Transactions on Economics, Business and Management Research
ISSN: 2960-1789, eISSN: 2960-2254 | Volume 6
FEMS 2024

The Impact of Government R&D Subsidies on the Transformation of Innovation Achievements in Enterprises

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Abstract. Based on the differences in the amount and effect of government R&D subsidies (g-R&D-s) in different regions, this study measures the transformation of innovative achievements by measuring the sales revenue of new products. Using high-tech industries in 30 provinces (regions, cities) in China from 2009 to 2021 as research samples, this study explores the impact and mechanism of g-R&D-s on the transformation of innovative achievements by enterprises, and incorporates the degree of market as a threshold into the research framework. Empirical research has found a significant U-shaped relationship between g-R&D-s and the transformation of innovative achievements in high-tech industries in China. When g-R&D-s are low, they have an inhibitory effect on the transformation of innovative achievements in enterprises. However, when the level of market exceeds the threshold of 3.7390, the inhibitory effect of g-R&D-s on the transformation of innovative achievements in high-tech industries is weakened and turns into a positive impact. It is recommended that the government increase R&D subsidies for enterprises, scientifically refine fund management, and improve the level of market in various regions to help enterprises overcome the dilemma of insufficient market.

Keywords: Government R&D Subsidies; High-tech Industries; Enterprise Innovation; Market.

1. Introduction

The 20th National Congress's report underscored the imperative of maintaining innovation at the forefront, expediting the innovation-driven strategy, and securing innovation's pivotal role in the nation's modernization efforts. It called for the improved distribution of innovation resources, a boost in self-reliant innovation capabilities, and the promotion of comprehensive integration among the innovation, industry, capital, and talent ecosystems. This approach aims to elevate the overall performance of the national innovation framework and seize the momentum of development. The high-tech sector, a confluence of knowledge, skilled personnel, and advanced technology, is pivotal for sustainable regional progress and serves as the principal executor of innovative transformation and advancement under this strategy. This industry is a critical catalyst for societal advancement and economic expansion. In recent years, the collective growth of China's high-tech sector has accelerated, entering a phase of rapid development.In 2021, the main business revenue of the high-tech industry reached 20.99 trillion yuan, a year-on-year increase of 20.20%. Among them, the sales revenue of new products in the high-tech industry reached 8.17 trillion yuan, a year-on-year increase of 19.25%

Government-provided research and development funding assistance, which encompasses monetary support and other types of aid, is designed to stimulate businesses to engage in scientific and technological innovation, thereby enhancing their technological prowess and the competitive edge of their products. This initiative aims to encourage firms to boost their own investment in innovation, elevate their technological standards, enhance product quality, and strengthen their market competitiveness. The allocation of R&D subsidies by the government to facilitate innovative projects within the high-tech sector is, to an extent, indicative of the local authorities' commitment to fostering advancements in science and technology. Such backing is crucial for the effective translation of corporate innovative achievements into tangible outcomes. The g-R&D-s for high-tech industries increased from 6.705 billion yuan in 2009 to 30.663 billion yuan in 2021.

Government research and development subsidies can compensate for the financial risks that enterprises need to bear, directly reducing the negative impact of insufficient investment in innovation and research and development. Therefore, enterprises can focus more on the research and development of innovative technologies and products, thereby improving the transformation of innovation achievements. This article uses data related to high-tech industries to comprehensively reflect the true level of innovation achievement transformation of enterprises. New product sales revenue is selected to measure the level of innovation achievement transformation of enterprises, and the impact of g-R&D-s is explored. In addition, existing literature has not considered the impact of g-R&D-s on the transformation of corporate innovation achievements, which may be influenced by factors such as government intervention, industrial structure, and economic growth. Therefore, this article takes 30 provinces and cities in the high-tech industry from 2009 to 2021 as the research object, considers the mechanism of g-R&D-s on the transformation of enterprise innovation achievements, and examines the threshold effect of marketization scale in the transformation of enterprise innovation achievements. Furthermore, heterogeneity is analyzed, and the impact process of g-R&D-s on the transformation of enterprise innovation achievements is empirically analyzed from multiple perspectives.

Scholars remain divided in their opinions regarding the influence of governmental research and development subsidies (g-R&D-s) on the commercialization of corporate innovation due to varying research approaches and analytical techniques. This paper makes the following significant contributions: (1) It employs new product sales revenue as the metric for assessing the transformation of innovation achievements in the base regression analysis. In the robustness examination, the paper initially substitutes the dependent variable and subsequently trims the sample size by omitting four municipalities directly governed by the central government. This approach prevents the potential bias in innovation achievement metrics and takes into account a broad range of regional development and human capital factors that influence the transformation of innovation achievements; (2) The study examines the threshold effect of g-R&D-s and the influence of marketization level as a moderating factor on the relationship between g-R&D-s and the transformation of innovation achievements, thereby providing a clearer understanding of the role that g-R&D-s plays in a market-oriented context; (3) While utilizing the new product sales revenue as an indicator for innovation achievement transformation, this research acknowledges the substantial disparities in innovation achievement transformation among various enterprises. It categorizes the analysis into eastern, central, and western geographic regions based on the location of high-tech industries, and differentiates between state-owned and non-state-owned sectors according to the nature of the enterprises. By conducting separate heterogeneity analyses, the paper contributes to the existing body of research on government subsidies within the realm of enterprise innovation.

2. Literature Review and Theoretical Analysis

G-R&D-s can be divided into several forms[6], such as cash, credit, taxation, and government procurement, which are included in corporate income, thereby increasing corporate profits, enabling enterprises to obtain more funds for innovative R&D activities, and accelerating the completion of existing R&D projects, increasing their own R&D expenditures. Currently, most scholars believe that government subsidies have incentive effects on corporate research and development. Huang Wendi (2022) believes that the effect of government subsidies on corporate R&D investment is positively incentivizing, but has a non-linear relationship and threshold characteristics. Research has found that the government's incentive effect is more significant when the subsidy intensity is greater than 4.30%[2]. Wang Mansi and Wang Xudong (2020) believe that g-R&D-s can help solve market failures caused by the uncertainty and high risk of innovation itself, optimize social resource allocation, provide innovative R&D resources for enterprises, enhance their innovation enthusiasm, and ensure the quality of innovation achievements[5]. Wang Xi et al. (2022) found that government subsidies can make the positive incentive effect of R&D investment on corporate performance more obvious. On the contrary, government reverse subsidies make R&D investment unable to motivate or even have a negative impact on corporate performance. They also concluded that government subsidies are positively correlated with innovation performance[4]. However, Xiong Kaijun (2023), Wu Weiwei, and Zhang Tianyi (2021) believe that there is a non-linear relationship between g-R&D-s and corporate innovation[1][3]. Mao Qilin et al. (2015) believe that g-R&D-s have a moderate range of subsidies for new product innovation in enterprises[7]. Shao Min et al. (2012) found that the relationship between g-R&D-s and enterprise productivity depends on the amount of subsidy income. When the subsidy amount exceeds a certain threshold, g-R&D-s inhibit the improvement of enterprise productivity. This indicates that g-R&D-s are helpful in improving the innovation output of enterprises within a certain "moderate range"[8]. Li Wanfu et al. (2017) and Li Xiaozhong et al. (2016) believe that g-R&D-s will squeeze out the R&D and innovation costs of enterprises. An Tongliang et al. (2009) argue that companies do not use R&D subsidies obtained from the government to expand their total R&D and innovation investment, but instead use g-R&D-s to replace their own R&D expenses, thereby creating a substitution effect, and even a reverse effect[9].

Enterprise innovation activities not only enhance the core competitiveness and sustainable operation ability of enterprises, but also are key to high-quality economic development. How should the government guide enterprises to carry out innovation activities and regulate the innovation environment? The central government will issue a series of policies to encourage enterprises to carry out innovation activities and provide support, involving economy, industry, talent, etc. With the emphasis and importance placed on innovative development by the country, the government uses innovation related policies to support and incentivize enterprises to carry out research and development of innovative achievements, which directly or indirectly affects the choice of enterprise innovation models and strategies, and thus affects the transformation of enterprise innovation achievements[10]. The government formulates specific innovation policies, regulates the market environment, and promotes enterprises to accelerate the transformation of innovation achievements through market mechanism design. Government regulation is also one of the methods by which the government regulates the quality of innovation activities in enterprises. At different stages of innovation development, the government's regulatory efforts vary, seeking the "optimal boundary" between the government and the market to better promote financial development and serve the real economy.

The R&D activities of enterprises themselves have large funding needs, long spans, high risks, and knowledge intensity. When there are market failures, funding shortages, and other problems, g-R&D-s can effectively regulate the market, fill funding gaps, and motivate enterprises to increase innovation investment. Specifically, the positive incentive effect can be divided into three aspects: One is to reduce risks. G-R&D-s can diversify the risk of enterprise R&D investment and positively affect the innovation output of enterprises; The second is policy guidance. When g-R&D-s help enterprises attract other technological cooperation and support, they also send positive signals to other investors and target customer groups, thereby attracting more investment and improving the efficiency of enterprise research and development; The third is to obtain government supervision, which can improve the quality of enterprise innovation. The negative effects of g-R&D-s on enterprise innovation can be divided into two aspects. Firstly, it leads to a decrease in actual R&D expenditure by enterprises. For example, when g-R&D-s are mainly used to increase the salaries of R&D personnel, the actual R&D investment of enterprises decreases, which is not conducive to the transformation of innovation results; The second is the lack of long-term development momentum, weakening innovation willingness, which may be due to excessive reliance on g-R&D-s, neglect of self investment, and failure to fully establish a self-sufficient R&D system, thereby limiting the innovation ability of enterprises and making it difficult for them to sustain development and keep pace with the market.

Since the initiation of economic reforms and opening up, the synergistic progress of market-oriented reforms and technological innovation in China has been instrumental in advancing a unified national market and enhancing the effectiveness with which Chinese companies transform their innovative achievements. This, in turn, is a crucial factor for achieving high-quality economic growth. There has historically been a notable disparity in the extent of marketization across various regions within China. These disparities can result in varied characteristics of g-R&D-s, leading to divergent impacts on the commercialization of corporate innovations. Typically, in regions with advanced marketization, g-R&D-s positively influence business innovation. Conversely, in areas where marketization is less developed, the influence of g-R&D-s on corporate innovation may be constrained. Amidst the ongoing push for market-oriented reforms, the question of how to further leverage the beneficial effects of g-R&D-s on corporate innovation and improve the conversion of innovation achievements through increased marketization is critical for fostering high-quality economic progress. Addressing this issue has become an urgent priority.

3. Empirical Design

3.1. Model Design

Based on the above theoretical analysis, establish the following benchmark regression model:

$$lnsales_{it} = \beta_0 + \beta_1 gov_{it} + \beta_2 gov_{it}^2 + \sum \beta_j X_{it}^j + \eta_i + \delta_t + \varepsilon_{it}$$

In the formula, $sales_{it}$ represents the amount of new product sales revenue in year t of the i-th province (region, city); gov_{it} represents the proportion of government funds in the internal R&D expenditure of enterprises in high-tech industries. At the same time, considering that g-R&D-s may have a non-linear impact on the transformation of enterprise innovation achievements, this article includes its square term gov_{it}^2 in equation; X_{it}^j represents a series of control variables; η_i represents the fixed effect of provinces; δ_t represents the fixed effect of the year; ε_{it} represents a random perturbation term; β_0 represents a constant term; β_1、 β_2 represents the coefficients of the primary and quadratic terms of the core explanatory variables, reflecting the proportion of government funds in R&D internal expenditures and the degree to which their square terms affect the sales revenue of new products; β_j represents the estimated coefficient of the control variable.

3.2. Variables and Data

3.2.1. Dependent Variable

The explanatory variable of this article is the transformation of enterprise innovation achievements in high-tech industries, mainly measured by indicators such as the number of patent applications[10][12][16] and sales revenue of new products[11][14][15]. Patent applications can to some extent characterize the level of technology investment transformation in enterprises. Compared with the number of patent applications, the sales revenue of new products characterizes the commercialization level of innovative achievements[6]. Therefore, the sales revenue of new products can more appropriately reflect the current level of innovation achievement transformation in enterprises. Referring to this article, the sales revenue of new products (in 10000 yuan) is selected as the measurement indicator for the transformation of enterprise innovation achievements. In order to enhance the comparability of the data, this article further processes the data using ln (sales) as the measurement method.

3.2.2. Core explanatory Variables

The core explanatory variable of this article is the proportion of government funds and its square term for internal R&D expenditures of enterprises. Enterprise R&D expenditures refer to the research and experimental development funds of the whole society. According to the classification in the Statistical Yearbook of High tech Industries and drawing on the research of Lu Feng et al. (2018)[13], the proportion of government R&D funds in high-tech industries is selected to measure g-R&D-s.

3.2.3. Control Variable

To eliminate the influence of other factors, the following variables were added for control treatment in this article:

Government intervention(govinter), this article uses the proportion of fiscal expenditure to GDP to measure the degree of government intervention. According to Wagner's law, as the economy grows and per capita income increases, the proportion of fiscal expenditure to GDP also increases accordingly , which has an important impact on corporate innovation[17].

The optimization of regional industrial structure(thisec), can promote the development of innovation and have a significant positive impact on the high-quality development of enterprises. This article sets the industrial structure as measured by the added value of the tertiary industry/the added value of the secondary industry.

Economic growth (eco), a favorable economic growth trend provides a suitable environment for local enterprises to innovate and transform. Therefore, it is set to measure the economic growth of the region through per capita GDP.

Financial development(finance), the higher the level of financial development, the more comparative advantages it has in producing products with high technological complexity[15], specifically measured by the ratio of the total deposit and loan balance of each province and city to GDP.

Human capital(human), the more abundant human capital is, the more obvious advantages it has in high-tech industry innovation. Human capital is often directly proportional to the complexity of export technology[16]. This article measures the number of college students per 10000 people in each province.

Trade openness(trade), considering that it is conducive to the imitation and absorption of external technologies, improving local knowledge stock and stimulating enterprise innovation, promoting the increase of export technology complexity and affecting the transformation of enterprise innovation achievements[14], is necessary to add it to the control variable and measure it by the ratio of the total import and export volume of each province to the regional GDP.

3.2.4. Data Sources

To elucidate the depth and operational mechanisms of how g-R&D-s influence the commercialization of innovation in high-tech industries, this study utilizes panel data from 30 provinces in China, spanning from 2009 to 2021 (excluding Xizang, Hong Kong, Macao, and Taiwan due to data unavailability) as its dataset. Data on the share of government funding within companies' internal R&D expenses, the sales revenue of new products in the high-tech sector, fiscal spending, regional GDP, the value added by the tertiary and secondary sectors, banking deposits and loans, the number of college students, the permanent population at year-end, and the total trade volume of imports and exports for each province are extracted from sources such as the China Macroeconomic Statistical Yearbook, China High-Tech Industry Statistical Yearbook, China Statistical Yearbook, the National Bureau of Statistics online portal, and the respective provincial (municipal, district) statistical yearbooks.

4. Empirical Result Analysis

4.1. Descriptive Statistics

Before regressing the sample data, first understand the basic distribution of the data. By using descriptive statistical methods, present the basic characteristics of the sample, including sample size, concentration trend, variation trend, etc. Perform descriptive statistical analysis on the sample data, and the analysis structure is shown in the Table 1 below:

Table 1. Descriptive statistics of data.

Variables	Sample size	Mean	Std.	Min.	Max.
sales	390	1420.755	3134.633	0.021	24591.810
lnsales	390	14.840	2.177	5.369	19.321
gover	390	0.106	0.096	0.002	0.464
govinter	390	0.244	0.101	0.096	0.643
thisec	390	1.193	0.686	0.500	5.297
finance	390	3.216	1.165	1.518	8.131
human	390	199.392	57.105	78.603	424.875
trade	390	0.271	0.304	0.008	1.548
eco	390	5.441	2.908	1.031	18.398
lneco	390	10.777	0.505	9.241	12.123
market	390	7.892	1.906	3.359	12.390

The data presented in the table above reveals that the mean new product sales revenue, which serves as an indicator of the success in transforming corporate innovation into tangible results, amounts to 14,200,000. The standard deviation of this figure is 31,300,000, highlighting the considerable variation in the effectiveness of innovation transformation across various regions. Additionally, the average share of government funding in a company's internal R&D spending, which is 0.106, suggests that, on average, high-tech enterprises receive a modest level of g-R&D-s. This implies that their innovative endeavors are not predominantly dependent on state subsidies. Furthermore, the standard deviation of 0.096 for g-R&D-s indicates a relatively uniform distribution of such funding across different areas.

4.2. Benchmark Result Analysis

Firstly, based on the fixed effects (FE) model, a multiple benchmark regression was conducted to test the impact of g-R&D-s on the transformation of corporate innovation achievements. The benchmark regression results are shown in the Table2. Column (1) represents the regression results without the addition of control variables. Subsequently, control variables such as government intervention, industrial structure, and financial development were added sequentially. The outcomes displayed in columns (2) through (7) reveal that the coefficient of first-order term for the primary effect of g-R&D-s on the transformation of corporate innovation outcomes is significantly negative at the 1% level, while the quadratic coefficient is significantly positive at the 1% level. This pattern suggests a notable "U-shaped" influence of g-R&D-s on the process of innovation transformation within enterprises.

When other controlling factors are held constant, there is an inhibiting effect on the innovation transformation of businesses at intensities of g-R&D-s below a certain threshold. Nevertheless, once this threshold is surpassed, further increments in g-R&D-s will enhance the innovation transformation of businesses.

4.3. Heterogeneity Analysis

4.3.1. Regional Heterogeneity

Taking into account the varied economic growth traits, trade openness, and human capital levels across different regions in China, it is plausible that the influence of g-R&D-s on the commercialization of corporate innovation varies as well. The study divides the sample by geographic location into eastern, central, and western regions, with the findings presented in columns (1) to (3) of the Table3. The regression analysis indicates substantial disparities in how g-R&D-s affect the innovation conversion of businesses across these regions. In the eastern and western regions, g-R&D-s significantly influence the innovation transformation of businesses in a U-shaped manner at the 1% and 10% significance levels, respectively, aligning with the trend observed in the overall sample. Nevertheless, the central region's results did not meet the criteria for statistical significance.

Table 2. Fixed effect panel model regression results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
govper	-5.278***	-5.366***	-5.752***	-5.664***	-5.508***	-5.399***	-5.223***
	(-3.58)	(-3.63)	(-4.02)	(-3.97)	(-3.77)	(-3.73)	(-3.67)
gov2	9.090**	9.436**	9.609***	9.137**	8.789**	9.018**	9.292***
	(2.48)	(2.57)	(2.71)	(2.57)	(2.43)	(2.51)	(2.64)
govinter		1.465	2.873**	4.792***	4.848***	4.446**	6.485***
		(1.07)	(2.13)	(2.61)	(2.63)	(2.43)	(3.46)
thisec			-0.944***	-0.950***	-0.921***	-0.756***	-0.543**
			(-5.08)	(-5.12)	(-4.74)	(-3.75)	(-2.64)
finance				-0.213	-0.221	-0.240*	0.055
				(-1.54)	(-1.58)	(-1.73)	(0.35)
human					0.001	-0.003	-0.005*
					(0.52)	(-0.97)	(-1.93)
trade1						1.324***	1.672***
						(2.71)	(3.43)
lneco							1.704***
							(3.81)
_cons	14.041***	13.730***	14.352***	14.535***	14.304***	14.547***	-3.882
	(92.61)	(41.91)	(42.29)	(40.49)	(24.92)	(25.27)	(-0.80)
Time effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	390	390	390	390	390	390	390
R^2	0.584	0.584	0.612	0.614	0.613	0.620	0.634

t statistics in parentheses * p<0.10, ** p<0.05, *** p<0. 01

The eastern region has formed a relatively complete government subsidy network and a complete enterprise innovation chain. At the same time, its good economic and financial development foundation and the gathering of high-quality talents have enabled g-R&D-s to play a "icing on the cake" effect in the transformation and improvement of enterprise innovation achievements in the eastern region. For the central region, a relatively low economic structure and financial development level can easily lead to low-end lock-in. The breadth of g-R&D-s and the depth of enterprise use are both lacking, resulting in government funds not being able to effectively serve as innovation subsidies. Consequently, the influence of g-R&D-s on corporate innovation is not pronounced. In the western region, where there is a lower concentration of talent and slower economic growth, the share of government funding received is more substantial compared to the eastern and central regions. This leads to a greater reliance by businesses on governmental financial support for their innovation endeavors. As a result, g-R&D-s exert a significant effect on the conversion of innovative achievements

Table 3. Heterogeneity analysis results.

	Eastern	Midland	Western	SOE	Non-SOE
govper	-5.042***	1.394	-6.140**	-1.332	-6.372***
	(-3.16)	(0.58)	(-2.23)	(-1.25)	(-4.05)
gov2	12.643***	-5.033	10.975*	1.441	13.414**
	(3.01)	(-0.78)	(1.68)	(0.78)	(2.45)
govinter	7.216***	0.364	0.565	4.580*	6.203***
	(3.50)	(0.07)	(0.14)	(1.92)	(3.57)
thisec	-0.438***	-0.531	0.273	-0.574**	-0.213
	(-2.97)	(-1.37)	(0.44)	(-2.26)	(-1.18)
finance	0.026	0.443	0.248	-0.445**	0.067
	(0.19)	(1.11)	(0.70)	(-2.38)	(0.48)
human	-0.004*	0.003	-0.014*	0.003	-0.005**
	(-1.66)	(0.51)	(-1.96)	(0.99)	(-2.00)
trade1	0.704**	6.682**	-1.372	0.347	1.890***
	(2.02)	(2.58)	(-0.74)	(0.63)	(4.73)
lneco	1.851***	2.248**	-0.299	-0.396	2.399***
	(4.05)	(2.08)	(-0.28)	(-0.73)	(6.09)
_cons	-4.298	-10.585	16.207	16.814***	-11.432***
	(-0.81)	(-0.88)	(1.45)	(2.85)	(-2.65)
N	143	104	143	351	350
R^2	0.726	0.818	0.622	0.432	0.739

t statistics in parentheses * p<0.10, ** p<0.05, *** p<0. 01

4.3.2. Heterogeneity of Enterprise Property Rights

On the other hand, the property rights of enterprises determine the governance structure, and there are differences in the degree of dependence on g-R&D-s, which affects enterprise innovation. The effectiveness of using g-R&D-s for innovation also varies. Therefore, enterprises within the region are divided into state-owned and non-state-owned enterprises, and the transformation of innovation achievements is also divided into two types of enterprises. It can be seen that g-R&D-s have a significant U-shaped impact on non-state-owned enterprises at the 1% level, while they have no significant impact on state-owned enterprises.

This indicates that state-owned enterprises are less affected by government funds in R&D expenditure. As state-owned enterprises generally have fixed R&D strategies and development plans, they have sufficient funds and also enjoy long-term effective government support. Therefore, g-R&D-s cannot significantly affect the innovative R&D activities of state-owned enterprises. There are difficulties in affecting the original business plans and innovative activities of enterprises, and they will not show a significant promoting or inhibitory effect. However, non-state-owned enterprises themselves do not receive sufficient government funding support. In the case of low g-R&D-s, innovation activities have the characteristics of large funding needs, long spans, and high risks. If the enterprise happens to receive g-R&D-s when there is a funding gap in operation, non-state-owned enterprise operators are likely to use the obtained government funds to fill the existing company's operational loopholes, ultimately leading to the crowding out of enterprise innovation project funds, the stagnation of the company's innovation activities, which is not conducive to enterprise R&D, and thus has a restraining effect on the transformation of innovation achievements. When subsidies are high, the shortage of operating funds for enterprises is alleviated, and the funds that can be invested in innovation projects are guaranteed. More attention is paid to how to improve the long-term competitive advantage of enterprises. At this time, non-state-owned enterprises can increase the g-R&D-s they receive in their innovation investment. Assist in effectively improving the transformation of innovative achievements.The heterogeneity results are shown in Table3.

4.4. Threshold Effect Analysis

This article conducted a threshold effect analysis using 300 Bootstrap sampling methods to test the scale of marketization, in order to verify whether there is a threshold effect of market on the transformation of innovative achievements in high-tech industries, and to analyze the results of the threshold effect. According to the test results of the threshold model (Table4), single threshold has significance at the 1% level, while double threshold and triple threshold have no significance.

Table 4. Self-sampling test of threshold effect.

Threshold variable	Number of thresholds	F value	P value	Critical value		
				10%	5%	1%
Market	Single threshold	59.42	0.0067	21.5385	31.3582	49.1284
	Double threshold	10.53	0.3367	20.3917	26.5711	37.4170
	Triple threshold	4.54	0.8800	21.2899	25.3834	33.7893

Based on the above results, a single threshold model is adopted to test the market effect, determine the estimated threshold value and 95% confidence interval. According to the Table5, the estimated Market threshold value within the sample interval is 3.7390, with a 95% confidence interval of [3.5380, 4.1380].

Table 5. Threshold Estimation Analysis.

Threshold Factor	Threshold Model Utilized	Threshold Value Determination	95% confidence interval	
Market	Single threshold model	3.7390	3.5380	4.1380

Based on the estimation results of the single threshold model based on market, it can be found that the scale of market has a significant single threshold effect on the innovation activities of high-tech industry enterprises. In the Table6,when the degree of market is less than or equal to 3.7390, that is, not less than or equal to the threshold value, the coefficient of g-R&D-s is -7.607, which is significant at the 1% level, indicating that in areas with low market, g-R&D-s inhibit the transformation of innovation achievements of high-tech enterprises; But when the degree of market exceeds 3.7390, which is greater than the estimated threshold value, the government R&D subsidy coefficient is 0.002 but there is no significant relationship. Therefore, it can be inferred that when the scale of market reaches a certain level, the inhibitory effect of g-R&D-s on innovation of high-tech enterprises will be weakened, indicating that in high market areas, the negative impact of g-R&D-s will be weakened. The reason for this may be that with the increase of government funding, local government investment gradually becomes irrational, leading to a lack of significant impact of g-R&D-s on the transformation of high-tech industry innovation achievements.

In summary, the level of regional market directly affects the effect of g-R&D-s on the transformation of innovative achievements in high-tech industry enterprises. At a relatively low level of market, it is unable to provide important environmental protection for innovation in high-tech industries, and government funds cannot be effectively utilized. The innovation enthusiasm of high-tech industries is suppressed, which in turn hinders the overall process of transforming innovation achievements in high-tech industries.

Table 6. Threshold regression results.

Variables	(1)
lns(Market≤3.7390)	-7.607***
	(-4.89)
lns(Market>3.7390)	0.002
	(0.00)
Controls	Yes
_cons	-9.479***
	(-2.80)
N	390
R^2	0.690

4.5. Robustness Test

To test the robustness of the regression model results mentioned earlier, the following two methods were used for further validation.

4.5.1. Replace the Dependent Variable

(1)To assess the consistency of innovation achievement transformation, the dependent variable was altered from new product sales revenue to the ratio of new product sales revenue to patent application number. This modification serves to evaluate the strength of the transformation of innovative accomplishments. The benchmark regression outcomes are presented in the Table7. Following this variable substitution, the results in column (1) demonstrate statistical significance at the 5% level, and the presence of a U-shaped pattern aligns with the findings from the primary regression analysis.

(2)To evaluate the resilience of the transformation effectiveness of innovative achievements, the dependent variable was redefined to reflect the per capita new product sales revenue within a region, calculated as the local new product sales revenue divided by the local population. This adjustment allows for a measure that accounts for regional population differences. The resulting benchmark regression data is displayed in the accompanying table. Column (2) of the regression outcomes reveals statistical significance at the 5% level. The orientation and magnitude of the principal explanatory variable coefficients are in line with the U-shaped trend observed in the primary regression. This consistency in the findings suggests that the empirical conclusions drawn in this study exhibit a degree of robustness.

4.5.2. Reduce Sample Size

Due to China's vast territory and uneven economic development levels among different regions, especially in Beijing, Tianjin, Shanghai, and Chongqing, the economic scale of the four municipalities directly under the central government far exceeds that of other cities, which may lead to differences in the role of g-R&D-s in enterprise innovation. Therefore, following the approach of Qian Haizhang[18] et al., this article excluded the regional samples of the four municipalities directly under the central government and retested the conclusions. The robustness benchmark regression results are shown in the Table7, and column (3) shows a significant U-shaped relationship between g-R&D-s and the transformation of innovative achievements in high-tech enterprises. The regression results are still valid and consistent with the main regression results.

Table 7. Robustness test results.

	(1)	(2)	(3)
govper	-8.108**	-6.631**	-5.386***
	(-2.53)	(-2.01)	(-3.43)
gov2	13.152*	14.039*	9.960***
	(1.66)	(1.72)	(2.62)
govinter	9.076**	2.835	5.782***
	(2.15)	(0.65)	(2.64)
thisec	-0.100	-2.634***	-0.512**
	(-0.22)	(-5.52)	(-2.00)
finance	-0.442	-0.729**	0.160
	(-1.25)	(-2.01)	(0.85)
human	0.001	-0.025***	-0.006**
	(0.19)	(-3.99)	(-1.98)
trade1	1.467	-7.115***	2.108***
	(1.33)	(-6.29)	(2.95)
lneco	1.040	0.933	1.405***
	(1.03)	(0.90)	(2.72)
_cons	-9.359	2.276	-1.069
	(-0.85)	(0.20)	(-0.19)
N	390	390	338
R^2	0.037	0.463	0.643

t statistics in parentheses * p<0.10, ** p<0.05, *** p<0. 01

5. Conclusion and Recommendations

5.1. Conclusion

Utilizing data from the high-tech sectors across 30 provinces in China from the years 2009 to 2021, with the exclusion of Xizang, Hong Kong, Macao, and Taiwan due to data unavailability, this study examines the influence of governmental R&D subsidies on the commercialization of innovative achievements. It further investigates the threshold effects influenced by the degree of market. By integrating a review of existing literature and theoretical framework analysis, the research employs a fixed effects model and a threshold model for the empirical assessment, leading to the derivation of the following conclusions.

Initially, a pronounced U-shaped correlation is identified between g-R&D-s and the conversion of innovation outcomes in China's high-tech industries. The robustness of this relationship is confirmed through the substitution of the dependent variable and the downsizing of the sample, with outcomes aligning with those of the fixed effects model-based benchmark regression, suggesting a dependable set of findings. Secondly, the panel threshold model indicates that the role of g-R&D-s in the transformation of innovative achievements within high-tech sectors is contingent upon the degree of regional market. A singular threshold effect is observed with respect to market levels; when the level of market is at or below the threshold, g-R&D-s exert a significant negative impact on the innovation efficiency of high-tech industries.

Once the level of market surpasses a certain threshold, g-R&D-s exert a notably positive influence on the conversion of innovative outcomes in the high-tech sector, with the previous negative impact at early stages of market being mitigated; Thirdly, considering regional and ownership distinctions, the effect of g-R&D-s on the innovation achievement transformation in China's high-tech industries displays considerable heterogeneity across the eastern, central, and western regions, as well as between state-owned and non-state-owned enterprises. In the eastern and western regions, a pronounced U-shaped relationship is observed between g-R&D-s and the transformation of innovation outcomes in high-tech industries, whereas in the central region, the impact of g-R&D-s on enterprise innovation is not significant. Non-state-owned enterprises experience a greater influence from g-R&D-s in innovation achievement transformation compared to state-owned enterprises, with the effect being more pronounced.

5.2. Recommendations

Although China's investment in innovation and research and development and the number of innovation patents have jumped to the top in the world in recent years, there is still room for progress in the transformation of innovation achievements. Based on the conclusions of this study, this article proposes policy recommendations from the following aspects:

Firstly, the government should continue to attach importance to the incentive and promotion effect of R&D subsidies on the transformation of innovative achievements in high-tech enterprises, increase capital investment, stimulate the enthusiasm of enterprises for innovation, enhance their innovation capabilities and achievement transformation. At the same time, the government needs to adhere to the core position of innovation based on the actual situation of financial development and talent resources in various regions, combined with the national strategy of innovative development, comprehensively judge the market competition level and technological innovation ability of enterprises themselves, and do a good job in strategic layout planning with a development perspective, rather than blindly subsidizing high-tech enterprises. It is necessary to guide the high-quality development of enterprises, attract relevant high-tech enterprises to enter the local area, and build high-tech industry innovation clusters.

Secondly, the government's decision-making and management of research and development subsidies need to be scientifically refined. From the previous conclusion, it can be seen that the impact of g-R&D-s on enterprises with different regions and property rights varies greatly. Based on this, scientific management and precise refinement of R&D subsidy decisions can improve the efficiency of government fund utilization. Non state-owned high-tech enterprises have a high dependence on government funds and strong innovation potential, which can effectively utilize government funding resources and maximize the investment of government subsidies in innovation activities. At the regional level, g-R&D-s have a more significant effect on the transformation of innovation achievements in enterprises in the eastern and western regions. After comprehensively examining various financial indicators of enterprises and understanding their actual needs, the government sets up corresponding supervision and assessment mechanisms for enterprise R&D innovation projects, strictly implements the use of g-R&D-s, and better leverages the advantages of enterprises in the eastern and western regions.

Thirdly, when high-tech enterprises face the problem of low regional marketization level, their innovation ability will be suppressed. The government should help enterprises overcome the dilemma of insufficient marketization level and improve the marketization level in various regions. The government should focus on substance, content, and action in cultivating and supporting innovative operations in high-tech industries. At the same time, it should strengthen guidance and support for leading enterprises and small enterprises in high-tech industries, help the market connect the production, supply, and sales of innovative achievements of enterprises, connect them, and move them to achieve the goal of improving market conditions, playing market functions, and enhancing market efficiency. When the level of marketization increases, the inhibitory effect of g-R&D-s is weakened, and government funds can better play a positive promoting role in enterprises.

Fourthly, g-R&D-s should fully play a leading role and shift from result guidance to process guidance, paying more attention to the R&D process of enterprises using government funds, and avoiding the occurrence of adverse situations such as misappropriation and indiscriminate occupation of funds. The leading role of government funds is reflected in the correct guidance and strict supervision of enterprises themselves. The government can establish a data recording platform for enterprise innovation and research and development projects, and establish a dynamic database covering high-tech industries; The second is the introduction of social capital, and g-R&D-s will serve as a social orientation. This can not only increase the enthusiasm of enterprises for their own R&D investment, improve their R&D funding system, but also encourage social capital to help enterprises develop. By combining multiple aspects and channels to increase enterprise innovation investment, we can jointly promote the transformation of enterprise innovation achievements.

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