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Research on the Impact of Research and Development Subsidies on Technological Innovation of Pharmaceutical Companies

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Abstract: Pharmaceutical enterprises' technological innovation exhibits significant externalities, and relying solely on market regulation can lead to market failure, necessitating intervention and guidance from regulatory authorities. This paper based on data from pharmaceutical companies listed on the stock market from 2009 to 2019, employs a panel fixed effects model to analyze the impact of R&D subsidies on technological innovation in pharmaceutical enterprises. The results indicate that R&D subsidies can promote the input of technological innovation in pharmaceutical enterprises, with a greater incentive effect on private enterprises than on state-owned enterprises. Therefore, regulatRoy authorities can appropriately increase subsidies for pharmaceutical enterprises and ensure that the subsidized funds are genuinely used for corporate technological research and development. At the same time, it is important to assist pharmaceutical enterprises in expanding channels for R&D funding and attract more social capital to be invested in corporate research and development. This study provides a reference basis for incentivizing technological innovation in pharmaceutical enterprises.

Keywords: Research and Development Subsidies; Pharmaceutical Companies; Technological Innovation; Heterogeneity Analysis

1. Introduction

Since 2018, China has implemented the "Healthy China Strategy," prioritizing the well-being of its populace within its developmental agendas, striving to comprehensively and persistently safeguard public health. The successful execution of this strategy necessitates the pharmaceutical industry to ensure the provision of medicine. By the close of 2024, the population of individuals in China aged 60 and above has reached 260 million, constituting 18.3% of the total populace, with 190 million individuals aged 65 and above, making up 13.5% of the total population. The aging population and the increased complexity of diseases highlight the continuous need for innovation within the pharmaceutical sector to address the public's health demands. In 2022, the cumulative investment in technological innovation by the top 10 pharmaceutical companies in China amounted to only 37.788 billion yuan, approximately 5% of the 104.32 billion US dollars globally, underlining a significant gap in technological innovation investment. Hence, it is imperative to explore methods to incentivize Chinese pharmaceutical companies to actively engage in technological innovation.

The technological innovation of pharmaceutical companies presents significant externalities. By solely depending on market regulation, these companies frequently encounter market failures in their independent innovation endeavors. Market failures can hamper innovation efficiency, resulting in problems like inadequate supply and environmental pollution. As a result, government intervention and guidance are essential for fostering technological innovation within pharmaceutical companies. Technological innovation in this sector necessitates substantial investments, long development cycles, and high risks, particularly in the realm of new drug development. This not only influences the research and development profits of pharmaceutical firms but also impacts public health and safety. Thus, government subsidies play a crucial role in supporting technological innovation within pharmaceutical companies.

Research on R&D subsidies and technological innovation predominantly considers two viewpoints. The first perspective argues that governmental support might crowd out innovation in companies [1,2]; furthermore, these subsidies may escalate the expenses of innovation elements, leading to an increase in research and development costs and thereby diminishing firms' enthusiasm for innovation and potentially compromising their competitive advantages [3]. The second perspective suggests that, from the lens of innovation risk, R&D subsidies can motivate innovation within companies given the societal benefits of corporate innovation outweighing individual gains [4,5]. Due to the imperfect intellectual property protection systems, there is a risk of replication in corporate innovation outcomes, thus subsidies can help reduce uncertainty in these returns [6]. Therefore, this study will focus on whether R&D subsidies can, to a certain extent, drive technological innovation and progress in pharmaceutical companies or only offer interim relief from their financial constraints. Specifically based on data from public pharmaceutical companies in the industry from 2009 to 2019, this paper empirically assesses the impact of R&D subsidies on fostering technological innovation within the pharmaceutical sector.

2. Theoretical Analysis

2.1 R&D Subsidies and Enterprise Technological Innovation Investment

Independent research and innovation activities often entail significant risks, demanding substantial financial and human resources from companies. Over investing in research activities may impede the seamless operation of current business functions. R&D subsidies can mitigate the risks and costs associated with technological innovation, thereby fostering research and innovation endeavors. According to Lach [7], R&D subsidies play a role in reducing companies' technological innovation costs. In their research on industrial enterprises, Zou et al. [8] discovered that R&D subsidies for technological innovation positively influence companies' investments in innovation. Building upon the aforementioned analysis, this paper posits the following hypothesis:

H1: R&D subsidies positively impact the technological innovation investments of pharmaceutical companies.

2.2 R&D Subsidies Exhibit Varying Effects on the Stimulation of Technological Innovation across Enterprises of Different Natures

State-owned enterprises, with a lengthy establishment history, benefited from relatively lenient standards for new drug research and registration reviews in China's early years, enabling them to amass numerous new drugs and market share [9]. Consequently, their profitability stands relatively strong, but this may hamper innovation drive within these enterprises. Conversely, private enterprises, with a shorter history and weaker accumulation, heavily rely on innovation to compete and meet new market demands for increased profits, resulting in a heightened innovation momentum [10]. Thus, based on this analysis, the paper puts forward Hypothesis 2: H2: The stimulating impact of R&D subsidies on the technological innovation investments of private pharmaceutical enterprises surpasses that of state-owned counterparts.

3. Research Design

3.1Data Source and Processing

To ensure the adequacy, effectiveness, accessibility, and accuracy of the sample, the study commences in 2009 as the starting point. Accordingly, this research selects A-share pharmaceutical companies from the period 2009 to 2019 as the study sample, with data predominantly sourced from the WIND database. The collected data was organized based on securities codes, leading to the exclusion of companies designated as ST, *ST, those delisted prematurely, and those with less than a 5-year listing history. In order to make the analysis results more accurate and effective and prevent extreme values from affecting the empirical effect, all the variables were reduced, excluding the first 1% of the sample and 99% of the sample. Using STATA 15.0 econometric software and relying on unbalanced enterprise panel data, the study analyzed the effect of R&D subsidies on technological innovation within pharmaceutical firms.

3.2Variable Setting

This study examines the influence of R&D subsidies on technological innovation investment in the pharmaceutical industry, specifically focusing on their impact on the technological innovation capabilities of enterprises. The study defines technological innovation investment ($RD1_{it}$) and technological innovation investment intensity ($RD2_{it}$) as dependent variables, measured by the ratio of technological innovation investment to main business income. The explanatory variables include R&D subsidies ($GROVE1_{it}$) and government subsidy intensity ($GROVE2_{it}$) represented as a proportion of main business income. Considering the various factors affecting technological innovation investment in enterprises, neglecting control variables could introduce omitted variable bias, leading to inconsistent and biased estimation results. Thus, the study incorporates relevant control variables to improve the robustness of the analysis.

In the context of control variables, the asset-liability ratio (LEV_{it}) of the enterprise reflects the operational capacity of the company. Larger companies with significant capital and comparative advantages in technological innovation investment are represented by total assets ($SIZE_{it}$) to denote their size in this study. The return on assets (ROA_{it}) is utilized as a measure of company profitability. Furthermore, the age at which a company has been listed is considered as it can signal the company's ability and pace of continual growth, thus the control variable of listing age (AGE_{it}) is incorporated. Detailed definitions and computation methods for these variables are outlined in Table 1.

Table 1. Meanings and Calculations of Variables

Variable Name	Symbol	Calculation Method
Technological innovation investment	$RD1_{it}$	Logarithm of corporate R&D expenditure
R&D subsidies	$GROVE1_{it}$	R&D subsidies count
Intensity of investment in technological innovation	$RD2_{it}$	Research and Development Investment / Main Business Revenue
Government subsidy intensity	$GROVE2_{it}$	R&D subsidies / Main business revenue
Debt-to-asset ratio	LEV_{it}	Total Liabilities / Total Assets
Company size	$SIZE_{it}$	Total Assets Logarithm
Return on Total Assets	ROA_{it}	(Profit Total + Interest Expense) / Average Total Assets × 100%
Listing age	AGE_{it}	2019 - Year of release

3.3 Model Setting

To ensure the effectiveness and accuracy of the estimation results, this study controls for the asset-liability ratio, enterprise scale, earnings per share, listing age, and management shareholding ratio of the company to mitigate the impact of omitted variables on the estimation results. The model reflecting the impact of R&D subsidies on technological innovation investment of enterprises is represented as Model (1), while the model for the impact of government subsidy intensity on the intensity of technological innovation investment of enterprises is represented as Model (2). The specific models are as follows:

$$RD1_{it} = \beta_0 + \beta_1 GROVE1_{it} + \beta_2 LEV_{it} + \beta_3 SIZE_{it} + \beta_4 ROA_{it} + \beta_5 AGE_{it} + \varepsilon_{it} \quad (1)$$

$$RD2_{it} = \beta_0 + \beta_1 GROVE2_{it} + \beta_2 LEV_{it} + \beta_3 SIZE_{it} + \beta_4 ROA_{it} + \beta_5 AGE_{it} + \varepsilon_{it} \quad (2)$$

In this context, $RD1_{it}$ represents the technological innovation investment of the enterprise, and $GROVE1_{it}$ represents R&D subsidies; $RD2_{it}$ represents the intensity of technological innovation investment of the enterprise, and $GROVE2_{it}$ represents the intensity of R&D subsidies. The coefficient β_1 measures the impact of government subsidy intensity on the intensity of technological innovation investment of enterprises, which is the core explanatory variable of this study. Other variables are control variables, including the asset-liability ratio of the enterprise, company size, return on total assets, and listing age.

3.4 Descriptive Statistics of Variables

Table 2 presents the number of observations, means, residuals, minimum, and maximum values of each variable for different ownership entities, including state-owned and private enterprises. Private enterprises have a mean total technological innovation investment of 17.53, slightly below the 17.79 mean for state-owned enterprises. In terms of technological innovation investment intensity, private enterprises show a mean of 2.23, considerably higher than the 0.03 mean for state-owned enterprises, highlighting the strong focus of

private pharmaceutical companies on technological innovation. While the standard deviation of overall technological innovation investment indicates insignificant differences in total amounts, the standard deviation of technological innovation intensity reveals greater variability in private enterprises compared to state-owned ones. Regarding R&D subsidies, the mean for private enterprises is 15.97, slightly less than 16.26 for state-owned enterprises. In terms of subsidy intensity, although state-owned enterprises receive larger subsidies, the subsidy intensity for private enterprises is significantly higher at 0.17 compared to 0.01 for state-owned enterprises. This suggests that R&D subsidies are relatively less effective in stimulating innovation and research investments in private enterprises compared to their state-owned counterparts.

Table 2. Descriptive Statistics Analysis of Variables

Variables	Private Enterprises					State-Owned Enterprises				
	Observations	Mean	Residual	Minimum	Maximum	Observations	Mean	Residual	Minimum	Maximum
rd1	1381	17.53	1.20	14.22	20.53	417	17.79	1.24	14.22	20.53
grove1	1381	15.97	1.35	11.83	19.00	417	16.26	1.45	11.83	19.00
rd2	1381	2.23	31.65	0.00	909.30	417	0.03	0.02	0.00	0.15
grove2	1381	0.17	2.23	0.00	51.87	417	0.01	0.02	0.00	0.38
size	1381	21.31	1.11	19.10	24.04	417	22.04	0.99	19.21	24.04
lev	1381	29.07	16.83	3.36	82.81	417	37.22	19.30	3.36	82.81
roa	1381	11.66	13.47	-147.23	99.90	417	9.49	7.12	-26.80	39.90
age	1381	16.43	5.87	2.00	42.00	417	18.99	5.94	9.00	40.00

4. Empirical Testing and Results

Analysis In this research, a linear regression analysis utilizing the econometric software STATA 15.0 was conducted with technological innovation investment as the dependent variable and R&D subsidies as the independent variable. Prior to model analysis, a Hausman test was carried out, revealing an F-statistic of 178.13 with a probability of 0.000, meeting the 1% significance level criterion. As a result, a fixed effects model was chosen for empirical testing. Initially, a panel fixed effects model was established using data from publicly traded pharmaceutical companies spanning from 2009 to 2019 to assess the influence of R&D subsidies on technological innovation in the pharmaceutical sector. The outcomes are presented in Table 3, where Model (1) examines the impact of R&D subsidies on enterprises' technological innovation investment, while Model (2) explores the effect of government subsidy intensity on the intensity of technological innovation investment in enterprises.

Table 3. The Impact of Government Subsidy Intensity on the Innovation Capability of High-Tech Industries

	Model (1)	Model (2)
GROVE	0.054*** (3.78)	10.945*** (40.42)
SIZE	0.405*** (12.55)	-0.395 (-0.44)
lev	0.002*** (2.16)	-0.012 (-0.39)
roa	0.009*** (6.40)	-0.3047*** (-7.39)
age	0.152*** (23.43)	-0.147 (-0.76)
_cons	5.205*** (9.09)	14.975 (0.87)
N	1789	1789
F	793.23***	350.01***
R2	0.2397	0.608

Note: Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

From Model (1) in Table 3, it can be observed that government subsidies significantly promote R&D investment in pharmaceutical companies. With each unit increase in average government subsidies, the average technological innovation investment of companies rises by 0.054 units, passing the 1% significance level test. In Model (2), it is evident that the intensity of government subsidies significantly stimulates the intensity

of technological innovation investment in the pharmaceutical industry. For every 1% increase in average government subsidy intensity, the average intensity of technological innovation investment by companies increases by 10.95%, passing the 1% significance level test. This indicates that government subsidies reduce the innovation risk for companies. Companies utilize government subsidies to boost technological innovation investment, inducing a "crowding-in effect" on innovation. Effective innovation enhances a company's social competitiveness, and government subsidies can boost the proactive nature of technological innovation in companies, playing a positive regulatory role in fostering innovation.

Table 4. The Impact of Government Subsidy Intensity on Technological Innovation in State-Owned and Private Pharmaceutical Companies

Variables	(1) State-Owned Companies RD1	(2) Private Pharmaceutical Companies RD1
GROVE1	-0.016 (-0.55)	0.084*** (4.84)
SIZE	0.515*** (5.61)	0.481*** (12.65)
lev	0.003 (1.12)	0.004*** (3.56)
roa	0.023*** (4.89)	0.007*** (4.91)
age	0.166*** (11.92)	0.118*** (13.55)
_cons	3.238834* (1.91)	3.784*** (5.64)
N	417	1381
F	204.87***	553.50***
R^2	0.2867	0.3391

Note: Standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01.

The descriptive statistics in Table 2 allow for a preliminary assessment of the impact of R&D subsidies on the technological innovation investment of private and state-owned enterprises, showing differences not only in total amounts but also in relative values. The empirical results in Table 4 present the effects of R&D subsidies on innovation in state-owned and private enterprises. From Model (1) in Table 4, it is evident that R&D subsidies significantly promote the technological investment intensity of private enterprises, exhibiting a positive regulatory effect. For each unit increase in R&D subsidies, there is a 0.084 increase in stimulating technological innovation investment by the government, a value significantly higher than the national sample result (0.054), passing the 1% significance level test. However, the impact of R&D subsidies on promoting technological innovation in state-owned pharmaceutical companies is not clear, with a negative coefficient that does not pass the significance test. It can be seen that R&D subsidies have a relatively significant promoting effect on technological innovation in private enterprises, validating hypothesis 2 of this study.

5. Conclusion and Countermeasures

5.1 Main Findings

This study focuses on publicly-listed pharmaceutical companies and explores the impact of R&D subsidies on research and development (R&D) investments using unbalanced micro-panel data spanning from 2009 to 2019. The results reveal a substantial promotional influence of R&D subsidies on the technological innovation investments of companies. Regarding company ownership, R&D subsidies tend to result in lower levels of R&D investments in private enterprises compared to state-owned enterprises. However, the amplifying effect of R&D subsidies on private enterprises is more pronounced. Against the backdrop of the economic "new normal" and the challenges posed by the "middle-income trap," changes in market dynamics and resource allocation have become evident. Thus, there is a necessity for the government to bolster R&D policy incentives, while companies are urged to prioritize innovative R&D endeavors.

5.2 Countermeasures

Based on the conclusions of empirical research, the following suggestions are put forward to promote technological innovation activities in China's pharmaceutical enterprises and enhance the quality of pharmaceutical industry development.

First, the government should increase subsidies for new product research in pharmaceutical enterprises. By enhancing the intensity of subsidies for product innovation activities, the government can leverage its "guiding role" to encourage pharmaceutical companies to intensify their research and development efforts. It is recommended that the government increase funding for basic research and applications within these enterprises. This should focus on technological innovation, with particular emphasis on strengthening guidance in key areas of new drug research and critical technologies. The goal is to maximize the leverage effect of R&D subsidies, reduce the proportion of non-R&D subsidies, and ensure that these subsidies truly incentivize pharmaceutical enterprises to innovate new products.

Secondly, governments ought to scientifically devise a variety of subsidy schemes to enhance the efficacy of fund utilization. In devising these subsidy methodologies, it is imperative for governments to integrate both pre- and post-incentive mechanisms, tailoring policies that cater to the specific requirements of enterprises. For pharmaceutical enterprises, the clinical trial and new drug application phases necessitate substantial research and development funding. By offering targeted subsidies, governments can effectively incentivize product innovation within these companies, thereby augmenting the overall innovation performance of the industry. Furthermore, governments should underscore the pivotal role of subsidies in fostering technological innovation. This necessitates further innovation in subsidy methodologies, including the enhancement of research and development grants, project funding matching, and loan interest subsidies, to elevate the overall effectiveness of R&D subsidies.

Thirdly, the government should strengthen the supervision mechanism for R&D subsidies. Increasing the intensity of supervision will enhance the incentive efficiency of these subsidies. Government R&D subsidies play a crucial role in promoting the development of high-tech industries. To standardize the use of subsidy funds and ensure that they achieve their intended purpose, it is essential to enhance the supervision and management of subsidy usage. Implementing transparent management and external oversight can effectively reduce the misuse and misappropriation of funds. Establishing a transparent government subsidy management platform is also vital. Furthermore, government departments must promptly identify and terminate subsidies for any non-compliant or abnormal behaviors in the use of corporate funds, and investigate and hold the relevant units and enterprises accountable.

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