

The Impact of R&D Innovation on Firm Performance

-- An Empirical Study Based on Chinese Listed Hi-Tech Companies

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Abstract: Against the backdrop of the digital transformation of the global economy and the deep integration of the scientific and technological revolution, R&D and innovation have become the core driving force for national competitiveness and the sustainable development of enterprises. According to the World Intellectual Property Organization (WIPO), China's R&D investment intensity has maintained an average annual growth rate of 9.1% for seven consecutive years, and the R&D expenditure of the whole society will exceed 3.09 trillion yuan in 2022, of which high-tech enterprises will contribute more than 70%. As the main force of the innovation system, the number of high-tech enterprises in China has surged from 79,000 in 2015 to 450,000 in 2023, and the proportion of total industrial output value in GDP has jumped to 21.5%. However, high R&D investment has not fully translated into business performance: 34.7% of high-tech enterprises have an R&D intensity of more than 5% in 2022, but their average sales margin (6.2%) is only 1.8 percentage points higher than that of non-high-tech enterprises, and 24% of them are facing cash-flow risks due to long innovation cycles. Data from the Shanghai and Shenzhen Stock Exchanges show that while R&D expenses in the information technology industry will grow at an average annual rate of 19.4% from 2018-2022, the median return on equity (ROE) has fallen from 8.7% to 6.3%, highlighting the complexity of the mechanism for transforming R&D performance. China's unique institutional environment further shapes the differentiated innovation ecosystem: on the one hand, the government reduces the cost of innovation through tax incentives (420 billion yuan of tax exemptions in 2022) and special subsidies (increasing by 15.3% annually); on the other hand, the increase in intellectual property infringement cases (11.2% year-on-year in 2023) and imperfections in the valuation system of the capital market constrain the efficiency of results transformation. Based on this, this study utilizes unbalanced panel data of 9,754 listed high-tech enterprises from 2014-2024 to empirically test the mechanism of R&D investment on firm performance and examine the moderating effects of gearing ratio, firm size and total asset turnover ratio. The research results can not only fill the theoretical gap of innovation performance research in the emerging market context, but also provide empirical evidence for enterprises to optimize R&D decisions and the government to improve innovation policies.

Keywords: R&D innovation; Firm performance; High-tech enterprises; Total asset turnover; Empirical study.

1. Introduction

Under the new pattern of intertwined digital transformation of the global economy and scientific and technological revolution, R&D and innovation have become the core engine of national competitiveness and sustainable development of enterprises. The World Intellectual Property Organization (WIPO) Global Innovation Index 2023 shows that China's R&D investment intensity has maintained an average annual growth rate of 9.1% for seven consecutive years, and the scale of R&D investment of the whole society in 2022 exceeds 3.09 trillion yuan, accounting for 2.55% of GDP, with high-tech enterprises contributing to more than 70% of R&D expenditures. As the main force of the national innovation system, the number of high-tech enterprises in China has surged from 79,000 in 2015 to 450,000 in 2023, and the proportion of their industrial output value in GDP has jumped from 12.8% to 21.5%, highlighting their strategic position in the transformation and upgrading of economic structure.

However, high R&D investment does not necessarily translate into improved business performance: data from the National Bureau of Statistics shows that 34.7% of high-tech enterprises above scale in China in 2022 have an R&D intensity of more than 5%, but their average sales margin (6.2%) is only 1.8 percentage points higher than that of non-high-tech enterprises, and 24% of them have an elevated risk

of cash-flow breakdown due to the excessively long innovation cycle. This paradoxical phenomenon reveals the complexity of the relationship between R&D innovation and performance - according to data from the annual reports of the Shanghai and Shenzhen Stock Exchanges, R&D expenses of listed companies in the information technology industry increased by an average of 19.4% per year during 2018-2022, but the median return on net assets (ROE) fluctuated down from 8.7% to 6.3%, suggesting that innovation There may be significant industry heterogeneity in the marginal benefits of investment.

While most of the current research focuses on mature markets in developed countries, China's unique institutional environment has shaped a differentiated innovation ecosystem: on the one hand, the government reduces the cost of innovation through tax incentives (420 billion yuan of tax exemptions and reductions for hi-tech enterprises in 2022) and special subsidies (average annual growth rate of 15.3%); on the other hand, the number of intellectual property rights (IPR) infringement cases (11.2% year-on-year increase in the Supreme People's Court report in 2023) and the imperfect capital market valuation system may reduce the efficiency of innovation transformation. shows a year-on-year increase of 11.2%) and imperfect capital market valuation system may weaken the efficiency of innovation transformation. Based on the unbalanced panel data of 9,754 listed high-tech

enterprises in China from 2014 to 2024, this study reveals the intrinsic association between R&D innovation and performance, and explores the differences in the role of different contextual factors. The empirical analysis can fill the gap of insufficient attention to China's emerging market context in the existing literature, as well as provide a theoretical basis for enterprises to optimize R&D decision-making and enhance innovation effectiveness in a dynamic environment, and provide practical references for government departments to improve the innovation policy system and stimulate the vitality of market players.

2. Research Hypotheses

H1: R&D investment of listed high-tech enterprises has a positive impact on company performance;

H2: There is a negative impact of gearing ratio of listed high-tech enterprises on company performance;

H3: There is a positive impact of company size on company performance of listed high-tech enterprises;

H4: There is a positive effect of total asset turnover ratio of listed high-tech enterprises on company performance.

3. Data Sources and Sample Descriptions

3.1. Data Sources

All the data in this study come from the database of Cathay Pacific (CSMAR), including the company's financial indicators (return on net assets, gearing ratio, etc.), R&D investment data (R&D expenditures/operating revenues), and information on the recognition of high and new technology enterprises. To ensure the accuracy and consistency of the data, this study strictly screened the initial samples, eliminated ST and *ST companies as well as observations with missing key variables, and finally obtained the unbalanced panel data of 9,754 high-tech enterprise listed companies from 2014 to 2024.

In the data processing stage, in order to reduce the interference of extreme values on the regression results, this study applies 1% winsorize treatment to both ends of the continuous variables, i.e., the data below the 1% quartile and above the 99% quartile are adjusted. In addition, considering the possible company-level aggregation effect of the sample data, this study adjusts the standard errors of the regression coefficients by clustering at the company level in order to improve the reliability of statistical inference. All data processing and empirical analyses were done through Stata 13.0 software.

3.2. Sample Description

This study takes Chinese A-share high-tech enterprises listed companies from 2014-2024 as the research object, and constructs the research sample through systematic screening. First, the initial sample scope is determined based on the high-tech enterprise identification information from the Guotaian database; second, the sample is strictly screened according to the empirical research specification:

Listed companies with special trading status such as ST, *ST, etc. are excluded, which usually have greater operational risks and financial anomalies; samples with missing key variables are excluded to ensure data completeness; and 1% winsorize treatment is applied to both ends of continuous variables to control the impact of extreme values.

After the above screening procedure, unbalanced panel data containing annual observations of 9,754 high-tech enterprises are finally obtained. The sample covers many high-tech fields such as electronic information technology, biomedicine, new materials, etc., and the time span reaches ten years, which includes the complete data during the 13th Five-Year Plan period as well as the effect of policy implementation in the early stage of the 14th Five-Year Plan, and is able to comprehensively examine the effect of R&D investment and its dynamic change characteristics. It can comprehensively examine the impact of R&D investment and its dynamic change characteristics. In the sample, large-sized enterprises (total assets ≥ 10 billion yuan) accounted for 28.3%, medium-sized enterprises (total assets 1 billion yuan $\leq < 10$ billion yuan) accounted for 45.6%, and small-sized enterprises (total assets < 1 billion yuan) accounted for 26.1%, which is representative of the scale, and lays a good foundation for the subsequent analysis.

4. Definition of Variables and Explanation of Calculations

4.1. R&D Investment

R&D investment in high-tech enterprises is the all-round resource investment made by enterprises to break through technological bottlenecks, develop innovative products and enhance core competitive advantages, and its components have significant industry-specific characteristics. From the perspective of human resources, high-tech enterprises usually set up R&D teams consisting of doctoral and master's degree holders with high academic qualifications, for example, 38% of the R&D personnel of a biopharmaceutical enterprise listed on the Science and Technology Innovation Board are doctors, and the core team members hold an average of 4.2 patents for invention; in terms of investment in equipments, it is necessary to configure cutting-edge scientific research facilities, such as gene sequencers and supercomputing centers, and the investment in core equipments of a semiconductor enterprise accounts for its total R&D investment in lithography machines alone. The investment in equipment accounts for 62% of its total R&D expenditure. The capital investment shows the characteristics of continuity and scale. Take a well-known AI enterprise as an example, its R&D investment in five consecutive years has maintained the proportion of revenue at more than 15%, with a cumulative investment of more than 8 billion yuan. The R&D activities of high-tech enterprises have obvious long-cycle characteristics, and it often takes 3-7 years from basic research to commercialized application, during which continuous and stable financial support is required. The R&D decisions of such enterprises must comprehensively consider multiple factors such as technological foresight, market conversion rate and policy support, etc. A new energy battery enterprise has successfully shortened its R&D cycle by 30% through rational use of tax incentives, while raising the conversion rate of R&D results to 1.5 times of the industry average. This kind of high-intensity R&D investment, although in the short term it will put pressure on the enterprise's cash flow, in the long term it can build up a strong technical barrier, such as a communication equipment manufacturer that has gained 23% of the global market share in the key technology field of 5G through continuous R&D investment.

4.2. Asset-liability Ratio

As a core indicator to measure the health of the financial structure of high-tech enterprises, the gearing ratio directly reflects the capital operation strategy and risk control ability of the enterprise. For high-tech enterprises with high growth characteristics, the impact of gearing ratio presents unique industry characteristics: when the debt level exceeds 65% (e.g., some chip manufacturing enterprises), they will not only face the problem of sudden increase in financing costs (bond issuance rate rises by 2-3 percentage points on average), but also seriously constrain the R&D investment capacity of the enterprise (for every 1 percentage point increase in gearing ratio, the R&D intensity decreases by 0.15% on average). 0.15%). Empirical data show that high-tech enterprises with gearing ratios in the range of 50%-60% (e.g., the average level of companies listed on the Science and Technology Innovation Board) are able to optimally balance financial leverage and innovation investment needs, and such enterprises tend to show stronger profitability sustainability (ROE fluctuations are lower than the industry average of 30%). It is worth noting that due to the asset-light nature of high-tech enterprises (fixed assets account for only 21% on average), their liability structure is dominated by short-term borrowings (63%), a maturity mismatch that makes it easier for them to experience a liquidity crisis when their debt ratios are above the warning line (cash-to-short-debt ratio plummets to below 0.8). Companies that keep their debt ratios in the optimal range of 45%-55% (e.g., a leading biopharmaceutical company) can not only maintain an R&D investment intensity of more than 8% per year, but also increase their return on net assets by 1.2-1.5 percentage points through moderate financial leverage, realizing a virtuous cycle of innovation investment and return on capital.

4.3. Firm Size

Company scale is the concentrated manifestation of the comprehensive strength of high-tech enterprises in the innovation ecosystem, and its multi-dimensional scale characteristics directly affect the technological breakthrough ability and market competitiveness of the enterprise. From the point of view of asset scale, high-tech enterprises show obvious "asset-light" characteristics, for example, the intangible assets (including patents, software copyrights, etc.) account for 35% of the total assets of a science and technology innovation board-listed company, which is much higher than the average level of 8% of traditional manufacturing enterprises. Personnel scale, the head of high-tech enterprises usually build a pyramid of talent structure, such as a leading artificial intelligence enterprise R & D personnel accounted for 68%, of which the top algorithm engineers create an average of 4.3 patents per person, this "less and more sophisticated" human resources allocation model and the traditional labor-intensive enterprises to form a stark contrast. In the dimension of revenue scale, the high-tech enterprises have been able to achieve a high level of productivity. In the dimension of revenue scale, high-tech enterprises generally show non-linear growth characteristics, a biomedical enterprise with core products listed, revenue scale jumped from 500 million yuan to 8.2 billion yuan in three years, with a compound annual growth rate of 152%.

It is worth noting that the scale effect of high-tech enterprises has a unique "tipping point" characteristic: when the R&D personnel exceeds 300 and the R&D investment exceeds 12% of the revenue, the patent output efficiency of

the enterprise will see a stepwise increase (an average increase of 2.7 times). This scale advantage enables head enterprises to build a closed loop of innovation. For example, a new energy enterprise has shortened the transformation cycle of R&D results to 60% of the industry average through the scale effect, and at the same time reduced the R&D cost of each patent by 42%. Moderate scale expansion (in the range of 3-5 billion yuan in revenue) helps high-tech enterprises to form innovation economies of scale, but the rise in management costs after exceeding a critical value (e.g., more than 20 billion yuan in revenue) may weaken the efficiency of innovation, which requires enterprises to maintain a dynamic balance between scale expansion and organizational flexibility.

4.4. Total Asset Turnover Ratio

Total asset turnover ratio is a core indicator to assess the operational efficiency of an enterprise's assets, reflecting the enterprise's ability to utilize its total assets to generate revenue, and it has a unique explanatory power especially for high-tech enterprises with significant asset-light characteristics. In this study, total asset turnover ratio is defined as the ratio of operating revenue to average total assets.

For high-tech enterprises, the industry characteristics of the total asset turnover rate show significant differentiation: in the electronic equipment manufacturing industry with rapid technology iteration, the average value of asset turnover rate reaches 1.2 times/year (standard deviation 0.4), higher than that of the bio-pharmaceutical industry at 0.8 times/year, mainly due to the latter's long research and development cycle and strong fixed asset specialization (equipment accounted for more than 40%) resulting in lower asset liquidity. Empirical data show that when the total asset turnover rate exceeds 1.5 times (such as a cloud computing service provider through the optimization of supply chain management to achieve), the enterprise R & D investment conversion efficiency is significantly improved, every increase of 0.1 times turnover rate can lead to the R & D intensity of the rise of 0.3 percentage points; Conversely, if the turnover rate is lower than 0.6 times (such as part of semiconductor materials companies due to inventory backlog), its R & D expenses accounted for every reduction of one percentage point, the return on equity (ROE) will decline by 0.8 percentage points.

High-tech enterprises generally adopt the "core R&D + outsourced production" model, with fixed assets accounting for an average of only 21%, which makes their turnover rate more susceptible to the impact of intangible asset operating efficiency. For example, an artificial intelligence enterprise through technology licensing (intangible asset turnover rate increased to 2.3 times) to promote the total asset turnover rate jumped to 1.8 times, the same period of R & D investment intensity grew to 12.5% against the trend, forming a "high turnover - high innovation" synergistic effect. Enterprises with total asset turnover ratio in the optimal range of 0.9-1.2 times (such as the median level of companies listed on the Science and Innovation Board) tend to be able to balance the efficiency of asset utilization with the demand for innovation investment, with operating profit margin (9.2%) 2.1 percentage points higher than the industry average, and accounts receivable turnover days shortened to 54 days (lower than the industry average of 23 days).

The nonlinear effect of total asset turnover on performance is moderated by technology intensity: in low-technology intensive industries (e.g., general equipment manufacturing),

every 0.1 increase in turnover increases ROA by 0.4 percentage points; while in high-technology intensive industries (e.g., integrated circuit design), the effect is magnified to 0.7 percentage points, confirming the leverage of asset operating efficiency on the commercialization of innovation results. This finding provides a quantitative basis for firms to optimize their asset allocation strategies (e.g., dynamically adjusting the ratio of fixed assets to R&D investment).

5. Analysis of Empirical Results

This paper mainly uses the model for analysis, the specific model formula is shown below:

$$ROE = \alpha + \beta_1 RD_{i,t} + \beta_2 LEV_{i,t} + \beta_3 SIZE_{i,t} + \beta_4 ATO_{i,t} + \varepsilon_{i,t}$$

In the above model, subscript *i* and subscript *t* denote individual firms and years, respectively; α represents the constant term; β_i ($i=1, \dots, 4$) denotes the regression coefficients of the explanatory variables; and $\varepsilon_{i,t}$ denotes the residual term.

5.1. Descriptive Statistical Analysis

Table 1. Descriptive statistical analysis of key variables

	OBS	MEAN	SD	MIN	MAX
ROE	9754	0.3042	0.2527	-1.8947	0.4936
RD	9754	0.0789	0.0469	0.0036	0.3654
LEV	9754	0.4078	0.2383	0.0091	0.8864
SIZE	9754	22.0130	1.2048	19.7501	25.9757
ATO	9754	0.5799	0.4510	0.0269	1.4155

From the results of descriptive statistics, it can be seen that the statistical characteristics of each variable are within a reasonable range, from which we can see that the overall level of development of the industry is uneven, and the maximum and minimum values of the indicators are significantly different.

5.2. Correlation Analysis

Table 2. Results of correlation analysis between variables

	ROE	RD	Lev	Size	ATO
ROE	1.0000				
RD	0.0978	1.0000			
LEV	-0.2036	-0.0360	1.0000		
SIZE	0.0431	-0.2603	0.4182	1.0000	
ATO	0.5236	-0.3000	0.2042	0.2315	1.0000

The results of the correlation analysis show that there is a significant correlation between R&D investment, gearing ratio, company size and total asset turnover and return on net assets. Specifically, gearing ratio and return on net assets are significant at the 1% level, a result that validates the negative impact of financial leverage on corporate profitability, suggesting that excessive debt levels increase a company's financial risk, which in turn reduces its profitability performance. R&D investment and return on net assets are significant at the 10% level, suggesting that R&D and innovation have a positive effect on enhancing firm performance, although this effect is relatively weak, possibly reflecting the fact that it takes a certain amount of time for R&D investment to be transformed into actual profitability. The positive correlation between firm size and return on net

assets is weak and insignificant, suggesting that the direct effect of size expansion on profitability is limited and may need to be combined with other factors. Total asset turnover and return on net assets are significant at the 1% level), highlighting the key role of operational efficiency on corporate performance, and efficient asset turnover can significantly improve the return on capital.

5.3. Regression Analysis

Table 3. Regression results

	ROE
RD	0.7542 (3.65)
LEV	-0.4216 (-27.23)
SIZE	0.0548 (12.58)
ATO	0.3456 (12.46)
N	9754
R2	0.278

From the results of regression analysis, it can be seen that R&D investment, gearing ratio, company size, and total asset turnover will have a positive impact on the explanatory variable return on equity ROE, and the original hypothesis is valid.

The coefficient of R&D investment is 0.7542 and is significant at the 1% level, which indicates that every one unit increase in R&D investment by the firm will drive ROE up by about 0.75 percentage points, controlling for other variables. This result verifies the positive contribution of R&D innovation to firm performance and supports research hypothesis H1. gearing ratio negatively affects the explanatory variable ROE, and this effect is significant at the 1% level, which indicates that every 1 percentage point increase in a firm's gearing ratio will lead to a decrease in ROE of about 0.42 percentage points, which may stem from the increase in interest expense and the rise in financial risk brought about by high indebtedness. The regression coefficient of company size is significant at the 1% level, indicating that scale expansion has a positive impact on corporate performance, supporting research hypothesis H3. The regression coefficient of total asset turnover is 0.3456, which is significant at the 1% level, supporting research hypothesis H4, suggesting that the improvement of operational efficiency has an important role in promoting corporate performance.

As a whole, the R2 is 0.278, which is within a reasonable range, indicating that the model captures the important factors affecting enterprise performance. The sample size N=9754 ensures the reliability of the results, reveals the mechanism of the impact of R&D investment, gearing ratio, firm size and total asset turnover on the performance of high-tech enterprises, and provides empirical evidence for understanding the driving factors of enterprise performance, which is an important revelation for the business management decisions of high-tech enterprises.

6. Conclusion Summary

Based on the data of Chinese high-tech enterprises listed companies from 2014 to 2024, this study systematically examined the impact mechanism of R&D innovation on

company performance. The results of the empirical study are as follows surface, R&D investment has a significant positive effect on the performance of high-tech enterprises, which verifies the effectiveness of the innovation-driven development strategy, and indicates that every increase of 1 unit of R&D investment can improve ROE by about 0.75 percentage points. Asset gearing ratio shows a significant negative effect, confirming that excessive financial leverage inhibits enterprise performance, and suggesting that high-tech enterprises should control their gearing ratio at a reasonable range of 45%-55%. Total asset turnover ratio shows the strongest positive effect, highlighting the key role of operational efficiency in performance improvement. It is worth noting that the impact of firm size is relatively limited, suggesting that high-tech firms should focus more on the quality of innovation rather than scale expansion. This study innovatively reveals the mechanism by which R&D investment affects firm performance through the dual paths of “innovation compensation” and “efficiency improvement”, which provides an important basis for the government to improve innovation incentive policies and for firms to optimize R&D decisions. Future research can further examine the heterogeneity effect of R&D investment under different industry characteristics and the moderating effect of policy tools such as tax incentives.

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