6. IMPACT OF GOVERNMENT SUBSIDIES ON ENTERPRISES' TECHNOLOGICAL INNOVATION INPUTS AND OUTPUTS: MODERATING EFFECT OF REGIONAL INNOVATION CAPACITY

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Abstract

The technological innovation of enterprises was a key topic of attention in recent years. The government introduced relevant policies to support such innovation, in which the incentive effect of government subsidies attracted considerable attention. To explore the relationship between government subsidies and the enterprises' technological innovation inputs and outputs, using the data of Shanghai and Shenzhen A-share listed manufacturing companies from 2008 to 2016, the impact of fiscal policies, mainly government subsidies, on the technological innovation of enterprises and the moderating role of regional technological innovation capacity in the above relationship were empirically tested. Results show that: (1) government subsidies can effectively promote the technological input investment of enterprises, (2) government subsidies can improve the technological innovation output level of enterprises to a certain extent, and (3) regional innovation capacity has a positive moderating effect on the relationship between government subsidies and technological innovation inputs and outputs. The conclusions obtained from this study can provide theoretical support for further enhancing the technological innovation level of enterprises under the guidance of government subsidies and exerting the moderating effect of regional innovation capacity.

Keywords: government subsidies, enterprise innovation, regional innovation capacity

JEL Classification: A14, C12, C15, C63

1. Introduction

Technological innovation is an important driving force for the sustainable and healthy development of enterprises and means for improving their competitiveness (Du *et al*., 2015). Adhering to an innovation-driven development strategy and making technological self-reliance and self-improvement the strategic support for national development is necessary. As the core of the national technology innovation system, enterprise technology innovation can provide undeniable value to the country to occupy a favorable position in the world economy. Schumpeter

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proposed that enterprises' financing technology can restrict their technological innovation (Brown *et al*., 2009), and technological innovation has the characteristics of high risk, destructiveness, and externality (Uribe-Echeberria *et al*., 2020). Thus, enterprises' R&D requires considerable financial support. However, current manufacturing enterprises are difficult to finance, and enterprise financing has become highly bounded, so government intervention is essential. Presently, governments have adopted a series of means to promote enterprise financing, among which government subsidies are the most representative.

Studies focused on the effect of government subsidies on technological innovation. Some scholars pointed out that government subsidies for enterprises, that is, R&D and non-R&D subsidies, can promote enterprises' technological innovation input to a certain extent (Rettberg and Witt, 2021), and government subsidies play different roles in various economic fields. In the field of new-energy vehicles, government subsidies can reduce the cost and risk of production and innovation, improve the output capacity of new-energy vehicle innovation, and increase innovation efficiency (Chen *et al*., 2022). In the field of agricultural production, government subsidies can promote the comprehensive and systematic innovation of agricultural technology and improve the utilization rate of agricultural new-technology resources. In the field of pharmaceutical manufacturing, government subsidies for R&D can reduce the uncertainty of medical output results and give full play to the advantages of human and material resources (Badu *et al*., 2018).

Enterprises' technological innovation capability results from the joint action of their innovation level, government support, and regional characteristics, and enterprises in different regions have different regional characteristics. The integration of enterprises with the same regional characteristics is conducive to creating a unique corporate image and forming a characteristic corporate culture. In addition, the economic base, market environment, and industrial structure differ in different regions; the economic development status varies considerably; and differences exist at the regional innovation level (Liefner *et al*., 2021). The problem of information asymmetry exists between the government and enterprises in different regions, so government subsidy policies also vary, but research on regional innovation capacity in the academic field remains slightly weak. Thus, the problem of the differences in the innovation power of different regions must be considered when examining the role of government subsidies in enterprise technological innovation.

Therefore, this study attempts to use the 2008–2016 Shanghai and Shenzhen A-share listed manufacturing companies as the research sample and conduct a regression analysis, a moderating effect test, and a robustness analysis on the sample using Stata to reveal the influence of government subsidies on the inputs and outputs of enterprise technological innovation. In addition, this study explores the moderating effect of regional innovation capacity to provide a theoretical reference and decision basis for the improvement of enterprise innovation-technology-level ability.

The remainder of this study is organized as follows: Section 2 reviews the relevant literature on government subsidies for enterprise and regional innovation capability and presents the research hypotheses; Section 3 introduces the data sources and design of the main variables; Section 4 presents the regression analysis, moderating effect test, and robustness analysis on the data; Section 5 discusses the empirical results; and Section 6 contains the research conclusions and insights.

2. Theoretical Analysis and Hypothesis Development

2.1 Government subsidies for enterprise technology innovation

Science and technology were the first productive forces, and technological innovation plays an important role in economic activities. The risky natures of innovative technology will likely lead to market failure and other problems. According to relevant Keynesian studies, the lag and inaccuracy of market regulations require government intervention to improve enterprises' level of technological innovation investment and remove obstacles for their development. Governments around the world typically use subsidies to promote enterprises' level of innovation.

The role of government subsidies in firms' technological innovation was discussed by scholars around the world, who have differing opinions about the topic. For instance, by examining the data of privately listed firms in China, Wang *et al.* (2021) concluded that government subsidies have a negative impact on firms' performance. As government subsidies have the property of ex-ante incentives, many firms use government subsidies as "face-saving" means to respond to inspections, and the link between government subsidies and firms' innovation investment cannot be established, resulting in the significant weakening of the role of government subsidies. Some scholars also found that government subsidies and enterprise innovation are in an inverted U-shaped curve. Government subsidies have a single threshold effect, and when the subsidy intensity exceeds a certain threshold value, the effect of the enterprise technology innovation policy will be weakened significantly (Huang and Li, 2002). In this study, we argue that government subsidies have a positive effect on firms' technological innovation inputs and outputs. First, government subsidies are ex-ante incentives, and by giving enterprises certain subsidies, the government can alleviate the problem of insufficient financing and increase the enterprises' R&D investment. Second, the government can reduce the marginal cost of enterprises' R&D investment and improve their marginal revenue through R&D subsidies to improve their innovation output capability. Many scholars around the world verified the positive effect of government subsidies on enterprises' technological innovation inputs and outputs through empirical analysis. By using panel data that link the 2015 through 2019 waves of the South Korean Survey on the Technology of SMEs, Kiman (2022) found that certain government subsidies for enterprise R&D can promote enterprise R&D and drive companies to reach a high level of technological innovation.

For firm innovation, government subsidies can not only provide resource attributes but also transmit signals. Different innovative firms are heterogeneous, and information asymmetry exists between listed firms and investors, and government R&D subsidies can help alleviate such information asymmetry and have synergistic effects on promoting firms' technological innovation (Li *et al*., 2020). Owing to the problem of information asymmetry, potential conflicts between the agents and principals of a firm can trigger agency problems. For firms, information transparency and government subsidies can effectively mitigate agency conflicts and thus increase technological innovation inputs and outputs (Min *et al*., 2020). The effect of government subsidies varies in different economic environments and the higher the degree of marketization, the greater the incentive effect of government R&D subsidies on firms' investment in technological innovation (Jia *et al*., 2021). A favourable financial environment can strengthen government investment in enterprise innovation (Kulu, 2023.). For enterprises with an inadequate financial environment, especially private enterprises, government subsidies can effectively alleviate financially mismatched enterprises' innovation output, improve enterprises' innovation capacity, and generate a positive "crowding-in effect" on enterprises' R&D investment; however, the effect is not significant for state-owned enterprises (Mensah *et al*., 2002). Under the influence of trade

protectionism, the global trade policy is uncertain, and for non-state-owned enterprises, exporters, and high-tech enterprises, moderate government subsidies can enhance the positive effect of trade policy uncertainty on their innovation input (Chung *et al*., 2023). Differences exist in the technological innovation capabilities of enterprises in different fields, but in general, all types of enterprises require government subsidies to support their innovation input, and government subsidies have a positive impact on enterprises' technological innovation in the cultural industry (Benito-Hernández *et al*., 2023). In the biotechnology industry, which started late, enterprises that benefit from government R&D subsidies have considerable opportunities and resources for making additional R&D investments (Shin *et al*., 2019). Based on this discussion, this study proposes the following hypotheses:

Hypothesis 1-1: Government subsidies positively affect firms' technological innovation input.

Hypothesis 1-2: Government subsidies positively affect firms' technological innovation output.

2.2 Moderating role of regional innovation capacity

Regional innovation capacity refers to a region's ability to import new knowledge and transform it into new products, processes, and services that can measure its competitiveness and is a microcosm of a country's innovation capacity (Hamidi *et al*., 2019). Differences exist in the level of innovation, innovation methods, and innovation efficiency among different regions in the same country (Dauda *et al*., 2019), and the differences in regional innovation capabilities can lead to imbalances in regional and international economic development (Pei *et al*., 2022). Enterprises mostly adopt knowledge innovation, technological innovation, industrial innovation, and service innovation to improve their regional innovation efficiency (Kim *et al*., 2020) to cope with uncertainties in the market environment and enhance their market competitiveness (Asheim, 2019). The introduction of national macro policies can also motivate enterprises to increase their R&D investment and improve their regional innovation capacity (Njos and Jakobsen, 2018). An economic virtuous cycle may form when the state allocates fiscal funds to local governments and the local governments subsidize the R&D of innovative enterprises.

Regions with a strong regional innovation capacity pay considerable attention to the protection of intellectual property (IP) rights, and an ideal IP rights system can attract enterprises to invest in R&D activities, thereby obtaining the corresponding government subsidies. By contrast, regions with weak regional innovation capabilities are less aware of IP protection, and the government is prone to under-subsidize or crowd out such regions owing to information asymmetry (Kumar, 1996). In addition, regions with a strong regional innovation capacity will experience industrial clustering, and government subsidies are conducive to attracting high-quality enterprises to accumulate and absorb innovation resources, which in turn can enhance their innovation investment capacity (Birkner *et al*., 2022). Based on this discussion, this study proposes the following research hypothesis:

Hypothesis 2-1: Regional innovation capacity has a positive moderating effect on the relationship between government subsidies and enterprises' technological innovation investment.

Studies on the relationship between regional innovation capacity for government subsidies and R&D expenditures are few. Wu and Hu (2013) selected high-tech industries in 29 Chinese provinces for a panel data analysis and found that the financial support received by regions with different regional innovation capacities has different effects on patent results. Qi (2022) determined that regional innovation differences are an important factor leading to regional differences in the output efficiency of China's digital economy, and financial support plays an important role in enhancing output efficiency. Firms in the start-up stage are undercapitalized and experience considerable difficulties in financing and often require substantial financial support. Firms in regions with different regional innovation capabilities require corresponding government subsidy support, and regional innovation capabilities may play a positive moderating role in the

promotion effect of government subsidies on R&D output. Based on this discussion, this study proposes the following hypothesis:

Hypothesis 2-2: Regional innovation capacity has a positive moderating effect on the relationship between government subsidies and firms' technological innovation output.

3. Methodology

3.1 Modeling

To analyze the effect of government subsidies on enterprises' technological innovation inputs and outputs and test whether the level of regional innovation capacity regulates government financial subsidies for enterprises' innovation inputs and outputs, the following models are constructed, with reference to Li and Yang (2019).

$$RD_{i,t} = \alpha_0 + \alpha_1 Gsub_{i,t-1} + \sum \lambda_i Controls_{i,t-1} + \sum \eta_j year_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$RD_{i,t} = \alpha_0 + \alpha_1 Gsub_{i,t-1} + \alpha_2 Inca_{i,t} + \alpha_3 Gsub\_Inac_{i,t} + \sum \lambda_i Controls_{i,t-1} + \sum \eta_j year_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$output_{i,t} = \alpha_0 + \alpha_1 Gsub_{i,t-1} + \sum \lambda_i Controls_{i,t-1} + \sum \eta_j year_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$output_{i,t} = \alpha_0 + \alpha_1 Gsub_{i,t-1} + \alpha_2 Gsub\_\mathrm{Inc}a_{i,t} + \alpha_3 \mathrm{Inc}a_{i,t} + \sum \lambda_i Controls_{i,t} + \sum \eta_j year_{i,t} + \varepsilon_{i,t} \quad (4)$$

where *RD* represents the innovative research input of an enterprise, *i* represents different enterprises, *t* represents the year, *Gsub* represents government financial subsidies, *Inca* represents the regional innovation level, *Gsub_Inca* represents the cross-product term of regional innovation level and government financial subsidies, and *Output* represents the output of enterprises' innovative products and is divided into four indicators. *Controls* represents the control variables, and ε represents the random error term.

3.2 Variables

(1) Explanatory variables: Drawing on the research method of Lai *et al.* (2018), this study sets the enterprise technology innovation input as the ratio of the funds invested in technology innovation to the total assets of the enterprise. The indicators of enterprise innovation output are divided into the number of invention patent applications (*OP1*), the number of utility model applications (*OP2*), the number of design applications (OP3), and the total results of technological innovation (*OP4*, the sum of the three items of invention patent applications, utility model applications, and design applications).

(2) Explanatory variables: In this study, referring to the method of He *et al.* (2018), government subsidies are defined as government financial assistance programs that act on the R&D inputs and outputs of enterprises, and the natural logarithm is taken for smoothing. As government subsidies have the characteristic of lagging, in this study, financial subsidies are treated with a one-period lag.

(3) Moderating variable: regional innovation capacity: The comprehensive utility value of regional innovation capacity in the 2008 – 2016 China Regional Innovation Capacity Report is used in this study to measure the strength of regional innovation capacity.

(4) Control variables: Drawing on the studies of An (2009) and Dai (2008), the enterprise size (*Size*), gearing ratio (*Lev*), return on net assets (*Roe*), current ratio (*Liratio*), operational efficiency

(*Operate*), age at IPO (*Age*), and nature of the enterprise (*Soe*) are selected as the control variables for the enterprise technological innovation output. The descriptions and definitions of the variables are presented in Table 1.

Table 1. Main variable connotation and definition

Types of variables	*Symbol*	*Variable names*	*Variable definitions and descriptions*
Explained variable	RD	Number of invention patent applications	Ratio of technological innovation input to total enterprise assets
	OP1	Number of invention patent applications	Number of invention patent applications of the enterprise in the current year
	OP2	Number of utility model applications	Number of utility model applications of the enterprise in the current year
	OP3	Number of design applications	Number of design applications of the enterprise in the current year
	OP4	Total achievements of technological innovation	Total number of the previously mentioned three items
Explaining variable	Gsub	Government subsidy	The amount of government subsidies for enterprises' innovation activities, takes the natural log of one stage lag.
Regulated variable	Inca	Regional innovation capability	The comprehensive utility value of regional innovation capability is derived from the Report on China's Regional Innovation Capability.
Control variable	Size	Enterprise scale	Natural log of the enterprise's total assets
	Lev	Asset-liability ratio	Ratio of total liabilities to total assets of an enterprise
	Cfc	Operational cash flow	Ratio of net cash flow from business activities to total assets
	Liratio	Liquidity ratio	Ratio of current assets to current liabilities of an enterprise
	Tang	Tangible assets	Ratio of tangible assets to total assets
	Roe	Return on equity	Net profit/total assets.
	Operate	Efficiency of operation	Net profit/operating income.
	Age	Age to market	Natural logarithm is calculated by adding 1 to the difference between the observation year and time of listing of the firm
	SOE	Enterprise nature	If the enterprise is a state-owned enterprise, SOE is 1; otherwise, it is 0

3.3 Data source and sample selection

The financial crisis in 2008 had an impact on the world economy and on the technological innovation of enterprises. Schumpeter proposed that the technological innovation cycle should

be 8-10 years. The data selected in this study come from the "Guidelines on Industry Classification of Listed Companies" issued by the China Securities Regulatory Commission, from which the manufacturing companies listed as Shanghai and Shenzhen A-shares from 2008 to 2016 are selected as the research sample. The sample is subjected to the following treatments: (1) the listed companies that underwent special treatment, namely, ST and *ST, and the delisted companies in the sample period are deleted; (2) the sample companies with missing main variables in the study period are deleted; and (3) to circumvent the problem of heteroskedasticity that may arise from outliers and enhance the reliability of the empirical analysis results, tailing (winsorization) is performed at the 1% level for all the continuous variables. After the data screening and processing, annual sample observations for 9,226 Chinese A-share listed companies in the manufacturing industry are obtained. The financial data and other related data of the listed manufacturing companies are obtained from the Cathay Capital (CSMAR) and Wind databases, and regional innovation capability is obtained from the China Regional Innovation Capability Report.

4. Results Analysis

4.1 Regression analysis

In terms of the role of government subsidies in firms' innovation input, Table 2 presents the regression results of the sample. The regression coefficient of *Gsub* is 0.424, which is significantly positive, indicating that government subsidies can promote enterprises' R&D investment. Thus, the above regression results verify Hypothesis 1-1.

Table 2. Regression results of government subsidies and technological innovation input

Variables	*(1)*	*(2)*
Gsub	0.424*** (13.013)	-1.064*** (-2.933)
RD		0.005*** (6.272)
Gsub_Inca		0.415*** (4.124)
Cfc	0.020*** (6.750)	0.019*** (6.411)
Soe	0.002*** (3.416)	0.002*** (5.071)
Liratio	-0.000*** (-3.656)	-0.000*** (-3.426)
Lev	-0.010*** (-7.637)	-0.010*** (-7.198)
Size	-0.000* (-1.732)	-0.000** (-2.025)
Age	-0.001*** (-4.385)	-0.001*** (-3.491)

Variables	*(1)*	*(2)*
Tang	0.012*** (3.718)	0.012*** (3.725)
_cons	0.018*** (3.387)	0.002 (0.280)
Year	Yes	Yes
N	6851	6829
r2	0.085	0.115

*Note: t values are in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%.*

Regarding the role of government subsidies in firms' innovation output, the regression results of the sample are presented in Table 3. The effect of government subsidies on the total technological innovation output is significantly positive, which indicates that government subsidies can effectively promote the firms' technological innovation output. In addition, firm size and profitability are positively associated with innovation technology output. Specifically, the larger the enterprise, the higher its profits, the more its capital, the more its resources, the higher its ability to bear business risks, and the lower its trial-and-error costs in the process of technological innovation and thus its ability to generate innovative technological outputs.

Table 3. Regression results of government subsidies and technological innovation output

Variables	*(1)* *OP1*	*(2)* *OP2*	*(3)* *OP3*	*(4)* *OP4*
Gsub	0.054*** (3.675)	0.017** (2.234)	0.054*** (3.961)	0.061*** (3.676)
Size	0.480*** (9.273)	0.157*** (5.722)	0.443*** (8.818)	0.528*** (9.261)
Lev	-0.387** (-2.201)	-0.100 (-0.999)	-0.313* (-1.842)	-0.454** (-2.290)
Roe	1.809*** (5.043)	0.633*** (2.993)	1.777*** (5.075)	2.118*** (5.230)
Liratio	0.008 (1.241)	0.009*** (2.811)	0.004 (0.673)	0.010 (1.392)
Operate	-1.844*** (-4.911)	-0.429** (-2.109)	-1.710*** (-4.886)	-2.145*** (-4.979)
SOE	0.136 (1.104)	-0.058 (-0.822)	0.133 (1.179)	0.145 (1.077)
Age	0.015 (0.336)	-0.040 (-1.470)	0.007 (0.171)	0.013 (0.264)
_cons	-9.269*** (-8.705)	-3.510*** (-6.314)	-8.867*** (-8.620)	-10.014*** (-8.589)
Year	Yes	Yes	Yes	Yes

Variables	(1) OP1	(2) OP2	(3) OP3	(4) OP4
N	9226	9226	9226	9226
r^2	0.119	0.074	0.137	0.118

*Note: t values are in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%.*

In addition, the ratio of the net operating cash flow to tangible assets is positively proportional to a firm's R&D investment, and the liquidity ratio, firm size, and a firm's time in the market are inversely proportional to a firm's R&D investment. The reason for this outcome is that enterprises need financial support for R&D and innovation, and the more the cash flow and tangible assets, the more they can help the enterprise's R&D. In addition, the larger the enterprise and the longer the time of listing, the more likely the economic benefits will be covered by the scale benefits, and the longer the time of listing, the more the funds for enterprise development, and correspondingly, the less the funds for R&D investment.

4.2 Analysis of moderating effects

According to models (1) and (2), the interaction term (*Gsub_Inca*) of government subsidies and regional innovation capacity level is listed in Table 2, and the results show that the coefficient of the interaction term is significantly positive; thus, the Hypothesis 2-1 holds. This result indicates that regional innovation capability has a positive moderating effect on the relationship between government subsidies and R&D investment. The reason for this outcome is that regions with high regional innovation capacity will likely attract government financial subsidies for enterprises owing to their superior geographical location, satisfactory business environment, abundant entrepreneurial resources, and mature rule of law system.

Similarly, the cross-product term (*Gsub_Inca*) of regional innovation capacity and government subsidies is added to the relationship between regional innovation capacity and enterprise innovation technological output in Table 4, and the results reveal that the effect of *Gsub_Inca* on enterprise innovation is significantly positive; thus, Hypothesis 2-2 holds. This outcome indicates that the effect of government subsidies on enterprise innovation output is positively moderated by regional innovation capacity.

Table 4. The moderating effect of regional innovation

Variables	(1) OP1	(2) OP2	(3) OP3	(4) OP4
Gsub	0.021 (0.930)	0.001 (0.114)	0.021 (1.001)	0.029 (1.118)
Inca	-0.715* (-1.871)	-0.361* (-1.738)	-0.735** (-2.097)	-0.705 (-1.632)
Gsub_Inca	0.047** (2.019)	0.023* (1.751)	0.048** (2.230)	0.046* (1.774)
Size	0.478*** (9.243)	0.155*** (5.659)	0.442*** (8.801)	0.526*** (9.224)
Lev	-0.389** (-2.212)	-0.095 (-0.950)	-0.311* (-1.828)	-0.458** (-2.306)
Roe	1.797***	0.643***	1.769***	2.106***
	(5.017)	(3.031)	(5.059)	(5.209)

Variables	*(1)* *OP1*	*(2)* *OP2*	*(3)* *OP3*	*(4)* *OP4*
Liratio	0.008 (1.208)	0.009*** (2.741)	0.004 (0.726)	0.010 (1.358)
Operate	-1.835*** (-4.890)	-0.435** (-2.138)	-1.703*** (-4.876)	-2.135*** (-4.958)
SOE	0.141 (1.145)	-0.057 (-0.803)	0.139 (1.227)	0.150 (1.116)
Age	0.013 (0.285)	-0.044 (-1.616)	0.004 (0.102)	0.011 (0.220)
_cons	-8.730***	-3.220***	-8.331***	-9.480***
	(-7.810)	(-5.498)	(-7.769)	(-7.731)
year	Yes	Yes	Yes	Yes
N	9167	9167	9167	9167
r^2	0.119	0.074	0.138	0.119

*Note: t values are in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%.*

4.3 Robustness analysis

To test the reliability of the research results, robustness tests are conducted on the relationship between government subsidies and enterprises' technological innovation inputs and outputs using the split-sample test and explained variable substitution method. First, a regression analysis is conducted on the relationship between government subsidies and the enterprises' technological innovation inputs using the quantile regression method. The results in Table 5 show that the coefficient of government subsidies is significantly positive, which once again confirms Hypothesis 1-1 and indicates that government subsidies can promote enterprises' innovation inputs, with robustness.

Table 5. Quantile regression results

Variables	*25% quantile regression*	*75% quantile regression*
Gsub	0.189*** (8.124)	0.704*** (19.886)
Cfc	0.021*** (7.406)	0.027*** (6.456)
Soe	0.001** (2.259)	0.002*** (3.169)
Liratio	-0.000*** (-4.444)	-0.000*** (-4.451)
Lev	-0.012*** (-8.707)	-0.008*** (-4.039)
Size	-0.000** (-2.286)	-0.000 (-0.653)
Age	-0.002***	-0.001***

Variables	*25% quantile regression*	*75% quantile regression*
	(-7.518)	(-2.597)
Tang	0.010*** (3.005)	0.015*** (3.014)
_cons	0.016***	0.017**
	(3.210)	(2.245)
year	Yes	Yes
N	6851	6851
r^2	0.0594	0.0523

*Note: t values are in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%.*

Moreover, the explained variable substitution method is used to replace the same index in the current year with the level of patent, utility model, appearance design, and comprehensive innovation in the succeeding year. The regression results (Table 6) reveal that government subsidy policies significantly positively promote the enterprises' technological innovation outputs, and government subsidies can promote the robustness of the enterprises' innovation outputs.

Table 6. Robustness test: Replace explained variables

Variables	*(1)* *OP11*	*(2)* *OP21*	*(3)* *OP31*	*(4)* *OP41*
Gsub	0.031*** (2.614)	0.038*** (3.151)	0.002 (0.355)	0.038** (2.560)
Size	0.350*** (6.066)	0.352*** (5.993)	0.033** (2.072)	0.409*** (5.843)
Lev	-0.337** (-2.054)	-0.340** (-2.078)	-0.022 (-0.420)	-0.395** (-1.966)
Roe	0.369 (0.991)	0.448 (1.194)	0.165 (1.295)	0.515 (1.145)
Liratio	0.006 (1.151)	0.005 (0.877)	-0.001 (-0.687)	0.008 (1.193)
Operate	-0.228 (-0.581)	-0.284 (-0.733)	-0.089 (-0.883)	-0.359 (-0.732)
SOE	0.174 (1.416)	0.131 (1.143)	0.074* (1.855)	0.193 (1.347)
Age	0.010 (0.240)	-0.008 (-0.187)	-0.002 (-0.099)	0.040 (0.744)
_cons	-7.340*** (-6.265)	-7.633*** (-6.359)	-0.603** (-1.966)	-8.534*** (-6.023)
Year	Yes	Yes	Yes	Yes
N	7836	7836	7836	7836

Variables	(1) OP11	(2) OP21	(3) OP31	(4) OP41
r^2	0.148	0.187	0.046	0.143

*Note: t values are in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%.*

5. Discussion

In terms of government subsidies for firms' technological innovation, this study verifies the findings of Rettberg and Witt (2021) on the effect of government subsidies on firm performance. Further, government subsidies play a positive leveraging role in reducing enterprise financing risks and R&D costs, correcting market failures, and increasing the enthusiasm of enterprise technological innovation (Bright *et al*., 2022), thereby prompting the formation of a level playing field in the market, which plays an indispensable role in promoting enterprises' R&D investment, especially start-ups and small and micro enterprises, and helping expand the scale of enterprise innovation, thereby improving the level of technological innovation inputs and outputs. Moreover, enterprises protected by IP rights have high market value (Naveed and Shabbir, 2022), considerable profits, and substantial capital to invest in innovation activities, which can stimulate innovation capacity improvement. Government subsidy policies can lead to an increase in the number of patent applications, especially non-invention patent applications, and IP rights are protected, leading enterprises to engage in high-quality innovation, which can increase enterprise value (Ahmadi, 2015). In addition, when the cost of technology is the same among firms and the objective is to increase the market of products, the strong competitiveness between firms can put the party that improved the technology in a "prisoner's dilemma," and government subsidies can effectively alleviate this dilemma and motivate firms to increase their technological innovation inputs and outputs and expand the market for their products, which can lead to a satisfactory competitive environment in the market economy and improve social welfare (Yang *et al*., 2020; Palm, 2022).

The moderating effect of regional innovation capacity on the effect of government subsidies on firms' technological innovation is a novel finding of this study. The government has limited insights into the market and is prone to information asymmetry in the process of subsidizing enterprises (Kumar, 1996), and the intensity of government subsidies is influenced by enterprises' level, local region, and other factors. In addition, differences exist in subsidies for enterprises with different innovativeness in different regions (Bianchini *et al*., 2019), and enterprises with a high regional innovation capacity, satisfactory infrastructure, high-quality labour force, excellent innovation environment, and remarkable innovation achievements can attract considerable government subsidies (Birkner *et al*., 2022). The second board in the early stage is composed mainly of high-tech enterprises with a low-entry threshold, short establishment time, and small scale. However, their unique technology, high-technology content, strong irreplaceability, and relatively difficult financing result in high demand for government subsidies. Government subsidies will promote R&D input in the second board market, and regional innovation capability will play a positive moderating role in this process.

6. Conclusions and Implications

6.1 Main findings

In this study, the impact of government subsidies on enterprise technological innovation and the moderating role of regional technological innovation capacity were empirically tested by using data from Shanghai and Shenzhen A-share listed manufacturing companies from 2008 to 2016. The following conclusions are obtained:

(1) Government subsidies can effectively promote enterprises' technological innovation input. Appropriate government subsidies for enterprises can be based on enterprise financial support, thereby expanding the scale of enterprise innovation to a certain extent. The protection of enterprise-related IP rights is also strong, and the market value is high, thereby leading enterprises to carry out high-quality innovation and increase their investment in technological innovation.

(2) Government subsidies can improve enterprises' level of technological innovation output to a certain extent. The size of an enterprise is positively proportional to the level of its technological innovation output. The economic and resource benefits generated by government subsidies for enterprises can help them improve their ability to bear business risks and reduce the cost of trial and error to produce increased technological innovation results.

(3) Regional innovation capacity has a positive moderating effect on the relationship between government subsidies and technological innovation inputs and outputs. Regions with high regional innovation capacity are typically geographically advantageous and have a satisfactory investment environment and business environment, abundant technological innovation resources, an excellent rule of law environment, high IP rights protection, and high achievement transformation ability, which will likely attract the government's attention and corresponding financial subsidies.

6.2 Managerial insights

According to the findings of this study, the following management revelations for the improvement of enterprises' innovation technology are obtained.

(1) Give full play to the leading role of the central government. The central government should focus on the current market environment, create a fair competition environment in the market, and prompt enterprises to enhance their competitiveness by upgrading innovation technology. The government should also introduce relevant policies to support enterprises' innovation technology and reasonably adjust and optimize policies to improve the IP rights protection mechanism. At the same time, the government should expand domestic demand and strengthen demand-side structural reform while deepening supply-side structural reform to prompt enterprises to enhance their investment in innovative technologies.

(2) Coordinate the role of local governments. The government should increase financial support for enterprises, standardize and transparently manage support policies, and give full play to the role of subsidies. It should also strengthen the introduction of talents, explore and cultivate innovative talents, and give full play to the integration of universities, research institutes, and enterprises as well as to the advantages of human, teaching, and research resources and scientific research resources to enhance enterprises' innovation level.

(3) Enterprises should have satisfactory awareness ability and make full use of government subsidies, continuously optimize their system according to market changes, and improve their resource utilization. In addition, enterprises should introduce excellent technologies, improve their R&D efficiency and R&D level, enhance their core competitiveness, create a hardcore enterprise image, and set up a legal component to maintain their IP achievements, improve their IP protection ability, and enhance their innovation level.

6.3 Research limitations and prospects

The sample period of this study is 2008-2016, which is a short range. This insufficient period may lead to incomplete research results and cannot fully reflect the role of government subsidies in

enterprises' technological innovation and may affect the scientificity and accuracy of this study. Moreover, the variables in this study have limitations, and other variables with regional characteristics can be selected in future research on the effect of regional innovation capacity on enterprise innovation technology inputs and outputs to enrich and deepen the research results. The aforementioned shortcomings characterize the research limitations of this study, which require further examination in the future.

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