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The Impact of Innovation on Operational Performance in Chinese High-Tech Enterprises

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[Abstract]

The technological innovation of high-tech enterprises plays a positive driving role in operational performance. Investigating the factors influencing the operational performance of high-tech enterprises and the effects of technological innovation on operational performance is a targeted approach to promoting the growth of economic benefits and enhancing the foundation of enterprise efficiency. Additionally, it holds positive significance for the increase in market share of high-tech enterprises. This paper, considering the characteristics of high-tech enterprises, selects three influencing factors: research and development (R&D) investment intensity, the number of authorized patents, and the increment of intangible assets. Theoretical analysis is conducted on the impact mechanism and effects of these factors on operational performance. Based on this, empirical analysis is performed using relevant data of Chinese high-tech enterprises from 2011 to 2019. The study indicates that R&D investment intensity has a significant positive promoting effect on operational performance, the number of authorized patents also positively influences operational performance significantly, while the asset-liability ratio of high-tech enterprises has a notable inhibitory effect on operational performance. Finally, relevant recommendations are proposed.

▸ **Key words**: High-tech enterprises, Innovation, Performance, Impact

[요 약]

하이테크 기업의 기술 혁신은 경영 성과에 긍정적인 영향을 미친다. 따라서, 하이테크 기업의 경영 성과에 영향을 주는 요인 및 정도를 파악하는 것은 기업의 경제적 효용을 촉진하고 기업의 효율성 기반을 강화하는 것을 목표로 하고 있다. 또한, 하이테크 기업의 시장 점유율 향상에도 정의 유의한 영향을 미친다. 본 연구는 하이테크 기업의 특징을 기반으로 연구개발 투자 강도, 특허 출원 수와 무형 자산 증가량이라는 3가지 요인을 선택하고 경영 성과에 대한 영향 메커니즘과 효과에 대해 이론적으로 분석하고 근거를 제시하였다. 2011년부터 2019년까지 중국 하이테크 기업 관련 데이터를 사용하여 실증분석을 진행하였고 분석 결과는 다음과 같다. 하이테크 기업의 연구개발 투자 강도는 경영 성과에 유의한 정의 영향을 미치고 하이테크 기업의 특허 출원 수도 경영 성과에 유의한 정의 촉진작용을 하며 하이테크 기업의 자산 부채율은 경영 성과에 대하여 유의한 부의 영향을 미친다. 마지막으로, 관련된 건의 사항과 시사점을 논의하였다.

▸ **주제어**: 하이테크 기업, 혁신, 성과, 영향

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I. Introduction

Against the backdrop of international trade, the development of high-tech enterprises in China is showing a promising trend. However, with the increasing pressure of industry competition, these enterprises are facing significant developmental bottlenecks. High-tech enterprises hold a strategic position in the development of the Chinese economy. The intensification of international competition in the high-tech market demands continuous innovation in products and technologies from these enterprises. The ongoing development of the Chinese economy has led to an improvement in the quality of life, accompanied by changes in consumer awareness and demands. To align with market demands and ensure sustainable development, enterprises need to enhance their levels of technological innovation and adaptability, promptly adjusting their production technologies and philosophies to maintain a competitive edge in the industry. Currently, high-tech enterprises have become a crucial driver of economic growth in China. With the robust support of the national "Thirteenth Five-Year Plan," China's technological innovation level has steadily risen from the 29th position in 2015 to the 14th position in 2019. However, data indicates that, despite stable annual growth in the technological innovation level of Chinese high-tech enterprises, there still exists a considerable gap compared to innovative countries like the United States and Japan. Numerous technological bottlenecks in the high-end industrial chain need breakthroughs, leading to the heavy reliance of many high-tech enterprises on foreign technologies. A prominent recent example is Huawei's smartphone chip, highlighting issues such as low investment in technological innovation resources, narrow channels for research and development funding, low conversion rates of innovative output, and insufficient marketization capabilities for technological achievements. Technological innovation in high-tech enterprises determines the output of new products and technologies, impacting the operational performance of enterprises. Given their correlation, technological innovation in high-tech enterprises has a definite influence on their overall operational performance. This paper aims to study and analyze the impact of technological innovation on the operational performance of high-tech enterprises, with a detailed analysis of influencing factors, contributing to the sustained development of the industry and the preservation of competitive advantages.

II. Literature Review

Around 1960, U.S. scholars first defined high technology as the use of cutting-edge scientific and technological equipment. In 1988, the Organization for Economic Cooperation and Development (OECD) provided an authoritative definition, stating that high technology is built on a foundation of sustained vitality and enhanced research and development. In 2016, China standardized the definition of high-tech enterprises in the "Management Measures for the Recognition of High-tech Enterprises," referring to continuous research and development and the transformation of technological achievements within the "National Key Support Areas for High-tech Fields." Enterprises should establish core independent intellectual property rights based on this and conduct business activities after being registered in China for more than one year (excluding Hong Kong, Macao, and Taiwan).

In selecting indicators for enterprise operational performance, most scholars opt for those reflecting financial profitability and growth. Bae Dongnyoung (2003) believes that enterprise operational performance includes sales growth rate and sales profit margin [1]. David J. Teece (2006) argues that indicators of enterprise operational performance should reflect both profitability and growth [2].

Scholars like Liu Zhiying (2015) propose that enterprise operational performance comprises financial and market performance, with financial indicators including operating income and profit growth rate, and market performance covering aspects like customers, internal operations, learning, and growth [3]. Zhang Jikun (2013) suggests that the output of innovation activities, such as the number of invention patents, sales revenue from new products, and export sales revenue from new products, can measure enterprise performance. He emphasizes that the business conversion rate of innovation is a crucial indicator reflecting enterprise operational performance [4].

Regarding the selection of indicators for enterprise operational performance, the emphasis is on new product output. Lu Y.H (2010) measures the development performance of new products from three dimensions: the success rate of new products, the impact of new product projects on the company, and the overall performance of projects [5]. Zhang Xuexin (2020) analyzes the relationship between enterprise operational performance and the time of technological innovation after perceiving market demand. In the absence of scientific market research and technological research and development concepts, measuring indicators of enterprise operational performance is challenging. Moreover, in a rapidly changing market demand and consumer consumption concept environment, it is difficult to ensure technological innovation time, making it challenging for enterprise technological innovation to achieve technological value and potentially leading to economic losses [6]. Additionally, some scholars argue that enterprise value is an indirect manifestation of enterprise operational performance. Scholars like Yang Daoguang (2019) believe that enhancing diversified value contributes to the improvement of enterprise operational performance, leading to increased revenue. Through empirical analysis using China's private listed companies as a sample, it is argued that the better a company's internal management control, the more development paths it has [7].

Many scholars, combining theory and empirical evidence, have shown that technological innovation can promote the growth of enterprise operational performance. Lafarga C V (2015), through research on the international competitiveness of the Mexican manufacturing industry, concludes that technological innovation significantly enhances enterprise performance and strengthens competitiveness [8]. Martín-de Castro G (2015), selecting enterprises from "Fortune Reputation" for long-term tracking analysis, finds that technological innovation not only promotes the improvement of enterprise operational performance but also enables enterprises to achieve long-term stable development. The level of enterprise operational performance is mainly determined by the input and output of enterprise innovation, and input plays a role in the level of enterprise operational performance through output [9].

In addition, a small number of scholars have come to different conclusions, suggesting that the interaction between enterprise innovation and operational performance is not entirely positive. Peng Zhizhen (2018), through empirical research, finds that enterprise innovation can hinder the rise of enterprise operational performance during specific periods. In general, enterprise innovation is a transformation process that does not directly affect enterprise operational performance. Enterprises with a strong level of technological innovation will continuously drive the rise of enterprise operational performance through continuous innovation input only when external factors such as infrastructure, enterprise scale, and industry attributes play a positive role [10].

Many domestic and international scholars have studied the impact of the number of authorized patents on operational performance, and the conclusions are generally positive. Patents, due to their uniqueness, technicality, and legal nature, represent technological achievements awarded through technical applications by patent offices, thereby receiving legal protection and possessing strong intellectual property rights. Some scholars have analyzed the relationship between the number of authorized patents held by companies and technological innovation, indicating that patent contributions manifest in the technological innovation of enterprises, ultimately improving operational performance. Edward (2011) conducted a data regression analysis on the number of authorized patents and the development of American companies. The data indicates that the more authorized patents a company possesses, the more prominent its operational performance, and the better its development trend [11]. Liu Jiao (2014) analyzed the core patents in the development of electric vehicles and the automotive industry. Core patents have strong patent value and play a crucial role in promoting the development of electric vehicle enterprises. At the same time, authorized patents can expand the value of patents, maximizing the economic benefits of patents [12]. Bao Di (2017) believes that the number of authorized patents serves as the ultimate embodiment of technological innovation. Patent technology is protected by law and can be classified into inventions, utility models, new types, and appearance designs. Inventions mainly involve entirely new technologies and are crucial for promoting the development of the field. They have high technological content and are a key development goal for current high-tech enterprises [13]. Wang Sheng (2019) conducted an in-depth analysis from a negative perspective on the "PTC Heater Utility Model Patent Infringement Dispute." The utility model functions as a technological innovation for existing items, and the lack of attention from innovation personnel to its claimed property rights leads to disputes over new patent infringements, thereby affecting the achievement and improvement of operational performance [14]. Gao Huangting (2020) analyzed the protection scope of design patents, emphasizing the importance of intellectual property rights for design patents. Design patents focus on the design of product packaging, with consumer aesthetics as a primary design factor, attracting consumer attention, driving product sales, and ensuring the intellectual property rights of product packaging through authorized patents to safeguard the rights of their own enterprises [15-17].

III. Research Hypotheses

3.1. R&D Investment Intensity and Corporate Operational Performance

R&D funding plays a crucial role in the development of high-tech enterprises. The development of these enterprises requires substantial investment in R&D activities, covering equipment, human resources, and raw material procurement. When R&D investments are transformed into tangible resources for the enterprise, the level of technological innovation is enhanced. Continuous and effective R&D funding is essential for the ongoing success of R&D projects and ensures the effectiveness of technological innovation[18-20].

Considering the inherent characteristics of high-tech enterprises, particularly those emphasizing technology as a selling point, continuous technological innovation is pivotal for sustained development. Strengthening R&D for new products is fundamental to driving innovation. Through consistent investment and development of products while enhancing their performance, companies attract more consumer groups, capture a larger market share, and improve sales performance.

Based on the feedback from different industries regarding R&D investments, the industry context influences the impact of R&D investments on companies differently. Continuous improvement in R&D technology allows companies to reduce waste in production processes, decrease production costs, and enhance production efficiency. These advantages, stemming from R&D investments, provide a solid foundation for expanding market share and improving business capabilities. Therefore, it can be inferred that, through R&D investments, companies can enhance operational and profit capabilities by increasing new product revenue and reducing costs. Based on this analysis, the first hypothesis of this study is formulated (H1): There is a positive correlation between the intensity of R&D investment and corporate operational performance.

Based on the theoretical framework presented in the above research context, we formulate the first hypothesis, H1: There is a positive correlation between the intensity of a company's research and development (R&D) investment and its operational performance.

3.2 Number of Authorized Patents and Corporate Operational Performance

In the context of authorized patents, patent technology, centered around advanced technology, is equivalent to shared intellectual property. Patented technology has strong technical value, and its application can yield high social and economic benefits, driving technological innovation in companies. Furthermore, through authorized patents, companies can obtain objective patent fees, significantly promoting technological innovation. Therefore, the number of authorized patents serves as an indicator of the impact of technological innovation.

The number of authorized patents is a measure of the output of technological innovation. However, as a representative form of R&D projects, patented technology holds strong technical value. Therefore, in the analysis of the output of technological innovation and corporate operational performance, it is valuable. Authorized patents are a crucial factor in enhancing corporate operational performance. The economic performance of authorized patents lies in their ability to generate increasing marginal benefits for innovative investments. Authorized patent technology is forward-looking and protected by patent law. Its application in company products can lead to the development of entirely new products, capturing a high market share upon market entry, thereby promoting the growth of product sales benefits. Based on this analysis, the second hypothesis of this study is formulated (H2): There is a positive correlation between the number of authorized patents and corporate operational performance.

Based on the theoretical framework presented in the above research context, we formulate the second hypothesis, H2: There is a positive correlation between the number of authorized patents held by a company and its operational performance.

3.3 Growth of Intangible Assets and Corporate Operational Performance

Various resources related to enterprises can provide competitive advantages. However, for high-tech enterprises, "intangible assets," primarily consisting of core technology, play the most crucial role and are essential resources for forming competitive advantages. The importance of intangible assets in the current era is becoming increasingly clear, with managers prioritizing intangible assets from being relatively unimportant to now being strategically oriented.

The growth of intangible assets is a vital factor influencing the impact of technological innovation on corporate operational performance. As economic development progresses, the interaction between the growth of intangible assets and technological innovation becomes increasingly important for the development of each enterprise. For high-tech enterprises, intangible assets mainly include research and technological resources and intellectual property. These intangible assets have high technical and economic value, positively contributing to enhancing corporate economic benefits and operational performance. Increased intangible assets can drive technological innovation, injecting new vitality into the enterprise's technological innovation system. Regardless of the type of intangible asset, each can promote technological innovation in high-tech enterprises. Companies must strengthen the application of intangible assets, given their high technical and economic value, to enhance both economic benefits and operational performance. Technological innovation in high-tech enterprises leads to an increase in the quantity of intangible assets, with the acquired technical value becoming higher. Based on this analysis, the third hypothesis of this study is formulated (H3): There is a positive correlation between the growth of intangible assets and corporate operational performance.

Based on the theoretical framework presented in the above research context, we formulate the third hypothesis,

H3: There is a positive correlation between the growth of intangible assets in a company and its operational performance.

IV. Empirical Analysis

4.1 Sample Selection and Data Sources

The main focus of this study is on the listed high-tech enterprises in China, encompassing four primary industries: new materials, computer, information technology companies, and biotechnology. Due to the lag and authenticity concerns in domestic corporate information disclosure, the empirical analysis report is based on data from the base year 2011 to the reporting year 2019. The reporting period of the data and the actual research outcomes are not affected. The primary databases utilized include Guotai Junan, Rui Si, and corporate annual report data. Simultaneously, to ensure the accuracy of the data, some processing has been applied.:

Samples with missing data due to undisclosed R&D investment, patent numbers, and intangible assets were deleted.

Samples labeled as Special Treatment (ST) were excluded.

Samples with missing values in control variables were removed.

In the end, 6,441 valid samples were obtained, involving 1,199 companies, including 207 state-owned enterprises. STATA 15.0 was used for the empirical analysis.

4.2 Variable Definitions and Model Establishment

4.2.1 Dependent Variables

New Product Sales Ratio: The ratio of revenue from new product sales to total operating revenue. It directly measures the innovation capability of enterprises, reflecting their ability to generate revenue through technological innovation without considering non-operating costs. A higher new product sales ratio indicates higher operational performance, while a lower ratio suggests weaker operational performance.

Total Asset Return on Investment (ROA): The ratio of the current year's net profit to the annual asset scale. It reflects the profitability of individual asset sizes in a company and is a crucial indicator for analyzing corporate profitability. The level of ROA directly reflects a company's competitive strength and development capabilities.

4.2.2 Independent Variables

Number of Authorized Patents: Patent technology allows companies to achieve high social and economic benefits, playing a crucial role in the economic growth of high-tech enterprises. The number of authorized patents, representing innovative achievements, includes both applied and granted patents, ensuring the scientific validity of the patent count.

Growth Rate of Intangible Assets: In the context of high-tech enterprises, intangible assets mainly refer to patent technology and intellectual property. The growth of intangible assets demonstrates the emphasis a company places on technological innovation. Only with increased investment in technological innovation can the quantity of intangible assets rise, effectively reflecting the impact of technological innovation on corporate operational performance.

R&D Investment Intensity: R&D expenses are crucial for innovation, requiring significant technical talent and research funding. For high-tech enterprises, ensuring continuous funding for R&D projects is vital for improving operational performance. This study uses R&D investment amount and the proportion of year-end assets to represent R&D intensity.

4.2.3 Control Variables

Company Size (lnsize): Calculated using the logarithm of the company's year-end disclosed financial statement data. Logarithmic transformation is applied during data preprocessing to reduce data volatility, meeting variable distribution requirements. The size of this indicator is positively correlated with a company's competitiveness and profitability.

Government Subsidies: For high-tech enterprises, government subsidies significantly impact their annual financials, reducing operating costs and increasing profits. This study uses the ratio of government subsidies to operating income to represent the extent of government subsidy.

Debt-to-Asset Ratio: Capital structure reflects the ratio of owner's equity to creditor returns. The financial leverage structure is reflected in the debt-to-asset ratio, directly related to a company's performance and future development capabilities.

Tobin's Q Value: Reflects whether a company's market value is greater than its reconstruction cost, providing insight into shareholder optimism about the company's future. Tobin's Q value is used to represent the market value of listed companies, emphasizing shareholder optimism through corporate operational performance.

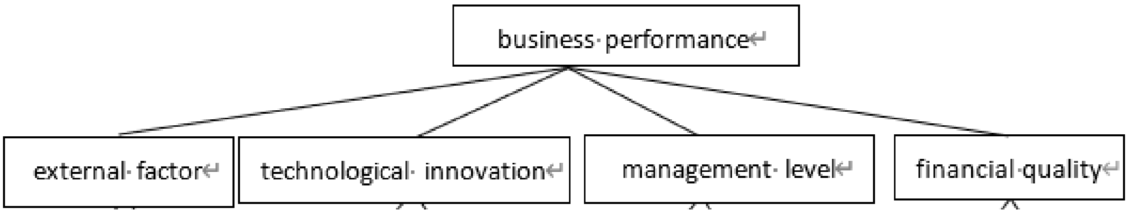
State-Owned Enterprise (Yes/No): Different types of equity ownership have differences, and state-owned enterprises typically have more financing convenience than private enterprises. In theory, this difference affects corporate operational performance. This study categorizes central and local state-owned enterprises as state-owned, while other enterprise types are classified as non-state-owned.

Company Age: Companies with different durations since going public may exhibit differences in operational performance. Generally, the longer a company has been listed, the more mature its operations, and shareholders gradually become familiar with the company's information transparency.

Refer to Table 1 for explanations of each variable.

Table 1. variable declaration

Variable type	New Product Sales Rate	symbol	explain
Dependent variable	Total Asset Return on Investment	Sronp	Year-end ratio of sales revenue from new products to total sales revenue.
	Number of Authorized Patents	Roa	Year-end ratio of net profit to total assets
Independent variable	Intangible Asset Growth Rate	lnpatent	log((number of authorized patents + 1)
	Research and Development (R&D) Investment Intensity	Inta	Ratio of net intangible assets to the net value of intangible assets at the beginning of the year, minus 1
	Enterprise Scale	Rd	Ratio of research and development (R&D) investment to year-end assets
Control variable	Government Subsidies	lnsize	log (year-end asset size)
	Asset-Liability Ratio	Sub	Ratio of government subsidies to year-end operating income
	Enterprise Value	Lev	Ratio of total liabilities to year-end total assets
	State Ownership (Yes/No)	Tobinq	Stock market compared to the value of assets and the cost of producing these assets for the enterprise
	Enterprise Age	Soe	State-owned enterprises set to 1, non-state-owned enterprises set to 0
	New Product Sales Rate	Age	Time since the enterprise went public.



4.2.4 Model Establishment

$Sronpit=c0+\beta i\sum xit+\theta i\sum controlit+indi+\lambda t+provincei+\varepsilon it$

$Roa_t=c0+\beta_i\sum x_{it}+\theta_i\sum control_{it}+ind_i+\lambda_t+province_i+\varepsilon_{it}$

Here, i represents the ith company, t denotes the tth year, c0 is the constant term, βi stands for the regression coefficients of the core explanatory variables: the number of authorized patents, the growth rate of intangible assets, and the ratio of research and development investment. ui is the individual effect of the company, ind indicates the industry to which the company belongs, λt represents the time effect of the study year, provincei is the province to which the company's registered location belongs, and εit is the residual term。The schematic diagram is as follows:

4.3 Regression Analysis

4.3.1 Variable Descriptive Statistics

A statistical summary of the variables is presented in Table 2. The mean of the new product sales rate is 3.4%, with a standard deviation of 0.064, close to twice the mean. The minimum value is -27.3%, and the maximum is 20.6%, indicating significant variation in this variable among companies. The mean total asset turnover is 4.3%, with a standard deviation of 0.071, again close to twice the mean. The minimum value is -29.8%, and the maximum is 19.3%, suggesting substantial diversity in the distribution of total asset turnover among companies.

The mean of the logarithm of authorized patents is 1.18, with a standard deviation of 1.31. The minimum value is 0, and the maximum is 5.17. Some companies exhibit a considerably higher number of authorized patents, contributing to a right-skewed distribution of the overall sample mean. The large standard deviation indicates significant variation in innovation outcomes among companies.

The mean growth rate of intangible assets is 0.48, with a standard deviation of 2.24, nearly 4.5 times the mean. The minimum value is 0.82, and the maximum is 18.02, demonstrating substantial variation in the growth of intangible assets among sample companies. The mean of the research and development investment intensity is 2.002, with a standard deviation of 2.09. The minimum value is 0, and the maximum is 10.76.

The mean logarithm of asset size is 3.34, with a

Table 2. Descriptive statistics of variables

symbol	variable	Mean	standard deviation	Min	Max
Sronp	New Product Sales Rate	0.034	0.064	-0.273	0.206
Roa	Total Asset Return on Investment	0.043	0.071	-0.298	0.193
lnpatent	Number of Authorized Patents	1.181	1.314	0.000	5.170
Inta	Intangible Asset Growth Rate	0.486	2.239	-0.819	18.016
Rd	Research and Development (R&D) Investment Intensity	2.002	2.087	0.000	10.764
lnsize	Enterprise Scale	3.342	1.052	1.364	6.385
Sub	Government Subsidies	0.014	0.018	0.000	0.117
Lev	Asset-Liability Ratio	0.342	0.188	0.053	0.839
Tobinq	Enterprise Value	2.399	1.386	0.933	7.997
Soe	State Ownership (Yes/No)	0.181	0.385	0.000	1.000
Age	Enterprise Age	17.162	5.491	6.000	32.000

minimum of 1.36 and a maximum of 6.39. The mean government subsidy ratio is 1.4%, with a maximum of 11.7%. The asset-liability ratio, Tobin's Q, and the overall distribution of the company's age exhibit relatively small differences. The proportion of state-owned enterprises (SOEs) in the sample is 18.1%.

4.3.2 Correlation Analysis

By calculating the Pearson correlation coefficients between variables, we observe that the correlation coefficients of the new product sales rate with the number of patents, intangible assets, and R&D investment are 0.126, 0.026, and 0.249, respectively. These coefficients are significant at the 1%, 5%, and 1% confidence levels, indicating a significant common trend change between these three independent variables and the new product sales rate during the study period. The correlation coefficients between the new product sales rate and the logarithm of enterprise asset size, government subsidy ratio, asset-liability ratio, and enterprise age are all consistently negative and highly significant at the 1% confidence level. This suggests a significant inverse trend change between these control variables and the new product sales rate. The correlation coefficient with the ownership attribute (state-owned enterprise or not) is -0.052, indicating that state-owned enterprises have a significantly lower new product sales rate than non-state-owned enterprises. The correlation coefficient between Tobin's Q and the new product sales rate is 0.138, significantly at the 1% confidence level. This implies that in situations where the market value of a company exceeds its book value, the company's new product sales revenue is high, showing a significant positive trend change.

For the dependent variable, total asset return rate, the correlation coefficients with the logarithm of patents, the growth rate of intangible assets, and the R&D investment ratio are 0.125, 0.029, and 0.181, respectively, all significant at the 1%, 5%, and 1% confidence levels. These three core independent variables show a significant trend change in the total asset return rate of companies during the study period. The correlation coefficients with the government subsidy ratio, asset-liability ratio, and enterprise age are all consistently negative and significant, indicating a significant negative trend change. The correlation coefficients with asset size and ownership attribute are not significant, showing no significant correlation. The correlation coefficients between the explanatory variables, except for the logarithm of asset size and asset-liability ratio (0.46, close to 0.5), are generally below 0.3. This preliminary assessment suggests that there is no strong multicollinearity among the explanatory variables.

4.3.3 Multicollinearity Test

To avoid the invalidity of estimates caused by multicollinearity, a variance inflation factor (VIF) test was conducted on the explanatory variables. According to the test standards, a VIF greater than 10 indicates the presence of some multicollinearity,

Table 3. Variable variance inflation factor

Variable	VIF	1/VIF
lnsize	1.54	0.648067
Lev	1.3	0.767132
Rd	1.18	0.846994
lnpatent	1.14	0.878267
Tobinq	1.13	0.886578
Soe	1.11	0.897558
Age	1.11	0.897882
Inta	1.01	0.990319
Sub	1	0.997953
MeanVIF	1.17	

and exceeding 100 indicates a more severe impact of multicollinearity. From Table 3, the maximum VIF is 1.54, and the average VIF is 1.07, which is far less than 10. This indicates that there is no multicollinearity among the explanatory variables.

4.4 Empirical Analysis

To avoid potential heteroscedasticity among panel data, this study used robust standard errors to replace ordinary standard errors for calculation. The results of Model 1 (Table 4) are summarized as follows: The regression coefficient for the logarithm of the number of authorized patents is 0.00344, significant at the 1% confidence level. This implies that, under equivalent conditions, an increase in the number of authorized patents significantly promotes the growth of the new product sales rate for enterprises. The regression coefficient for the growth rate of intangible assets is 0.0034 but not significant, indicating that, during the study period, there is no significant impact of the growth of intangible assets on the current performance of high-tech enterprises. The regression coefficient for the R&D investment ratio is 0.0058, significant at the 1% confidence level. This suggests that, with other conditions unchanged, a higher R&D investment intensity leads to a higher growth rate in new product sales revenue for enterprises. Among the control variables, the regression coefficient for the logarithm of asset size is 0.018, significant at the 1% confidence level. This indicates that, in high-tech enterprises, an increase in asset size significantly enhances the new product sales rate. The regression coefficient for the government subsidy ratio is -0.0038 but not significant, indicating that the intensity of government subsidies does not significantly affect the new product sales for enterprises. The regression coefficient for the asset-liability ratio is -0.17, significant at the 1% confidence level. This means that, with other conditions unchanged, an increase in financial leverage significantly inhibits the growth of the new product sales rate for enterprises. The regression coefficient for whether the enterprise is state-owned or not is 0.0034 but not significant, suggesting no significant difference in the new product sales growth rate between state-owned and non-state-owned enterprises. The regression coefficient for enterprise age is 0.0003 and not significant, indicating that the length of time since the establishment of the enterprise does not significantly affect the new product sales rate.

In Model 2 (Table 5), the results are as follows: The regression coefficient for the logarithm of the number of authorized patents is 0.0032, significant at the 1% confidence level. This implies that, under equivalent conditions, a higher number of authorized patents significantly promotes the

Table 4. Empirical summary (dependent variable: Sronp)

Dependent variable: Sronp	coefficient	t value	standard error
lnpatent	0.00344***	[3.952]	[0.001]
Inta	0.00034	[1.166]	[0.000]
Rd	0.00575***	[4.461]	[0.001]
lnsize	0.01775***	[9.760]	[0.002]
Sub	-0.00038	[-0.128]	[0.003]
Lev	-0.17440***	[-11.790]	[0.015]
Tobinq	0.00185	[0.938]	[0.002]
Soe	0.00337	[1.497]	[0.002]
Age	0.00032	[1.261]	[0.000]
Year	Yes		
Industry	Yes		
Province	Yes		
_cons	0.03053***	[4.050]	[0.008]
R2	0.19		
F	22.55		
N	6441		

Table 5. Empirical summary (dependent variable: Roa)

Dependent variable: Roa	coefficient	t value	standard error
Inpatent2	0.00317***	[4.939]	[0.001]
Inta2	0.00022	[0.717]	[0.000]
Rd2	0.00359***	[5.290]	[0.001]
Insize	0.01876***	[18.388]	[0.001]
Sub	-0.00056	[-0.305]	[0.002]
Lev	-0.15907***	[-23.806]	[0.007]
Tobinq	0.00725***	[8.871]	[0.001]
Soe	0.00397**	[1.976]	[0.002]
Age	-0.00030*	[-1.782]	[0.000]
Year	Yes		
Industry	Yes		
Province	Yes		
_cons	0.03230***	[5.681]	[0.006]
R2	0.26916		
F	27.02929		
N	6441		

growth of the enterprise's asset return rate. The regression coefficient for the growth rate of intangible assets is 0.0022 but not significant, indicating that, during the study period, there is no significant impact of the growth of intangible assets on the asset return rate for high-tech enterprises. The regression coefficient for the R&D investment ratio is 0.0036, significant at the 1% confidence level. This suggests that, with other conditions unchanged, a higher R&D investment intensity leads to a higher total asset return rate for enterprises. Among the control variables, the regression coefficient for the logarithm of asset size is 0.019, significant at the 1% confidence level. This indicates that, in high-tech enterprises, an increase in asset size significantly enhances the total asset return rate. The regression coefficient for the government subsidy ratio is -0.0006 but not significant, indicating that the intensity of government subsidies does not significantly affect the asset return rate. The regression coefficient for the asset-liability ratio is -0.16, significant at the 1% confidence level. This means that, with other conditions unchanged, an increase in financial leverage significantly inhibits the growth of the enterprise's asset return rate. The regression coefficient for whether the enterprise is state-owned or not is 0.004, significant at the 5% confidence level, indicating that, compared to non-state-owned enterprises, state-owned enterprises have a significantly higher total asset return rate. The Tobin's Q regression coefficient is 0.007, significant at the 1% confidence level. This implies that, under equivalent conditions, overvaluation of enterprise market value significantly promotes the increase in the asset return rate. The regression coefficient for enterprise age is -0.0003, significant at the 10% confidence level. According to the 5% confidence level, the length of time since the establishment of the enterprise does not significantly affect the asset return rate.

4.5 Heterogeneity Analysis

According to enterprise attributes, the samples are divided into state-owned enterprises and private enterprises. The regression coefficient of state-owned enterprises is 0.0013, which is significant at 5% confidence level, and the regression coefficient of private enterprises is 0.0034, which is significant at 1% confidence level. Compared with state-owned enterprises, the number of authorized patents of private enterprises has a greater elasticity on the sales rate of new products of enterprises. Among the control variables, RD2, lnsize, and Tobinq all consistently show a positive effect on the new product sales rate, while sub and Lev consistently exhibit a negative impact.

Table 6. Heterogeneity Analysis (Sronp)

Dependent variable:Sronp	State-owned enterprise		private enterprise	
	coefficient	t value	coefficient	t value
lnpatent2	0.00134**	[2.551]	0.00345***	[5.576]
Inta2	0.00054	[0.850]	0.0001	[0.323]
Rd2	0.00433***	[6.964]	0.00740***	[15.859]
lnsize	0.01014***	[5.186]	0.01397***	[13.121]
Sub	-0.41232***	[-4.377]	-0.46847***	[-9.667]
Lev	-0.09441***	[-9.576]	-0.14289***	[-21.085]
Tobinq	0.00735***	[3.501]	0.00406***	[4.711]
Age	-0.00111**	[-2.891]	0.00002	[0.100]
_cons	0.03210***	[4.063]	0.03318***	[6.140]
r2	0.35954		0.30773	
F	11.15		31.23133	
N	1169		5272	

t statistics in brackets; * p<0.1, ** p<0.05, *** p<0.01

Table 7. Heterogeneity Analysis (Roa)

Dependent variable Sronp	State-owned enterprise		private enterprise	
	coefficient	t value	coefficient	t value
lnpatent2	0.00222**	[2.003]	0.00364***	[5.237]
Inta2	0.00089	[1.360]	0.00012	[0.336]
Rd2	0.00283***	[2.906]	0.00530***	[10.448]
lnsize	0.01682***	[9.090]	0.02016***	[16.313]
Sub	-0.27545***	[-3.126]	-0.36529***	[-6.826]
Lev	-0.12259***	[-9.734]	-0.16739***	[-21.285]
Tobinq	0.01096***	[6.996]	0.00619***	[6.714]
Age	-0.00095**	[-2.081]	-0.00026	[-1.347]
_cons	0.02597*	[1.804]	0.03385***	[5.540]
r2	0.36475		0.27835	
F	11.4		24.0689	
N	1169		5272	

t statistics in brackets; * p<0.1, ** p<0.05, *** p<0.01

When considering the dependent variable ROA, the regression coefficient for SOEs is 0.0022, significant at the 5% confidence level. In contrast, the regression coefficient for private enterprises is 0.0036, significantly higher at the 1% confidence level. Similar to the findings in the new product sales rate analysis, this suggests that, compared to SOEs, the impact elasticity of the number of authorized patents on the asset return rate is greater for private enterprises. Among the control variables, RD2, lnsize, and Tobinq consistently show a positive effect on the asset return rate, while sub and Lev consistently exhibit a negative impact.

4.6 Endogeneity Analysis

While technological innovation in high-tech enterprises can enhance operational performance, the improvement in operational performance may also lead to increased innovation investment. This implies the potential endogeneity issue of a reciprocal relationship between innovation and operational performance. To overcome endogeneity effects, this study uses the lagged patent variables (one period and two periods lag) as instrumental variables in the regression. The corresponding P-values from the Sargan test are 0.197 and 0.065, both exceeding 0.065, meeting the requirement for instrumental variable exogeneity.

The regression coefficients from this instrumental variable approach are close to the baseline regression coefficients, and both are significant at the 1% confidence level. This indicates that the conclusion that technological innovation significantly promotes the increase in new product sales rate and total asset return rate in high-tech enterprises has a high level of credibility..

Table 8. Endogeneity Analysis (Sronp)

Dependent variable : Sronp	coefficient	t value
lnpatent2	0.00315***	[2.984]
Inta2	-0.00029	[-0.512]
Rd2	0.00705***	[12.565]
lnsize	0.01956***	[15.896]
Sub	-0.43062***	[-7.280]
Lev	-0.14563***	[-23.430]
Tobinq	0.00674***	[8.186]
Age	0.00011	[0.513]
_cons	-0.00875	[-1.031]
r2	0.30405	
F	26.32131	
sarganP	0.197	
N	3617	

t statistics in brackets; * p<0.1, ** p<0.05, *** p<0.01

Table 9. Endogeneity Analysis (Roa)

Dependent variable : Roa	coefficient	t value
lnpatent2	0.00341***	[2.784]
Inta2	0.00002	[-0.006]
Rd2	0.00453***	[6.960]
lnsize	0.02661***	[18.644]
Sub	-0.37364***	[-5.446]
Lev	-0.18253***	[-25.317]
Tobinq	0.00884***	[9.248]
Age	-0.00016	[-0.660]
_cons	-0.004	[-0.406]
r2	0.2927	
F	24.90878	
sarganP	0.065	
N	3617	

t statistics in brackets; * p<0.1, ** p<0.05, *** p<0.01

4.7 Robust Regression Analysis

To test the robustness of the earlier regression results, this study employs a variable replacement method. There may be a time lag in the impact of corporate innovation on operational performance. By using the lagged one-period variables of both the independent and control variables as explanatory variables to replace the original ones, the regression results are obtained (see Tables 6 and 7). The direction, magnitude, and significance of the regression coefficients for the core explanatory variables are similar to the previous results. This indicates that the empirical conclusions drawn earlier are robust, providing a reliable reference.

V. Discussion and Insights

5.1 Conclusion

This study, based on the collection and analysis of relevant data on the development of high-tech enterprises from 2011 to 2019, reveals that while the number and scale of high-tech enterprises in China are continuously growing each year, their technological innovation capabilities and operational performance are also improving. However, they still face challenges such as uneven regional distribution, relatively insufficient research and development (R&D) investment intensity, low conversion rate of authorized patents, and narrow financing channels for R&D funds. The paper, combining relevant theories, outlines the influencing factors of high-tech enterprise operational performance. It then analyzes the

Table 10. Robust Regression Analysis (Dependent variable Sronp)

Dependent variable : Sronp	coefficient	t value	Standard error
L.lnpatent	0.00411***	[3.758]	[0.001]
L.Inta	0.00035	[0.642]	[0.001]
L.Rd	0.00717***	[10.176]	[0.001]
L.lnsize	0.00970***	[5.705]	[0.002]
L.Sub	0.00071	[0.127]	[0.006]
L.Lev	-0.10057***	[-11.571]	[0.009]
L.Tobinq	0.00446***	[3.661]	[0.001]
Soe	0.00800**	[2.063]	[0.004]
L.Age	0.00048*	[1.671]	[0.000]
Year	Yes		
Industry	Yes		
Province	Yes		
_cons	0.01154	[1.027]	[0.011]
R2	0.12281		
F	11.11335		
N	4904		

* p<0.1, ** p<0.05, *** p<0.01

Table 11. Robust Regression Analysis (Dependent variable Roa)

Dependent variable : Roa	coefficient	t value	Standard error
L.lnpatent	0.00351***	[4.411]	[0.001]
L.Inta	-0.00002	[-0.038]	[0.000]
L.Rd	0.00505***	[9.837]	[0.001]
L.lnsize	0.01074***	[8.683]	[0.001]
L.Sub	-0.00051	[-0.125]	[0.004]
L.Lev	-0.09690***	[-15.317]	[0.006]
L.Tobinq	0.00753***	[8.486]	[0.001]
Soe	0.00914***	[3.238]	[0.003]
L.Age	-0.00026	[-1.239]	[0.000]
Year	Yes		
Industry	Yes		
Province	Yes		
_cons	0.02590***	[3.168]	[0.008]
R2	0.18		
F	17.76		
N	4904		

* p<0.1, ** p<0.05, *** p<0.01

impact mechanism of technological innovation on the operational performance of high-tech enterprises, proposing three basic hypotheses regarding the relationship between the three influencing factors of technological innovation and operational performance.

In the empirical research, various statistical analysis methods such as descriptive statistical analysis, correlation analysis, multicollinearity test, endogeneity analysis, and robustness tests are applied to examine the impact of technological innovation on operational performance. The following conclusions and recommendations are drawn:

Firstly, the R&D investment intensity of high-tech enterprises significantly promotes operational performance. Given the current gap in R&D investment intensity between high-tech enterprises in China and innovation-driven countries, it is recommended that high-tech enterprises plan their assets wisely and increase the proportion of R&D investment appropriately.

Secondly, the number of authorized patents has a significant positive impact on operational performance. To maximize authorized patent output, high-tech enterprises should cultivate R&D personnel with patent awareness and establish award mechanisms for authorized patent output.

Thirdly, the asset-to-liability ratio has a significant inhibitory effect on operational performance. High-tech enterprises should evaluate the optimal internal asset-to-liability ratio, utilize their technological asset advantages for financing, reduce leverage financing, and optimize asset structure.

5.2 Recommendations

5.2.1 Increase the Proportion of R&D Funding

In light of the conclusion that R&D investment intensity has a significant positive impact on operational performance, it is recommended that high-tech enterprises, under reasonable asset planning, moderately and scientifically enhance the intensity of R&D investment. After determining technological innovation projects, internally, companies should increase R&D investment within a moderate range to support the normal conduct of technological innovation activities. Externally, efforts should be made to explore exclusive financing channels for technological innovation from various perspectives, such as attracting private business investment. Finally, it is crucial to ensure the scientific rationality of R&D intensity. Enterprises should conduct preliminary research and evaluation of the required R&D projects, ensuring that the investment in R&D projects is based on the characteristics and funding needs of technological innovation, realizing the highest utilization rate of R&D investment funds without affecting the smooth progress of technological innovation activities.

5.2.2 Cultivate R&D Personnel with Patent Awareness

Considering that the number of authorized patents has a significant positive impact on operational performance, it is recommended that high-tech enterprises build a team of R&D professionals with patent awareness. There is a need to strengthen the retraining of R&D personnel's patent awareness and focus on cultivating the competence of R&D personnel in this aspect. For high-tech talents with patent awareness, special attention should be given to their cultivation, making the most of their performance.

5.2.3 Establish a Reward Mechanism for Authorized Patent Output

As the empirical results show, authorized patents significantly enhance the operational performance of high-tech enterprises. To increase the number of authorized patents, internal mechanisms, such as awards or funds for authorized patent output, should be established within high-tech enterprises. This would ensure the effectiveness and initiative of technological innovation personnel and activities. Creating an incentive mechanism during the output process of innovative achievements is essential to enhance the innovation development strength of the enterprise.

5.2.4 Manage Liabilities Reasonably and Optimize Capital Structure

In the empirical analysis of the asset-to-liability ratio, it is found that an increase in the financial leverage ratio significantly inhibits the growth of new product sales rates and total asset returns for high-tech enterprises. Therefore, high-tech enterprises should evaluate the optimal internal asset-to-liability ratio, utilize their technological asset advantages for financing, reduce leverage financing, and optimize their asset structure. A reasonable level of debt is crucial for maintaining a balance between risk and profitability.

5.3 Prospects

While this study has achieved certain results, there are areas that need improvement:Comprehensive Indicator Selection: The selection of indicators in this study is limited. The technological innovation of high-tech enterprises has many influencing factors, and this study focuses on three aspects: intangible asset growth, the number of authorized patents, and R&D

investment intensity. However, factors such as corporate management level and top-level awareness also play a significant role in operational performance. Future research could explore these aspects for a more comprehensive understanding.

Data Collection of Operational Performance Indicators: The collection of operational performance indicators, including revenue and profits, may be influenced by changes in fiscal policies and accounting standards. Future research should consider the potential impact of these changes on data comparability.

In future studies, it would be beneficial to further explore the impact of various factors on the operational performance of high-tech enterprises and refine the research framework to provide more comprehensive and targeted guidance for the development of high-tech enterprises in China.

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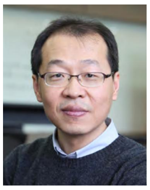

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