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The Impact of Government R&D Subsidies on Enterprise Technology Innovation

—Based on Evidence from Chinese Listed Companies

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Abstract

This paper selects the data of non-financial listed companies in Shanghai Stock Exchange and Shenzhen Stock Exchange from 2007 to 2015, and studies the impact of government R&D subsidies on technological innovation of enterprises, then draws the following main conclusions: First, appropriate government subsidies can indeed promote enterprises' technological innovation investment and output, but excessive government subsidies may have the opposite effect; second, there is a considerable amount of waste of resources in state-owned enterprises, and the problems of local state-owned enterprises are more complicated; the information asymmetry between the government and private enterprises may lead to serious "seeking support" behaviors in the process of applying for government subsidies. Based on this, this paper gives the following two policy recommendations: First, accelerate the governance reform of state-owned enterprises, especially for local state-owned enterprises, it is necessary to strictly control the process, to achieve the refinement of indicators, not only to see the results without looking at efficiency; second, efforts should be made to improve the relationship between private enterprises and the government, weaken the information asymmetry between each other, and ensure the effective allocation of resources.

Keywords

Government Subsidies, Technological Innovation, Innovation Efficiency, State-Owned Enterprises, Private Enterprises

1. Introduction

On April 16, 2018, under the background of Sino-US trade friction, the US Department of Commerce ordered the US company to ban the export of telecom-

munications components to ZTE, which is commonly known as the "chip door" incident, which caused an uproar at home and abroad. After expressing dissatisfaction with the United States deliberately provoked a trade war, everyone was uneasy to find that China has a lot of gaps with many developed countries in the high-end R&D market, especially the chip market.

As an important component of economic growth [1] [2], technological innovation has long been the consensus of all countries, but the obvious positive externalities and uncertainties of technological innovation have largely hindered technological innovation. The activity was carried out, but this could be compensated by government subsidies [3] [4]. In view of this theory, many countries have introduced government subsidy policies; they are striving to promote technological innovation. Back in the 1990s, China began to focus on innovation. From the "Decision of the CPC Central Committee and the State Council on Strengthening Technological Innovation, Developing High Technology, and Realizing Industrialization" issued in 1999, to the "National Innovation Driven Development Strategy Outline" and the "13th Five-Year National Science and Technology Innovation Plan" released in 2016, China have successively launched a series of innovative incentive policies, and invested a large amount of funds to subsidize innovation activities, taking 2013, 2014 and 2015 as examples, Chinese national financial technology grants were 618.49 billion, 645.45 billion and 700.58 billion respectively, correspondingly accounting for 4.41%, 4.25% and 3.98% of the public finance expenditure. With the continuous introduction of Chinese innovation incentive policies, Chinese technological innovation activities have indeed developed. From 2007 to 2015, Chinese R&D internal expenditures increased from 371.04 billion to 141.918 billion, accounting for 1.37% GDP corresponding increased to 2.07%. In terms of innovation output, the number of patent applications received at home and abroad increased from 693,917 to 2,798,500, which is a threefold increase. From these data, Chinese innovation policy has indeed achieved the expected results, but with the "chip door" happening, everyone has re-recognized that Chinese technological innovation is still far from enough, and questioned the effect of government subsidies invested over the years.

In Chinese current technological innovation, enterprises are the absolute main force. In 2015, the company invested a total of 10,881.35 billion in R&D expenditure, accounting for 76.8% of the national R&D expenditure. Therefore, studying the impact of government subsidies on technological innovation of enterprises has great significance. However, an overview of the existing research results, the academic community has not reached a consensus conclusion on this issue. Regarding the relationship between government subsidies and technological innovation, David proposed a theoretical analysis framework in 2000, pointing out that enterprises need to balance the marginal return (MRR) and the marginal cost (MCC) when making decision of innovation researches to ensure that they can get positive return through R&D activities. So the relationship between government subsidies and corporate R&D activities is uncertain. If the

original R&D activities of the company are lower than the optimal investment scale, then government subsidies can promote R&D, however, if the company is already above the optimal investment scale, then subsidizing the government at this time may be counterproductive [5]. This kind of uncertainty is also reflected in the empirical evidence. In the study of German enterprises, Czarnitzki and Fier draw a conclusion that government subsidies have a significant role in promoting R&D output of enterprises [6]. After studying the panel data of 32 industries in Shanghai as a sample, Pingfang Zhu believed that Chinese government subsidies and tax reductions can promote the innovation investment and output of enterprises [7]. Yang Yang conducted an empirical study on the data of Chinese industrial enterprises, taking the output value of new products as the proxy variable of enterprise innovation output, concluded that Chinese government subsidies have a positive effect on the innovation output of enterprises [8]. However, Gonzalez and Pazl used the PSM method to study 2214 companies in Spain and found that government subsidies have a significant squeeze on the company's R&D investment [9]. There is other scholars believe that the impact of government subsidies on corporate innovation is not a simple linear relationship. Dominique and Bruno used empirical data from 17 OECD countries to show that the relation curve of government subsidies and R&D investment of enterprises presented inverted U-shaped, that is, before the critical point, government subsidies will promote the company's own R&D investment, but after exceeding a certain interval, government subsidies will inhibit the company's R&D investment [10]. Qilin Mao used PSM-based multiple difference method and survival analysis method to study the impact of government subsidies on enterprise innovation output, and believed that only moderate subsidies can significantly stimulate enterprise innovation, and it was found that the inhibition of high subsidies was partly due to the "seeking subsidy" behavior of enterprises in further research [11]. Zhouyu Lin used the Tobit model to study the Chinese industrial enterprises, also found that there is an inverted U-shaped relationship between government subsidies and enterprise innovation, and this effect is different according to the nature, scale and industry of the enterprise. In addition, for different innovation agent indicators such as R&D investment and R&D output, government subsidies may also have different effects [12]. Jun Wang found that Chinese government subsidies can effectively promote R&D investment. However, the promotion of R&D output is not obvious [13]. Bing Guo also obtained the same conclusion after using the data of enterprises in Shanghai. Different from them [14], Xiaodan Guo takes Chinese strategic emerging industries as a sample, and finds that Chinese government subsidies have not significantly promoted the R&D investment of enterprises, but it has obviously promoted the R&D output of enterprises [15]. At the same time, in the study of Chinese enterprises, one topic that cannot be avoided is the low efficiency of state-owned enterprises [8] [16]. Because of the multiple reasons such as principal-agent problem and political promotion, the innovation efficiency of

state-owned enterprises seems to be lower than private enterprises, but there are also non-productive business activities such as "seeking support" existing in private enterprises [17]. Therefore, for the innovation efficiency of state-owned enterprises and private enterprises, further research is needed. In summary, the existing papers on the effect of government subsidies on corporate innovation activities have not drawn a unified conclusion. Generally speaking, only from a certain angle or a certain type of company, there is a lack of comprehensive analysis. So in order to have a more detailed study, this paper combines the three aspects of enterprises' innovation activities which contain the output, investment and efficiency, and divide the companies into three types which are central state-owned enterprises, local state-owned enterprises and private enterprises respectively, trying to compare different effect of government subsidies acting on different enterprise and different aspects of innovation, and draw a more profound conclusion than before.

2. Research Hypothesis

2.1. The Impact of Government Subsidies on the Innovation of Local State-Owned Enterprises

In order to promote the development of science and technology innovation in China and ensure the smooth realization of the goal of building a well-off society in an all-round way, China promulgated the "National Long-term Science and Technology Development Plan (2006-2020)" in 2006, which set the significant enhancement of the ability of independent innovation as the overall goal of Chinese science and technology development. Later, in 2010, the National Patent Development Strategy (2011-2020) was promulgated, and it was clearly stated that by 2015, the number of applications for various patents would reach 2 million, and the patent application rate of industrial enterprises above designated size would reach 8%; by 2020, the ratio of patent applications for industrial enterprises above designated size will reach 10%. Under the patent quantification target, the local government decentralized the patent application volume as the annual government task, and the patent application volume became an important indicator of the assessment. Among them, the local state-owned enterprises directly controlled by the local government are the main force of this task [18]. In order to promote the increase in the number of patent applications and complete political tasks, local governments have actively formulated relevant policies, such as government subsidies, in order to strive for scarce resources in constant flow to invest in innovation [19]. On the one hand, government subsidies can open up technological opportunities for companies' research and development activities by compensating for the high risks and externalities accompanying corporate innovation activities, and improve corporate R&D by increasing expected returns or reducing the cost of R&D and risks faced by enterprises balanced investment [10] [20]. On the other hand, government subsidies can not only make up for the lack of income, cost and capital shortages faced by enter-

prises, but also have other influences, which cause enterprises to generate additional behaviors [15]. For local state-owned enterprises, the government subsidies issued by local governments in order to promote the number of patent applications are not only a kind of subsidy, but also the significance of political tasks, which in turn requires local state-owned enterprises to increase innovation output.

However, promoting innovation isn't the only task for local governments. The Chinese economy has maintained rapid growth for nearly 40 years since the reform and opening up. It is called the "growth miracle". This miracle is inextricably linked to the "promotional championship" of Chinese local government officials. In order to achieve promotion, local government officials Very keen on the ranking of GDP and related economic indicators [21]. Due to its uncertainty, long-term nature and slow to achieve short-term economic growth, innovative projects are not so favored by local governments in political considerations, and their priorities are far less than those of high-yield and effective investment projects such as transportation, communications and other infrastructure which even led to a large number of repeated construction and over-investment in China's high-speed economic growth [22] [23] [24]. In this process, the main force for completing local government tasks is still local state-owned enterprises. At the micro level, there is a large amount of literature that proves that local intervention will lead to excessive investment by local state-owned enterprises [25] [26]. This trend became more apparent after the financial crisis, leading to a sharp expansion of China's local debt. As the main body of debt for local debt, local state-owned enterprises bear a large amount of financial burden [27]. In this "promotional tournament", local state-owned enterprises invested a large amount of money in projects and projects that only pursue surface economic indicators. For other investment activities and projects, such as innovation activities, local state-owned enterprises have no funds to invest [28]. Even if government subsidies can stimulate an increase in R&D investment, it may not bring a big increase. In order to complete the established political tasks and increase the output of innovation, local SOEs should seek other means to increase the efficiency of R&D. Based on the above analysis; this paper proposes the following hypothesis:

Hypothesis 1a: government subsidies are positively related to innovation output of Local State-owned Enterprises.

Hypothesis 1b: government subsidies are positively related to innovation investment of Local State-owned Enterprises.

Hypothesis 1c: government subsidies are positively related to innovation efficiency of Local State-owned Enterprises.

2.2. The Impact of Government Subsidies on the Innovation of Central State-Owned Enterprises

In order to effectively guide the central SOEs to improve quality and efficiency, the State-owned Assets Supervision and Administration Commission promul-

gated the Interim Measures for the Evaluation of the Performance of Central Enterprise Leaders in 2003. This method was revised four times in 2006, 2009, 2012 and 2016 respectively. In addition to the consideration of the economic indicators of the central state-owned enterprises during the annual and term of office, there are corresponding requirements for research and development activities. Starting from the first revision in 2006, it emphasizes the importance of considering the innovation input and output of central state-owned enterprises, and identifies specific indicators and their weight of investigation in the letter of responsibility. Later, in the second revision in 2009, the economic value added was included in the basic indicators of the annual performance appraisal, considering that the value-added effect of the enterprise's innovation input could not be achieved in the short term. In the latest revision of 2016, the importance of innovation and development is repeatedly emphasized in Articles 5 and 8 [18]. Like local governments, in order to promote the innovation activities of central SOEs, the SASAC will also provide corresponding policy subsidies to encourage central SOEs to increase R&D investment and increase R&D output. On the one hand, these government subsidies alleviate the difficulties encountered by enterprises in innovation activities and increase their willingness to innovate. At the same time, they also require central SOEs to increase R&D investment and R&D output.

As mentioned above, local government officials are keen on "promotion of the tournament" and may improperly intervene in state-owned enterprises. Unlike local state-owned enterprises, although central state-owned enterprises may be within the jurisdiction of local governments, central state-owned enterprises are not directly controlled by the local government, but are managed by the State-owned Assets Supervision and Administration Commission, and the central state-owned enterprises themselves are subject to stricter supervision, which makes it difficult for local governments to directly intervene in central state-owned enterprises [26]. Because it does not assume the political task of stimulating the economy and maintaining economic indicators that local governments urgently need, the central state-owned enterprises have sufficient funds to invest. For those innovative projects with high returns and low risks, they may already use their own funds to carry out, and those projects that receive government subsidies are often highly uncertain and difficult to develop. At the same time, although the State-owned Assets Supervision and Administration Commission considered the innovation investment and innovation output of the central state-owned enterprises in the assessment method, because the differences between the research and development projects are huge, there is no comparability, and the innovation efficiency is not an easy-to-quantitative indicator. Government subsidies are a kind of redistribution of resources by government agencies on behalf of all the people. State-owned enterprises are operated by operators selected by government agencies. The separation of the two rights of ownership and management rights has led to a principal-agent relationship between all people and government agencies and state-owned enter-

prise executives. This kind of principal-agent problem plus the inefficiency of innovation efficiency makes it impossible for state-owned enterprises to be properly used for R&D and innovation as expected by the client after receiving government subsidies. There may be a certain amount of waste [29]. Based on the above analysis, this paper proposes the following hypothesis:

Hypothesis 2a: government subsidies are positively related to innovation output of central state-owned enterprises.

Hypothesis 2b: government subsidies are positively related to innovation investment of central state-owned enterprises.

Hypothesis 2c: government subsidies are negatively related to innovation efficiency of central state-owned enterprises.

2.3. The Impact of Government Subsidies on the Innovation of Private Enterprises

Government subsidies are an important part of fiscal expenditure. They are the free transfer of funds directly or indirectly provided to microeconomic entities according to the specific goal and the political, economic, policies during a certain period of time [30]. In particular, direct government subsidies are highly desirable and selective because they are issued after approval by the regulatory authorities [5]. These goals are often based on improving business efficiency or social benefits, including encouraging technological innovation, technological advancement, and job creation and taxation. However, there is information asymmetry in the process of the government's decision to grant subsidies to the enterprises. The government does not fully understand the production technology, product market, development potential and profitability of the private enterprises [31].

Compared with state-owned enterprises, private enterprises do not have natural political ties, and the degree of information asymmetry with the government is also greater. In order to obtain government subsidies, private enterprises need to carry out some research and development activities in advance to show their own research and development capabilities, and release innovative signals. After that, the government may give corresponding subsidies [32]. After receiving government subsidies, private companies will increase R&D investment to continue the remaining R&D activities. But if it does not succeed in obtaining government subsidies, based on the considering of cost and reward [5], companies will likely abandon the project without any innovative output.

In addition, although this information asymmetry can be partially attenuated by private enterprises transmitting their own innovation signals, such information asymmetry can easily lead to adverse selection and "seeking subsidy" behavior [17] [33], made private enterprises not all invested in research and development activities after receiving government subsidies, but partially used for other purposes, reducing the efficiency of research and development, and not fully meeting the government subsidy policy. Based on the above analysis, this paper proposes the following hypothesis:

Hypothesis 3a: government subsidies are positively related to innovation output of private enterprises.

Hypothesis 3b: government subsidies are positively related to innovation investment of private enterprises.

Hypothesis 3c: government subsidies are negatively related to innovation efficiency of private enterprises.

3. Research Design

3.1. Samples and Data

This paper selects the 2007-2015 Shanghai Stock Exchange and Shenzhen Stock Exchange listed companies as a research sample, deletes financial companies, companies with asset-liability ratios greater than 1, and companies which explanatory variables or explained variables are missing. As mentioned earlier, in Chinese R&D activities, companies account for the vast majority. In the R&D activities carried out by enterprises, enterprises above designated size have played an important role. In 2015, for example, in all R&D investment of enterprises, enterprises above designated size accounted for 90%. At the same time, the information disclosure of listed companies is relatively complete and the data availability is good. Therefore, based on representativeness and data availability, we selected Chinese listed company data as a research sample. The reason for choosing data from 2007 is because the Ministry of Finance promulgated new accounting standards in 2006. It was implemented in listed companies on January 1, 2007. The new standard revised the accounting for R&D expenses of enterprises. As a result, the statistics of the R&D expenditure data after 2007 and before have changed, so a unified analysis cannot be performed. And the reason why the research data is as of 2015 is because the database update is slow; it is only updated to 2015, so there is no way to do further research. In summary, we have selected data for 2007-2015. The equity nature data of this paper comes from the RESSET database, and the others are from the CSMAR database. In order to eliminate the influence of extreme values, we have processed winsorize for continuous variables at the upper and lower 1% level.

3.2. Variables

1) Innovative output: This paper uses the number of invention patent applications per year as the proxy variable of enterprise innovation output. As the main representation of the output and achievement of enterprise innovation activities, patents are the concentrated performance of independent intellectual property rights of enterprises [12]. Compared with patent applications, patent grants are subject to more factors, there are more uncertainties, and patented technology is likely to bring economic benefits to enterprises before authorization, so patent application data will be more reliable than grants [32]. According to Chinese "Patent Law", patents include three categories: invention patents, utility model patents and design patents, with reference to Wenjing Li [32]; Deqiu Chen [34],

this paper only uses the number of applications of invention patents because the highest technical, plus 1 and then take the logarithm to represent the innovation output of the enterprise.

2) Innovation investment: The ratio of corporate R&D expenditure to total assets. Enterprise R&D expenditure is the cost of the company for its own research and innovation and development of new technologies and new products [15]. However, due to the large difference in R&D expenditure among enterprises of different scales, refer to Weimin Jie [35]; Tong Lu [36]; Xiaofang Bi [37], this paper uses the total assets of enterprises to standardize R&D expenditures, in other words using the R&D investment intensity of the company to express innovation investment.

3) Government subsidies: The ratio of government subsidies to total assets acquired by a company. For companies of different sizes, the same amount of government subsidies will have completely different effects [30]. Reference Dongmin Kong [30]; Xiaofang Bi [37], this paper uses the total assets of enterprises to standardize government subsidies, namely using the government subsidy intensity of enterprises to express the government subsidies obtained.

4) Other control variables: Reference Jie Zhang [38]; Tong Lu [36]; Wenjing Li [32]; Minggui Yu [39], this paper selects the size of the enterprise, financing constraints, shareholding structure, age, capital intensity, governance structure, growth and marketing investment, those eight indicators used as control variables while controlling industry, year and province effects. Among them, the company's total assets taking the logarithm (lnasset) to represent the size of the enterprise; the enterprise cash flow (cf), asset-liability ratio (lev) and total return on assets (roa) are used to represent the internal financing constraints of the enterprise, external financing constraints and the profitability of the enterprise respectively; the first largest shareholder's shareholding ratio (cr1) and equity equilibrium (eqb) are used to measure the shareholding structure of the enterprise; the establishment age of the enterprise (lnage) is used to indicate the age of the enterprise; the fixed asset ratio (ga) is used to indicate the capital intensity of the enterprise; the corporate board structure (lndsrs) and the proportion of independent directors (ddzb) in it represent the corporate governance structure; selecting the company's Tobin q value (tobinq) to indicate the growth of the company; using the ratio of expenses to sales of the enterprise (sale) to express the marketing investment of the enterprise. The specific form and meaning of the variables are shown in **Table 1**.

3.3. Descriptive Statistics

Table 2 is a descriptive statistic for the variables in **Table 1**. First, we see that the sample size of the number of patent applications and the R&D intensity of the explanatory variables is significantly less than other variables, indicating that the innovation data at the micro level of the enterprise is still missing more.

Secondly, for the company's innovation output, the average value can be seen in the whole sample is only 1.9538, which is at a low level. At the same time, the

Table 1. Variable definitions.

meaning	name	sign	definition
innovation output	the number of applications of invention patents	lnpatent	ln(the number of applications of invention patents + 1)
innovation investment	R&D investment intensity	resass	R&D investment/total asset
government subsidy	government subsidy intensity	suba	government subsidy/total asset
scale of enterprise	total asset	lnasset	ln(total asset)
financing constraint	enterprise cash flow	cf	enterprise cash flow/total asset
	asset-liability ratio	lev	total debt/total asset
	total return on assets	roa	net profit/total asset
shareholding structure	the first largest shareholder's shareholding ratio	cr1	the shareholding ratio of the largest shareholder
	equity equilibrium	eqb	the sum of the shareholding ratio of the second to fifth shareholders/the shareholding ratio of the largest shareholder
age	the establishment age	lnage	ln(current-date of establishment + 1)
capital intensity	the fixed asset ratio	ga	fixed asset/total asset
governance structure	the corporate board structure	lndsrs	ln(the scale of board)
	the proportion of independent directors	ddzb	the number of independent directors/the scale of board
growth	Tobin q value	Tobin q	share price/replacement cost
marketing investment	the ratio of expenses to sales	sale	sales expense/main business income

difference between enterprises is very large, the minimum value is 0, the maximum value is 8.8721, and the standard deviation is 1.3804. This phenomenon is also reflected in three sub-samples, and a large difference of innovation output between enterprises in the central state-owned enterprise group can be seen, the standard deviation is 1.6365, which is greater than the 1.4051 and 1.2434 of local state-owned enterprises and private enterprises correspondingly. At the same time, according to the statistical data of the sub-samples, we can see that the average value of innovation output of central state-owned enterprises is 2.5249, which is significantly higher than 1.8221 and 1.8619 of local state-owned enterprises and private enterprises.

For the R&D investment intensity of enterprises, we also see that in the whole sample, the average value is only 0.0213, or 2.13%, which is also at a low level. Combined with the sub-samples, we can see that the R&D investment intensity of local state-owned enterprises is only 0.0150, which is remarkable. It is lower than the 0.0207 and 0.0232 of the central state-owned enterprises and private enterprises, and the standard deviation is also small, indicating that the local state-owned enterprises generally have insufficient research and development investment.

For the government subsidies obtained by enterprises, the average sample value is 0.0059, and the average sample size is 0.0057, 0.0054, 0.0063, respectively. The difference is not big. Although the government subsidy is not high enough from this data alone, it's combined with the overall enterprise in China.

Table 2. Descriptive statistics.

Variables	Sample size	Mean	Standard deviation	Minimum	Median	Maximum
			all sample			
lnpatent	12530	1.9538	1.3804	0.0000	1.7918	8.8721
resass	10011	0.0213	0.0179	0.0001	0.0179	0.0979
suba	18399	0.0059	0.0083	0.0000	0.0030	0.0519
lnasset	20495	21.7702	1.2692	19.1781	21.6142	25.6517
cf	18990	−0.0044	0.1194	-0.5209	0.0143	0.2707
lev	20492	0.4509	0.2149	0.0454	0.4546	0.9069
roa	20495	0.0401	0.0555	-0.1744	0.0371	0.2087
cr1	20493	0.3604	0.1528	0.0894	0.3415	0.7540
eqb	20493	0.6347	0.5767	0.0190	0.4660	2.6383
lnage	24615	2.4955	0.5446	0.0000	2.6391	3.5835
ga	20495	0.2415	0.1760	0.0021	0.2060	0.7463
lndsrs	20491	2.3194	0.2822	1.3863	2.1972	3.5835
ddzb	20491	0.3749	0.0671	0.1333	0.3571	0.8000
tobinq	20121	2.2568	2.0424	0.2181	1.6468	11.6726
sale	20367	0.0640	0.0745	0.0000	0.0397	0.4123
			central state-owned enterprises			
lnpatent	1916	2.5249	1.6365	0.0000	2.3979	8.4163
resass	1195	0.0207	0.0189	0.0001	0.0165	0.0979
suba	2612	0.0057	0.0085	0.0000	0.0026	0.0519
			local state-owned enterprises			
lnpatent	3120	1.8221	1.4051	0.0000	1.6094	8.5601
resass	1904	0.0150	0.0155	0.0001	0.0112	0.0979
suba	5488	0.0054	0.0090	0.0000	0.0022	0.0519
			private enterprises			
lnpatent	6938	1.8619	1.2434	0.0000	1.7918	8.8721
resass	6533	0.0232	0.0178	0.0001	0.0194	0.0979
suba	9334	0.0063	0.0079	0.0000	0.0037	0.0519

The proportion of government subsidies in R&D investment funds is only 4.44% on average in the period from 2007 to 2015. It can be found that government subsidies in R&D investment funds of listed companies in China still account for a considerable proportion and are significantly higher than the overall level of the company.

3.4. Models

1) The Impact of Government Subsidies on Enterprise Innovation Output

Because the number of invention patent applications is the limited explanatory variable with the lower limit of 0, in order to explore the influence of government subsidies on the innovation output of enterprises, this paper refers to Zhouyu Lin [12]; Yang Yang [8], Wenjing Li [32], sets the model (1) of the impact of government subsidies on the innovation output of enterprises as follows, and estimates using the Tobit model:

$$\ln \text{patent}_{it} = \alpha_1 + \beta_1 \text{suba}_{it-1} + \beta_2 \text{resass}_{it-1} + \sum \beta_* \text{control}_{it\text{-}1} + \varepsilon \quad (1)$$

Among them, the explained variable lnpatent is the number of invention patent applications. In the robustness test, we will use the sum of the invention patents and utility model patents of the enterprise to test the regression results. The explanatory variable suba is the government subsidy intensity. Ind, year and prov represent the fixed effects of industry, year and province respectively. The definitions of other variables are shown in **Table 1**. Considering the time lag of the development process and the endogeneity between variables, all the independent variables lag one period behind current period in model (1). If the coefficient of government subsidy is significantly positive, it means that government subsidies have a positive impact on the innovation output of enterprises, and inhibit the innovation output of enterprises in contrast.

2) The Impact of Government Subsidies on Enterprise Innovation Investment

Enterprise R&D is a restricted dependent variable. Only when the company chooses R&D, can we observe the R&D intensity of the company. If the company does not choose R&D, then we will set the R&D intensity of the enterprise to be zero [40], so the R&D investment of the enterprise Intensity is also a source of left truncation data. It should be prioritized to use the Tobit model for estimation. This paper sets the model (2) for the impact of government subsidies on enterprise innovation investment as follows:

$$\text{resass}_{it} = \alpha_2 + \chi_1 \text{suba}_{it\text{-}1} + \sum \chi_* \text{control}_{it\text{-}1} + \varepsilon \quad (2)$$

The explained variable resass is the investment intensity of the enterprise R&D. The meanings of other variables are shown in **Table 1**. Similar to the model (1), considering the time lag of the innovation and the endogeneity of the variables, we also lag all the independent variables in the model (2). In the robustness test, we will also report the regression results of the current government subsidies as explanatory variables. If the coefficient of government subsidy is significantly positive, it means that the government subsidy promotes the innovation investment of the enterprise, and squeezes out the innovation investment of the enterprise in contrast.

3) The Impact of Government Subsidies on Enterprise Innovation Efficiency

Based on the above analysis, this paper sets the model (3) of the impact of government subsidies on the innovation efficiency of enterprises as follows: Through the interaction items of government subsidy intensity and enterprise innovation investment intensity, the impact of government subsidies on enterprise innovation efficiency is discussed:

$$\ln \text{patent}_{it} = \alpha_3 + \lambda_1 \text{suba}_{it-1} + \lambda_2 r\text{esass}_{it-1} + \lambda_3 \text{suba}_{it-1} * \text{resass}_{it-1} + \sum \lambda_* \text{control} + \varepsilon \quad (3)$$

See the above and Table 1 for each variable in the model. In addition, in order to reduce the multicollinearity problem of each variable and its interaction term, we de-centered the above variables before performing regression. If the coefficient of interaction is significantly positive, then the government subsidy increases the innovation efficiency of the enterprise. If it is significantly negative, it means that the government subsidy reduces the innovation efficiency of the enterprise.

4. Measurement Results and Analysis

4.1. Empirical Analysis of the Influence Model of Government Subsidy on Enterprise Innovation Output

The empirical analysis of the effect of government subsidies on the innovation output of enterprises is shown in Table 3 below. Column (1) is the result of the whole sample. It can be seen that the government subsidies in China promote the innovation output of enterprises overall. Columns (2), (3), and (4) are the results of central state-owned enterprises, local state-owned enterprises, and private enterprises respectively. It can be seen that the impacts of government subsidies on central state-owned enterprises, local state-owned enterprises, and private enterprises are all significantly positive, then the hypotheses 1a, 2a and 3a were verified. At the same time, from the detail of the coefficient, government subsidies have the greatest promotion effect on central state-owned enterprises, with a coefficient of 21.53, which is larger than 13.83 of local state-owned enterprises. The promotion effect on private enterprises is the smallest, with a coefficient of 11.76. In addition, from the perspective of the output efficiency of R&D investment, private enterprises have the highest output efficiency, with a coefficient of 18.3, which is significantly higher than that of state-owned enterprises. Local state-owned enterprises have the lowest output efficiency with a coefficient of 13.54.

4.2. Empirical Analysis of the Impact Model of Government Subsidy on Enterprise Innovation Investment

Table 4 is the empirical analysis of the effect of government subsidies on enterprise innovation investment. Column (1) is the regression result of the whole sample. It can be seen that the government subsidies in China have significantly promoted the R&D investment of enterprises. Columns (2), (3), and (4) are the empirical results of central state-owned enterprises, local state-owned enterprises, and private enterprises. It can be seen that government subsidies have significantly promoted the R&D investment of the three types of enterprises, verifying hypotheses 1b, 2b and 3b. However, from the detail of coefficient point, the regression coefficient of local state-owned enterprises is only 0.0773, which is significantly lower than the 0.4690 and 0.3500 of the central state-owned enterprises

Table 3. The impact of government subsidies on enterprise innovation output.

	all	central SOE	local SOE	private enterprise
	(1)	(2)	(3)	(4)
suba	13.3600***	21.5300***	13.8300***	11.7600***
	(2.0010)	(4.9120)	(4.2220)	(2.5640)
resass	18.3800***	14.4900***	13.5400***	18.3000***
	(1.0390)	(2.8810)	(2.6310)	(1.2550)
control variables	control	control	control	control
ind	control	control	control	control
year	control	control	control	control
prov	control	control	control	control
N	6105	819	1214	3851
LR chi2	3142.80	812.97	902.44	1713.30
Pseudo R2	0.1459	0.2661	0.2053	0.1321

Table 4. The impact of government subsidies on enterprise innovation investment.

	all	central SOE	local SOE	private enterprise
	(1)	(2)	(3)	(4)
suba	0.3150***	0.4690***	0.0773**	0.3500***
	(0.0210)	(0.0519)	(0.0346)	(0.0295)
control variables	control	control	control	control
ind	control	control	control	control
year	control	control	control	control
prov	control	control	control	control
N	7813	1077	1767	4659
LR chi2	3925.16	975.12	1056.03	2272.62
Pseudo R2	−0.0960	−0.1770	−0.1080	−0.0940

and private enterprises, indicating that the government subsidies have a considerable difference in promoting the R&D investment of these three types of enterprises. The promotion role of local state-owned enterprises is significantly smaller than that of central state-owned enterprises and private enterprises.

4.3. Empirical Analysis of the Influence Model of Government Subsidy on Enterprise Innovation Efficiency

Table 5 is the empirical analysis of the effect of government subsidies on the efficiency of enterprise innovation. Column (1) is the regression result of the whole sample, and the coefficient of the intersection is significantly negative, which indicates that the government subsidies in China have inhibited the innovation efficiency of the enterprise as a whole. Column (2) is the result of the

Table 5. The impact of government subsidies on enterprise innovation efficiency.

	all	central SOE	local SOE	private enterprise
	(1)	(2)	(3)	(4)
suba	14.9700***	25.7500***	13.5500***	14.2000***
	(2.1250)	(5.2980)	(4.2040)	(2.7930)
resass	19.1700***	16.6100***	12.2000***	19.2700***
	(1.0950)	(3.0470)	(2.6520)	(1.3290)
suba*resass	−160.1000**	−367.5000**	590.3000***	−192.2000**
	(71.3600)	(175.2000)	(185.7000)	(87.6300)
control variables	control	control	control	control
ind	control	control	control	control
year	control	control	control	control
prov	control	control	control	control
N	6105	819	1214	3851
LR chi2	3147.83	817.36	912.50	1717.85
Pseudo R2	0.1460	0.2670	0.2080	0.1320

regression of the central state-owned enterprises, and the coefficient of the intersection is also significantly negative, indicating that the government subsidy has a significant inhibitory effect on the innovation efficiency of the central state-owned enterprises, and verifies the hypothesis 2c. Column (3) is the result of the return of local state-owned enterprises, and the coefficient of the intersection is significantly positive, indicating that government subsidies contribute to the improvement of the innovation efficiency of local state-owned enterprises, and verify the hypothesis 1c. Column (4) is the regression result of private enterprises, in which the coefficient of the intersection is significantly negative, indicating that the private enterprises do not make good use of government subsidies, resulting in waste of resources, reducing the innovation efficiency of enterprises, and verifying the hypothesis 3c. In addition, it can be seen from the coefficient of the R&D investment intensity that the innovation efficiency of local state-owned enterprises is significantly lower than that of central state-owned enterprises and private enterprises, which is consistent with the empirical analysis of the previous model 1, explaining that the efficiency of R&D and innovation of local state-owned enterprises has to be improved. , and government subsidies have spurred the innovation efficiency of local state-owned enterprises.

5. Further Analysis

In the past literature, many scholars discussed the possible nonlinear relationship between government subsidies and technological innovation of enterprises from the perspective of theory and evidence [5] [10] [11] [12]. Therefore, this paper will further study the possible non-linear effects of government subsidies on the technological innovation activities of three different types of enterprises,

and discuss whether the government's innovation activities will have different effects when the government subsidies are too high.

5.1. Research Hypothesis

First, according to the above analysis and empirical results, the innovation activities of central state-owned enterprises are greatly affected by political pressure. Then, when the current R&D scale and efficiency of the central state-owned enterprises are sufficient to meet the targets issued by the higher authorities, and then increase the government subsidies, the enterprises have no incentive to increase investment, and even use a large amount of subsidies for other purposes, resulting in more waste of resources. The same is true for local state-owned enterprises. If the amount of government subsidies is sufficient, the company will not consider improving the efficiency of current R&D activities, and may even cause more losses than before.

For private enterprises, due to the existence of information asymmetry, it is still necessary to promote the research and development to transmit innovation signals. Therefore, high government subsidies will not inhibit the R&D investment of enterprises. However, after receiving government subsidies, especially in the case of very simple government subsidies, private enterprises may not be properly utilized, and the waste of government subsidies will be more serious, and even inhibit the R&D output of enterprises. Based on the above analysis, this paper proposes the following assumptions:

Hypothesis 4a: excessive government subsidies will curb R&D investment of central state-owned enterprises.

Hypothesis 4b: excessive government subsidies will curb R&D output of central state-owned enterprises.

Hypothesis 5a: excessive government subsidies will curb R&D investment of local state-owned enterprises.

Hypothesis 5b: excessive government subsidies will curb R&D output of local state-owned enterprises.

Hypothesis 6a: excessive government subsidies will not curb R&D investment of Private Enterprise

Hypothesis 6b: excessive government subsidies will curb R&D output of private enterprise

5.2. Models

Based on the above assumptions, this paper refers to the method of Hong Liu [41]; Zhouyi Lin [12], studying the impact of excessive government subsidies on enterprises through adding the quadratic term of government subsidies in models (2) and model (3), and then set the model (4) and model (5):

$$\text{resass}_{it} = \alpha_4 + \theta_1 \text{suba}_{it-1} + \theta_2 \text{suba}_{it-1}^2 + \sum \theta_* \text{control} + \varepsilon \quad (4)$$

$$\ln \text{patent}_{it} = \alpha_5 + \eta_1 \text{suba}_{it-1} + \eta_2 s\text{suba}_{it-1}^2 + \eta_3 \text{resass}_{it\text{-}1} + \sum \eta_* \text{control} + \varepsilon \quad (5)$$

The definition of each variable in the model is shown in Table 1. In model (4), if the coefficient of government subsidy is significantly positive, and the coefficient of the quadratic term of government subsidies is significantly negative, then indicating excessive government subsidies will curb R&D investment. Similarly, in the model (5), if the coefficient of government subsidy is significantly positive, and the coefficient of the quadratic term of government subsidies is significantly negative, it indicates that excessive government subsidies will curb R&D output.

5.3. Result and Analysis

1) Empirical Results of the Non-Linear Impact of government Subsidies on Corporate Innovation Investment

Table 6 is the empirical result of the non-linear impact of government subsidies on enterprise innovation investment. Column (1) is the regression result of the whole sample. It can be seen that, on the whole, the impact of government subsidies on enterprise innovation investment is indeed Inverted U-type, excessive government subsidies will squeeze out the company's innovative investment. Columns (2) and (3) are the regression results of central state-owned enterprises and local state-owned enterprises, respectively. It also shows that excessive government subsidies will squeeze out R&D investment of enterprises and verify hypotheses 4a and 5a. Column (4) is the result of the private enterprise, and the coefficient of the government subsidy quadratic item is not significant. Therefore, it can be considered that the government subsidy does not inhibit the R&D investment of the private enterprise, and verifies the hypothesis 6a.

2) Empirical Results of the Non-Linear Impact of Government Subsidies on Firms' Innovation Output

Table 7 is the empirical result of the non-linear impact of government subsidies on the innovation output of enterprises. According to the regression results of the whole sample in column (1), it can be found that, in general, the relationship between Chinese government subsidies and enterprises' innovation output is an inverted U-shaped structure. According to the results of columns (2), (3) and (4), it can be further considered that excessive government subsidies have an inhibitory effect on the innovation output of central state-owned enterprises, local state-owned enterprises and private enterprises, and the hypothesis 4b, 5b, 6b is verified.

6. Robustness Test

In order to test the robustness of the empirical results, we carry on the following robustness tests: 1) The sum of the number of invention patents and utility model patent applications is used as the explanatory variable in model (1), (3), (5). 2) Test the models (2) and (4) with the current government subsidies as explanatory variables. The results obtained are basically the same, indicating that the above empirical results are robust, and the test results are shown in Table 8, Table 9.

Table 6. The non-linear impact of government subsidies on corporate innovation investment.

	all	central SOE	local SOE	private enterprise
	(1)	(2)	(3)	(4)
suba	0.4640***	0.7800***	0.3460***	0.4200***
	(0.0510)	(0.1230)	(0.09110)	(0.0704)
suba2	−4.0430***	−8.4450***	−6.4440***	−2.0200
	(1.2610)	(3.0410)	(2.0200)	(1.8430)
control variables	control	control	control	control
ind	control	control	control	control
year	control	control	control	control
prov	control	control	control	control
N	7813	1077	1767	4659
LR chi2	3935.43	982.80	1066.17	2273.82
Pseudo R2	−0.0970	−0.1780	−0.1090	−0.0940

Table 7. The non-linear impact of government subsidies on corporate innovation output.

	all	central SOE	local SOE	private enterprise
	(1)	(2)	(3)	(4)
suba	48.8500***	43.9600***	63.4700***	44.0200***
	(4.7650)	(11.8200)	(10.6300)	(6.0270)
suba2	−978.9000***	−611.7000**	−1241.0000***	−931.7000***
	(119.4000)	(293.2000)	(244.4000)	(157.7000)
resass	18.1800***	14.0900***	12.5100***	18.1700***
	(1.0330)	(2.8800)	(2.6080)	(1.2490)
control variables	control	control	control	control
ind	control	control	control	control
year	control	control	control	control
prov	control	control	control	control
N	6105	819	1214	3851
LR chi2	3209.65	817.31	927.96	1747.82
Pseudo R2	0.1490	0.2670	0.2110	0.1500

7. Conclusions and Policy Recommendations

7.1. Conclusions

After the above analysis, the paper draws the following main conclusions:

First of all, Chinese government subsidies can effectively increase the company's innovation output and innovation investment. This is true for central state-owned enterprises, local state-owned enterprises and private enterprises. However, excessive government subsidies may inhibit corporate R&D activities.

Table 8. The sum of the number of invention patents and utility model patent applications.

	all	central SOE	local SOE	private enterprise
		Model 1		
suba	8.0050***	14.3300***	7.5880**	6.6370***
	(1.8160)	(4.5810)	(3.8500)	(2.3090)
resass	14.8000***	10.5500***	16.2400***	13.1700***
	(0.9430)	(2.6870)	(2.4070)	(1.1300)
control variables	control	control	control	control
N	6105	819	1214	3851
LR chi2	3688.29	883.98	1067.72	2016.63
Pseudo R2	0.1730	0.2910	0.2420	0.1580
		Model 3		
suba	9.0650***	18.6600***	7.4880*	7.1830***
	(1.9270)	(4.9340)	(3.8440)	(2.5130)
resass	15.3200***	12.7400***	15.5400***	13.3900***
	(0.9950)	(2.8400)	(2.4340)	(1.1980)
suba*resass	−106.800*	−378.6000**	317.0000*	−43.5500
	(64.8900)	(163.5000)	(170.7000)	(79.0600)
control variables	control	control	control	control
N	6105	819	1214	3851
LR chi2	3691.00	889.33	1071.16	2016.93
Pseudo R2	0.1730	0.2930	0.2420	0.1580
		Model 5		
suba	33.8500***	28.9800***	44.2100***	29.7500***
	(4.3300)	(11.0300)	(9.7140)	(5.4290)
suba2	−713.5000***	−399.8000	−915.7000***	−667.8000***
	(108.6000)	(273.9000)	(223.3000)	(142.0000)
resass	14.6600***	10.2900***	15.4900***	13.0700***
	(0.9400)	(2.6890)	(2.3970)	(1.1270)
control variables	control	control	control	control
N	6105	819	1214	3851
LR chi2	3731.32	886.11	1084.41	2038.66
Pseudo R2	0.1750	0.2920	0.2450	0.1600

Second, the effect of government subsidies on companies of different natures is not the same. For central state-owned enterprises, although political subsidies can promote R&D investment and R&D output they inhibit the innovation efficiency of enterprises, which means that central state-owned enterprises may have waste of resources in the use of government subsidies.

Table 9. The current government subsidy.

	all	central SOE	local SOE	private enterprise
		Model 2		
suba	0.3770***	0.4710***	0.0869**	0.0438***
	(0.0200)	(0.0508)	(0.0347)	(0.0275)
control variables	control	control	control	control
N	8889	1136	1829	5580
LR chi2	4442.47	1014.18	1089.76	2700.97
Pseudo R2	−0.0960	−0.1750	−0.1080	−0.0930
		Model 4		
suba	0.5490***	0.8390***	0.4040***	0.5420***
	(0.0482)	(0.1230)	(0.0905)	(0.0647)
suba2	−4.7220***	−10.2300***	−7.7360***	−3.0380*
	(1.2030)	(3.1170)	(2.0420)	(1.7120)
control variables	control	control	control	control
N	8889	1136	1829	5580
LR chi2	4457.86	1024.90	1104.06	2704.11
Pseudo R2	−0.0960	−0.1770	−0.1100	−0.0930

For local state-owned enterprises, although government subsidies have a positive effect on the investment, output and efficiency of enterprise innovation, combined with the fact that the local state-owned enterprises themselves are not high in innovation and research and development efficiency, it can be considered that local state-owned enterprises have great problems in their daily innovation activities.

For private enterprises, government subsidies also have a significant role in promoting R&D investment and output of enterprises, but combining the inhibition of government subsidies on innovation efficiency and further analysis of the impact of excessive government subsidies on private enterprises' innovation investment and innovation output. This means that private enterprises are likely to have "seeking support" in the process of applying for government subsidies, and government subsidies are difficult to achieve the expected goals.

7.2. Policy Recommendations

Based on the above conclusions, this paper proposes the following policy recommendations:

First, it is necessary to optimize the governance structure of state-owned enterprises and accelerate the reform of state-owned enterprises, especially for the governance of local state-owned enterprises. To quantify the process, we must not only focus on output but ignore efficiency, and then change the fact of the waste of resources in state-owned enterprises.

Second, the government departments need to further bridge the gap with private enterprises, and reduce the asymmetric information between them, in order to allocate resources to the most needed enterprises, and reduce the "seeking subsidies" and "seeking support" behavior in the application of government subsidies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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