive pressure-efficiency improvement", management may be constrained by short-term survival constraints and tight budgets, resulting in a relatively convergent marginal conversion rate for TMI.

By employee density, for low-employee density (column 3), the coefficient for executive innovation awareness (TMI) is 1.042, t=10.238, and significant at the 1% level. For high-employee density (column 4), the coefficient for executive innovation awareness (TMI) is 1.492, t=13.532, and significant at the 1% level. The main effect of executive innovation awareness (TMI) is significantly positive in both sample types, but the effect is significantly stronger in high-employee density firms. This is consistent with the complementarity between "human capital and organizational learning/knowledge sharing": when employee input accounts for a high proportion, executive innovation awareness (TMI) is more likely to be widely diffused to frontline functions through institutional innovation, process reengineering, and incentive design, resulting in higher conversion efficiency to innovation efficiency (InnoEff1). In contrast, in low-employee density (compared to capital /technology intensive) firms, improvements in innovation efficiency (InnoEff1) are more dependent on equipment upgrades, R&D cycles, and the pace of capital expenditures, resulting in a relatively small immediate marginal effect of executive innovation awareness (TMI).

Table 7. Heterogeneity Analysis

	(1)	(2)	(3)	(4)
	InnoEff1	InnoEff1	InnoEff1	InnoEff1
TMI	1.498***	1.085***	1.042***	1.492***
	(12.436)	(11.520)	(10.238)	(13.532)
ROA	0.029***	0.041***	0.037***	0.042***
	(2.860)	(6.398)	(5.633)	(3.631)
Lev	-0.002	0.008**	0.002	0.006*
	(-0.656)	(2.492)	(0.469)	(1.741)
Size	0.025***	0.029***	0.028***	0.028***
	(39.384)	(37.748)	(49.569)	(41.017)
Age	0.002***	0.001**	0.003***	0.001*
	(3.261)	(2.050)	(4.534)	(1.928)
Fee	0.065***	-0.000***	-0.000***	0.026*
	(4.627)	(-12.934)	(-12.469)	(1.893)
INSP	0.000**	-0.000***	-0.000	-0.000

	(1.981)	(-3.075)	(-0.593)	(-0.338)
Balance	-0.002**	0.000	-0.002**	-0.001
	(-2.383)	(0.218)	(-2.007)	(-0.599)
Dual	0.001	0.001	-0.000	0.001
	(0.584)	(0.791)	(-0.011)	(0.807)
Boardsize	0.001***	0.000	0.001**	0.001***
	(4.299)	(0.697)	(2.127)	(3.227)
_cons	-0.096***	-0.094***	-0.097***	-0.105***
	(-16.246)	(-15.732)	(-20.806)	(-18.187)
N	17794	17784	17794	17792
adj. R^2	1.498***	1.085***	1.042***	1.492***

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4. Conclusions and Recommendations

4.1 Conclusion

Executive innovation awareness significantly improves corporate innovation efficiency. The coefficient of TMI on InnoEff1 is positive and significant at the 1% level across the baseline and various settings. This conclusion remains consistent across multiple robustness tests. The positive impact of TMI remains significant at the 1% level, regardless of whether the dependent variable scope (InnoEff2) is modified, control variables are added, or even outlier years are excluded. Endogeneity is mitigated, and the effect is persistent. Even after adding individual fixed effects, the TMI remains significantly positive in the current period; even when lagged one to three periods, the coefficient remains significantly positive, demonstrating both leading and persistent effects.

There is partial mediation: management shareholding (MH). TMI significantly improves MH, which has a significantly positive effect on innovation efficiency. Furthermore, the direct effect of TMI only slightly decreases after incorporating MH, indicating that MH plays a small but clear mediating role.

Heterogeneity: Resource redundancy and labor intensity reinforce the effect. In low-competition (high market share) scenarios and high-employee-density firms, TMI has a stronger impact on innovation efficiency. In highly competitive environments, marginal conversion rates converge due to short-term constraints.

4.2 Management Practice Recommendations

Embed innovation awareness into corporate strategy and governance. Establish an annual innovation agenda, jointly reviewed by the board of directors and senior management, and clearly define three to five cross-departmental innovation themes with corresponding milestones, budgets, and responsible individuals. Optimize incentive compatibility and leverage the "partial intermediation" approach. Introduce equity/restricted stock plans tied to mid- to long-term performance, moderately increase management ownership (MH) to incentivize continuous exploration and transformation. Link this to

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R&D milestones, patent quality, and commercialization to prevent a focus on quantity. Tailor resource and organizational allocation to each company. Companies with low competition and significant resource redundancy: Establish a "platform-based R&D + shared technology middle platform" to accelerate the translation of executive innovation initiatives into processes and tools; expand external collaboration and scenario pilots to improve diffusion efficiency. Highly competitive industries: Implement a combination of "stage-gate" and "small, fast steps" to ensure sustained exploration intensity within budgetary and survival constraints. Companies with high employee density: Focus on institutional innovation and knowledge sharing (cross-departmental hackathons, internal workshops, and communities of practice) to enable frontline staff to more quickly absorb and reuse new approaches.

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