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The influence of government subsidy on enterprise innovation: based on Chinese high-tech enterprises

Tong Xinle^a, Wang Zhen^a and Li Xinting^b

^aSchool of Finance, Nanjing University of Finance and Economics, Nanjing, China; ^bBusiness School, Nanjing University of Information Science & Technology, Nanjing, China

ABSTRACT

This paper uses data from all the listed high-tech enterprises in China, from 2013 to 2018, as the samples employed to study the impact of government subsidies on the innovation of high-tech enterprises, as well as the subsidy mechanism. The mechanism is analysed mainly from the perspectives of resource effect and signal transmission effect. In the theoretical analysis, from the perspective of resource effect, the capital guiding role of government subsidies is considered. In addition, this study creatively discusses the impact of rent-seeking behaviour in combination with China's anti-corruption practice. From the perspective of signal transmission, government subsidies are no longer only interpreted as positive signals of the government being in favour of enterprise financing. This study further believes that government subsidies transmit a signal to the public, encouraging them to strengthen their supervision of subsidised enterprises. A multiple regression model and mediating effect model indicate that government subsidies achieve the purpose of stimulating enterprise innovation. The stimulating effect of government subsidies through financing constraints and signal transmission is 9.48% and 10.16%, respectively. These results are consistent with the positive externality theory and the signal transmission theory. At the end of the paper, several relevant suggestions are presented, according to the current developments.

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1. Introduction

In the process of economic globalisation, innovation has become an important foundation and characteristic of the development of productivity (Sultanuzzaman et al., 2019). Continuous and sufficient innovation investment can help enterprises to maintain long-term competitiveness (Hu et al., 2020; Mai et al., 2019; Moretti & Biancardi, 2020). However, enterprises face many difficulties in the process of innovation. First, enterprises' innovation investment faces financing constraints (Lin, 2020). Second, enterprise innovation costs are high. Innovation investment is a talent-intensive

CONTACT Tong Xinle  tongxinle730@163.com

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investment activity and therefore, once innovation investment is interrupted, in a worst-case scenario, the enterprise will face bankruptcy (Aghmiuni et al., 2020). Third, the market often fails in terms of the allocation and regulation of innovation resources. Innovation results face the risk of being imitated and infringed, making it impossible for enterprises to monopolise benefits.

Theoretically, government subsidies can provide financing and reduce R&D (research and development) costs, thus correcting the positive externalities of innovation activities (Behuria, 2020; Deng et al., 2019). Therefore, in practice, almost all governments around the world intervene to combat the positive externalities of innovation caused by market failure (Szücs, 2020), thereby hoping to promote enterprises' innovation ability. The Chinese government also attaches importance to innovation investment. In 2018, the government invested a total of 1967.79 billion yuan in R&D nationwide, a 0.04% increase over 2017. However, the question remains as to whether the government's subsidy for innovation investment can achieve its policy targets (Jia & Ma, 2017). In other words, do these subsidies promote enterprise innovation activities? If so, the next questions will be, how can government subsidies promote enterprise innovation, and how should the government improve the subsidy policy to better enhance enterprise innovation? To address these questions, this study investigates high-tech enterprises, constructs an intermediary effect model, and explores the mechanism with which government subsidies affect enterprise innovation investment. The reason why high-tech enterprises were chosen for this study is that these are key enterprises with regard to R&D and innovation. According to the National Bureau of statistics, the proportion of high-tech enterprises in China is only 10%, but their R&D expenditure accounts for 15.02% of the country's total. The government grants a wider range of subsidies to high-tech enterprises, compared with other enterprises. For example, the tax deduction ratio of R&D expenses in high-tech enterprises is 75% higher than that of ordinary enterprises.

The presented results show that government subsidies can promote enterprise innovation investment by easing the financing constraints of enterprises and communicating positive signals to external investors. In summary, government subsidies provide financial support for innovation projects, even if the enterprise disguises itself as a high-tech enterprise, just to fraudulently obtain subsidies. The government has social credibility and thus, obtaining government subsidies is equivalent to sending a reliable signal to the outside world about the promising prospects of a project and further implying strong supervision.

Compared with existing literature, our contribution is mainly embodied in the research object and mechanism design. First, the high-tech enterprises upon which we focus represent the innovation level of the manufacturing industry and even the national economy, to some extent. However, the innovation activities of high-tech enterprises are prone to produce an obvious positive spillover effect in a transition economy with an imperfect intellectual property protection system. Therefore, it is more practical to study the innovation effect of government subsidies for high-tech enterprises than for others. Second, we try to construct a theoretical analysis framework with inherent logical relations; the parallel mechanism of signal transmission

and financing constraints is also explored. This study explains how government subsidies affect enterprise innovation, both theoretically and empirically. The findings of this study further expand and enrich the relevant research. Third, we further develop the resource effect theory and signal transmission theory of government subsidies, respectively. From the perspective of resource effect, the guiding role of government subsidies is considered. In addition, this study creatively combines the above theories with China's anti-corruption practice, in order to explore the impact of rent-seeking behaviour on the effectiveness of government subsidies. The results indicate that the interference effect of rent-seeking behaviour is limited. From the perspective of signal transmission, different from other relevant literature, government subsidies are no longer only interpreted as positive signals conducive to enterprise financing. A signal has been sent to the public to strengthen the supervision of subsidised enterprises.

The remainder of the paper is organised as follows: Section 2 presents a relevant literature review. Section 3 formulates the research hypothesis. Section 4 presents an empirical analysis of how government subsidies affect the innovation of high-tech enterprises. Section 5 summarises the study's pertinent conclusions.

2. Literature review

2.1. Impact of government subsidies on enterprises

Existing literature mainly discusses the impact of government subsidies on enterprise innovation from the perspectives of the crowding out effect and the incentive effect. With regard to the crowding out effect, government subsidies are mainly based on the declaration information of enterprise innovation projects. This process suffers from selection bias, which ultimately leads to uneven resource allocation (Jaffe, 2002). In addition, other factors, such as factor market differences, product market liberalisation, and human factors may also cause the crowding out effect (Jia & Ma, 2017).

The incentive effect is supported by a large body of literature. Sung (2019) suggested that government subsidies can stimulate the innovation activities of enterprises by correcting externalities. Zhao et al. (2018) showed that the incentive effect and the crowding out effect of Chinese government R&D subsidies are significant. When the subsidised amount is large, the net effect is positive. Wu and Zhao (2021) found that the incentive effect of subsidies is more obvious with increases in R&D investment and R&D efficiency.

Other studies combine both of these effects (Szücs, 2020). For example, Xu et al. (2014) identified an optimal range of government subsidies. Government subsidies that remain below this range will exert an incentive effect on enterprise innovation, while when the subsidies exceed this range, they will exert a crowding out effect. Liu et al. (2019) explained this mechanism by using resource allocation, information efficiency, and risk control channels.

To sum up, most of the studies on the crowding out effect focus on the efficiency of government subsidies and how enterprises depend on subsidies. However, innovation investment is a risky activity, the success of which often depends on many factors, such as the amount of capital, the overall level of technology, and corporate governance environment (Camisón-Haba et al., 2019; Öberg, 2019). It is not a

convincing argument to attribute government subsidies to the inefficiency of enterprise innovation. In fact, the main source of R&D funding is not government subsidies, but external financing (Dai & Cheng, 2015; Kusnadi & Wei, 2017). The government subsidy dependence theory is worth pondering. On the contrary, the incentive effect of government subsidies has long been recognised. Existing literature mainly discusses the incentive effect of government subsidy on enterprise innovation from the perspectives of financing constraint and signal transmission. We also comb through the two aspects in turn.

2.2. Financing constraints mechanism

A large body of literature explains the promotion of government subsidies on enterprise innovation activities from the perspective of financing constraints. Enterprises usually require external financing when starting innovation projects (Dai & Cheng, 2015). This external financing can be mainly divided into equity financing and debt financing. Because of the stringency of listing conditions, obtaining financing directly from banks and other financial institutions has become the best choice for enterprises (Kusnadi & Wei, 2017). However, innovation projects also face difficulties with debt financing. The technology (or intangible assets) of innovation projects cannot be effectively used as collateral (Brown et al., 2012), and the risk associated with R&D investment is high (Rajan, 2012). Other reasons, such as the information asymmetry caused by commercial confidentiality, will lead to innovation projects encountering more serious financing difficulties than other traditional investment projects (Acharya & Xu, 2017; Zheng et al., 2015).

Several studies have shown that government subsidies can compensate for a lack of financial support for enterprise innovation projects (Behuria, 2020; Kou et al., 2020). Liu et al. (2019) suggested that government subsidies can promote the technological innovation of enterprises through capital reallocation and other relevant channels. Wang and Zhang (2016) also suggested that government subsidies can effectively drive the technological innovation of enterprises through financing channels.

2.3. Signal transmission mechanism

Because of the high investment cost of innovation activities, government subsidies alone are not sufficient to meet investment needs. External financing, therefore, remains an important way to fill the enterprise innovation investment funding gap (Dai & Cheng, 2015). Considering this, scholars have begun to seek other factors to explain the impact of government subsidies on innovation. The signal transmission theory offers a good explanation as to why and how government subsidies stimulate the innovation activities of enterprises.

The core point of the signal transmission theory is that government subsidies can alleviate the information asymmetry between enterprises and investors (Deng et al., 2019). Because of the robust professionalism of innovation projects, investors do not know much about their future earnings, since enterprises often hide the core

information of projects to protect trade secrets (Acharya & Xu, 2017). The resulting serious information asymmetry leads investors to decide not to invest, or to decrease the investment amount or increase the credit interest rate. In this context, obtaining government subsidies sends positive signals about innovation projects to the outside world (Fuchs & Skrzypacz, 2019). Wu (2017) and Zhao and Ziedonis (2020) all showed that government subsidies strengthen the relationship between responsive market orientation and innovation investment by alleviating information asymmetry.

Comprehensive research on the financing constraint and signal transmission channels shows that the two views are not in conflict. However, existing literature tends to separate them. The view of the financing constraint channel focuses more on the absolute amount of government subsidies, ignoring the additional external financing growth caused by the signalling effect of the behaviour of government subsidies. Research on signalling channels has revealed that the stimulating effect of government subsidies on enterprise innovation activities can be partially realised by easing financing constraints. However, these studies only examine the role of government subsidies in alleviating financing constraints as a sub-effect of signalling channels. This paper attempts to integrate the financing constraint channel and signalling channel as two equal influence mechanisms. Considering that the effects of government subsidies on enterprise innovation activities are both interrelated and different in the two mechanisms, we conduct empirical tests on them in turn. This helps us to clearly observe the full impact of government subsidies on each channel.

3. Hypotheses

Government subsidies can correct the positive externalities of innovation activities by sharing risks and reducing costs, thus encouraging enterprise innovation. Innovation is a costly economic activity, the benefits of which are uncertain. Therefore, companies prefer to make conservative investments, rather than to take risks with R&D. Particularly when the market fails, such as happens with the imperfect capital market and the imperfect protection of intellectual property rights, the private interests generated by enterprise innovation are less than the social interests. Consequently, reaching the optimum level of investment in spontaneous innovation is difficult (González & Pazó, 2008). Government should intervene when there are systemic problems that cannot be solved by market forces alone. Governments will ensure the effective allocation of resources by using industrial policies and fiscal policies (Kang & Park, 2012). Those policies can reduce the R&D costs of enterprises with insufficient innovation motivation, thus correcting the positive externalities caused by market failure. The problem of market failure in developing transition economies such as China is even more serious. The 'visible hand' of the government can play a role in making up for the gap between the social interests and private interests of enterprise innovation. Therefore, Hypothesis 1 is proposed:

Hypothesis 1: Government subsidies promote innovation in high-tech enterprises.

As mentioned above, financing constraints hinder enterprise innovation. Government subsidies can directly ease the financing constraints faced by enterprises. More importantly, subsidies have the function of guiding social capital (Zhang et al.,

2020). Assuming that the government's evaluation of innovation projects is fair and independent, the government subsidy is then an affirmation of enterprise innovation behaviour. This kind of signal can reduce the monitoring cost of potential investors and reduce moral hazard (Wu, 2017). For social investors, this positive signal is further interpreted as meaning that the high-tech enterprises receiving government subsidies have more reliable repayment ability and more profitable market space.

Rent seeking is an unavoidable problem. Scholars who have examined the ineffectiveness of government subsidies generally believe that, in an environment of low-cost corruption, enterprises can obtain profits and development through the enterprises' political connections, rather than through innovation (Liu et al., 2020). The Chinese government is aware of the dangers posed by corruption. In recent years, a large number of government officials and state-owned enterprise executives have been investigated. From 2003 to 2012, only 30 cadres above the deputy department level were investigated and dealt with each year. That number increased to 186 in 2013, rising to 380 in 2014. The rise of rent-seeking costs means the relative decline of innovation costs. This study speculates that pseudo high-tech enterprises with political connections will also use government subsidies and social funds to engage in innovation activities under the increasingly high pressure of the government's anti-corruption policies. Therefore, Hypothesis 2 is proposed:

Hypothesis 2: Government subsidies promote innovation in high-tech enterprises by easing financing constraints.

Consistent with the discussion from the perspective of financing constraints, government subsidies can promote high-tech enterprise innovation by releasing positive signals that are conducive to financing (Wu & Zhao, 2021). In this study, this is called the financing signal effect of government subsidies. Based on market-oriented logic, government subsidies ease the information asymmetry between enterprises and investors. Based on the logic of political dominance, obtaining government subsidies can be seen as a signal to high-tech enterprises to actively respond to policy guidance and maintain a good relationship with the government. All these factors assist enterprises in obtaining social funds several times in the form of government subsidies.

In addition, government subsidies also send an implicit signal that the public should strengthen their own supervision of the subsidised enterprises. The financing signal effect of government subsidies has a stronger effect on commercial banks. This kind of financial institution usually lacks an adequate understanding of the innovation projects of high-tech enterprises. However, for professional investment institutions, such as venture capitalists, the financing signal effect of government subsidies may be more manifested in the screening stage of investment objects, which occurs in the early stage of the survey. The investment decisions made during the later stage mainly depend on the investors' own survey and evaluation results. Therefore, through the screening of government subsidies, potential investors from all walks of life will pay more attention to the enterprises receiving subsidies. This helps to monitor and track the whereabouts of government subsidies and social investment funds, so as to promote enterprise innovation. Hypothesis 3 is thus proposed:

Hypothesis 3: Government subsidies promote the innovation of high-tech enterprises through the signal effect.

4. Data, variables, and model building

4.1. Sample selection and data sources

As samples, this study uses the annual data of high-tech companies listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange, from 2013 to 2018. In 2013, the Chinese government put forward a strategy of innovation-driven development, raising scientific and technological innovation to the highest level in terms of its importance in China's future destiny. As of 2018, a government work report pointed out that China's innovation-driven development had achieved fruitful results. The scale of R&D investment in the whole of society ranked second in the world. This sample period provides rich data for us to research the relationship between government subsidies and the innovation of high-tech enterprises.

During data cleaning, both ST and ST* companies were excluded. In addition, companies with missing key variables or significant outliers, which violates accounting standards and common sense, were excluded. The final sample includes 12 high-tech industries, such as electronic equipment manufacturing, information technology services, pharmaceutical manufacturing, and instrument manufacturing. Enterprise financial variables and government subsidy variables were obtained from the China Stock Market & Accounting Research (CSMAR) database and the China National Knowledge Infrastructure (CNKI) website.

4.2. Variables

Since the mediating model was used to test the influence mechanism of government subsidies on enterprise innovation, the variables were introduced in the order of key variables and control variables. Key variables contain a dependent variable, an explanatory variable, and intermediary variables.

4.2.1. Key variables

Enterprise innovation is a dependent variable. Following Zheng et al. (2015), this study uses the proportion of R&D expenditure in the revenue of major activities as a measurement of enterprise innovation activities. The larger the value of this index is, the more innovative the enterprise.

Government subsidies are the independent variable. Following Hu et al. (2019), this study uses the amount of direct government subsidies as the basis to measure government subsidies; specifically, the ratio of government subsidies to the total assets of enterprises at the beginning of the year is used.

Corresponding to Hypothesis 2 and Hypothesis 3, two mediating variables are introduced: financing constraints and the signalling transmission index. Following Hadlock and Pierce (2010), the SA index was used to measure the degree of financing constraints. The specific value is $-0.737 \times \text{Size} + 0.043 \times \text{Size}^2 - 0.04 \times \text{Age}$, and the absolute value is taken. Size is defined as the log of assets. Age is defined as the current year minus the first year that the firm has a non-missing stock price on the CSMAR. This SA index, composed of size and age, is not affected by endogenous

Table 1. Definition of variables.

Variable type	Name of variable	Variable symbol	Variable definitions
Dependent variable	Business innovation	RD	R&D expenditure/main business income
Independent variable	Government subsidies	SUBQD	Government subsidies/total assets at the beginning of the year
Intermediary variable	Financing constraints	SA	SA index
	Degree of information asymmetry	ILL	Information asymmetry index as proposed by Amihud (2002)
Control variable	P/E ratio	PER	Price per share/earnings per share
	Return on assets	ROA	Net profit/average balance of total assets
	Corporate leverage	LEV	Total liabilities/total assets
	Cash flow	CF	Cash flow from operating activities/total assets
	Tobin Q	Q	The current Tobin Q value of the company

Source: Authors.

financing variables and achieves strong robustness. The higher the value of the index is, the higher the degree of financing constraints.

The degree of information asymmetry can be used as a proxy variable of the signal transmission index (Fuchs & Skrzypacz, 2019). The illiquidity ratio proposed by Amihud (2002) was used to measure the degree of information asymmetry (ILL). The higher the value of ILL is, the higher the degree of information asymmetry will be. The specific calculation formula is as follows:

$$ILL_{it} = \frac{1}{D_{it}} \sum_{k=1}^{D_{it}} \sqrt{\frac{|r_{it}(k)|}{V_{it}(k)}} \quad (1)$$

where $r_{it}(k)$ represents the stock percentage return on the k th trading day of year t of the i th enterprise; $V_{it}(k)$ represents the daily transaction amount, and D_{it} represents the trading days of the i th enterprise in year t .

4.2.2. Control variables

This paper comprehensively controls the investment value, profitability, solvency and growth ability of enterprises. Specifically, in reference to the relevant literature, the P/E ratio (PER), return on assets (ROA), leverage ratio (Lev), cash flow (CF), and Tobin Q value (Q) are introduced as control variables (Kou et al., 2020; Kusnadi & Wei, 2017; Liu et al., 2019). Table 1 provides specific definitions for all variables.

4.3. Model building

The following Model (2) was used to test whether government subsidies stimulate the innovation of high-tech enterprises (i.e., Hypothesis 1) (Kou et al., 2020):

$$RD_{it} = \beta_0 + \beta_1 SUBQD_{it} + \beta_2 PER_{it} + \beta_3 ROA_{it} + \beta_4 LEV_{it} + \beta_5 CF_{it} + \beta_6 Q_{it} + \varepsilon_{it} \quad (2)$$

where RD_{it} represents the R&D expenditure and measures enterprise innovation, and $SUBQD_{it}$ represents the government subsidy. If β_1 is significantly higher than 0, Hypothesis 1 is verified. Government subsidies exert a positive marginal impact on enterprise innovation.

$$SA_{it} = \gamma_0 + \gamma_1 SUBQD_{it} + \gamma_2 PER_{it} + \gamma_3 ROA_{it} + \gamma_4 LEV_{it} + \gamma_5 CF_{it} + \gamma_6 Q_{it} + \varepsilon_{it} \quad (3)$$

$$RD_{it} = \theta_0 + \theta_1 SUBQD_{it} + \theta_2 SA_{it} + \theta_3 PER_{it} + \theta_4 ROA_{it} + \theta_5 LEV_{it} + \theta_6 CF_{it} + \theta_7 Q_{it} + \varepsilon_{it} \quad (4)$$

$$ILL_{it} = \gamma_0 + \gamma_1 SUBQD_{it} + \gamma_2 PER_{it} + \gamma_3 ROA_{it} + \gamma_4 LEV_{it} + \gamma_5 CF_{it} + \gamma_6 Q_{it} + \varepsilon_{it} \quad (5)$$

$$RD_{it} = \theta_0 + \theta_1 SUBQD_{it} + \theta_2 ILL_{it} + \theta_3 PER_{it} + \theta_4 ROA_{it} + \theta_5 LEV_{it} + \theta_6 CF_{it} + \theta_7 Q_{it} + \varepsilon_{it} \quad (6)$$

Model (2) is combined with Model (3) and Model (4) to test whether the alleviation of financing constraints plays an intermediary role between government subsidies and the innovation of high-tech enterprises (i.e., Hypothesis 2) (Pirlott & MacKinnon, 2016). Similarly, Model (2) is combined with Model (5) and Model (6) to test whether signal transmitting plays a mediating role between government subsidies and the innovation of high-tech enterprises (i.e., Hypothesis 3). According to the mediating effect test method, the coefficient β_1 has to be significant. Under the condition that β_1 is significant, the next judgement can be made. If both γ_1 and θ_2 are significant, but θ_1 is not significant, the mediating effect is complete. If at least one of γ_1 and θ_2 is not significant, then $\gamma_1 \times \theta_2$ should be tested through the bootstrap method. If all three are significant and $\gamma_1 \times \theta_2$ has the same sign as θ_1 , a partial mediating effect exists. If not, the mediating effect does not exist.

5. Empirical analysis

5.1. Summary statistics

To gain a preliminary understanding of the data, Table 2 provides the descriptive statistical results of the main variables, including overall group, between group and within group. Table 2 indicates that the financial indicators of each enterprise are quite different. Many variables, such as business innovation, government subsidies, P/E ratio, and return on assets, have the situation whereby the overall standard deviation exceeds the average. For example, the overall average R&D expenditure of high-tech enterprises is 0.0318, with an overall standard deviation of 0.0374. This identifies great differences in the level of innovation investment among enterprises. In addition, we found that the between group standard deviation of most variables (such as RD, SUBQD, and SA) is greater than the within group. This finding means that the difference in financial performance between different companies in the same year is greater than that of a single company in different years. This is because high-tech enterprises mainly focus on technological innovation and the R&D of value-added products. The

Table 2. Summary statistics.

Variable	Sample	Observations	Average	S.D.	Minimum	Maximum
RD	Overall	665	0.0318	0.0374	0	0.2989
	Between	111	–	0.0386	0.0002	0.2215
	Within	6	–	0.0220	–0.1110	0.2329
SUBQD	Overall	665	0.0073	0.0082	1.30e-06	0.1168
	Between	111	–	0.0060	0.0002	0.0377
	Within	6	–	0.0054	–0.0266	0.0862
SA	Overall	576	3.4051	1.1137	1.2175	8.4088
	Between	110	–	1.0559	1.4910	7.9297
	Within	5	–	0.3729	1.8772	4.5501
ILL	Overall	585	0.0013	0.0005	0.0004	0.0053
	Between	111	–	0.0003	0.0005	0.0024
	Within	5	–	0.0004	–0.0001	0.0045
PER	Overall	607	0.9894	2.8692	0.0377	54.7678
	Between	111	–	1.6339	0.1413	11.1519
	Within	6	–	2.3638	–9.8277	44.6192
ROA	Overall	641	0.0369	0.0502	–0.2926	0.2637
	Between	111	–	0.0328	–0.0498	0.1345
	Within	6	–	0.0375	–0.2195	0.2089
LEV	Overall	641	0.4703	0.1504	0.0453	0.9952
	Between	111	–	0.1329	0.2002	0.8095
	Within	6	–	0.0739	0.1749	0.7844
CF	Overall	641	0.0399	0.0624	–0.1914	0.3112
	Between	111	–	0.0447	–0.1072	0.2452
	Within	6	–	0.0451	–0.1111	0.2480
Q	Overall	619	2.4989	1.5008	0.8370	10.1536
	Between	111	–	1.1106	0.9759	6.6939
	Within	6	–	1.0032	–0.8101	8.7176

Note: PER = original price-earnings ratio/100; ILL = original illiquidity ratio \times 100.

Source: CSMAR database and authors' calculations.

high degree of uncertainty of these investment activities ultimately presents as a difference of financial indicators.

Other phenomena can also be observed from the overall group of Table 2. The minimum value of government subsidy is 1.30e-06, and the maximum value is 0.1168. This indicates significant differences in the volume of subsidies received by each company. This reflects the fact that the government's support for high-tech enterprises has direction guidance. The average value of the financing constraint index SA is 3.4051, indicating that high-tech enterprises face high financing constraints. The average value of ILL is 0.0013 with a standard deviation of 0.0005, indicating that the problem of information asymmetry is widespread in high-tech enterprises.

5.2. Impact of government subsidies on innovation of high-tech enterprises

Previous studies suggest that government subsidies may exert both an incentive effect and a crowding out effect on enterprise innovation. According to the above analysis, Model (2) was mainly used to test the promotion effect of government subsidies. Table 3 reports the empirical results in four columns. The first two columns are ordinary OLS regression; the last two are panel regression. Considering that the financial indicators of each enterprise are quite different (as described in the summary statistics above), and following Baum (2006), the between effect (BE) model for

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

Variable	(1)	(2)	(3)	(4)
	Enterprise innovation	Enterprise innovation	Enterprise innovation	Enterprise innovation
	OLS		BE	
SUBQD	0.5811*** (2.75)	0.4243** (1.97)	1.4765*** (2.47)	1.0893* (1.89)
PER		0.0002 (0.25)		0.00005 (0.22)
ROA		-0.0799 (-1.30)		-0.0657 (-0.35)
LEV		-0.0396*** (-2.94)		-0.0421 (-1.29)
CF		-0.0819*** (-2.72)		-0.146 (-1.60)
Q		0.0026** (1.99)		0.0038 (0.98)
Cons	0.0305*** (13.31)	0.0499*** (5.65)	0.0241*** (4.29)	0.0452* (1.96)
N	665	607	665	607
R2	0.0113	0.0511	0.0113	0.0474

The table shows the results obtained for different methods of estimation of our main Model (2). The dependent variable is enterprise innovation, and the main independent variable is government subsidies (SUBQD). See Table 1 for the definition of variables. The first two columns are general OLS; the last two are BE panel regression. Also, *, **, and *** indicate significant correlation at the levels of 0.10, 0.05, and 0.01; t values are in parentheses. Source: Authors.

panel regression is used to estimate the parameters. The BE model can ignore all the individual-specific variation in the business innovation that is considered by the within estimator. Therefore, this estimator may mitigate the estimation bias caused by data characteristics and therefore have higher efficiency.

Columns (1) and (3) in Table 3 show the regression results of the univariate model. Columns (2) and (4) show the regression results after controlling for enterprise specific variables. Under these two different model settings, the coefficients of SUBQD always exceed 0. These results are consistent with Sung (2019), who suggested that government subsidies can stimulate the innovation activities of enterprises, and thus, Hypothesis 1 is proved.

Innovation achievements have positive externalities, indicating that the outside world can obtain benefits from innovation achievements without paying for them. This makes it difficult for enterprises to achieve their optimal growth rate, which is a typical phenomenon of market mechanism failure. Government subsidies internalise externalities and correct market failures. This kind of subsidy directly compensates for the loss suffered by enterprises caused by externalities, thus effectively enhancing their enthusiasm for R&D and innovation.

A further reason why government subsidies can stimulate the innovation of high-tech enterprises is that these subsidies can reduce risks. The materialisation and commercialisation of innovative ideas take a long time. Either a break in the capital chain or a brain drain will cause huge losses for enterprises as a result of failed innovation investment. As a result, high-tech enterprises need to consider both their cash flow and loss-bearing capacity before engaging in innovation investment. Government subsidies not only can improve the loss-bearing capacity of enterprises by injecting external funds; these subsidies can also help enterprises to avoid brain drain by providing talent incentives.

5.3. Intermediary effect test of financing constraints

We mainly use the mediating effect model proposed by Baron and Kenny (1986) to test the two transmission mechanisms of the government subsidies upon innovation. This is a sequential test of mediating effects. In fact, there are two methods used to test the mediating effect: a coefficient product test and a coefficient difference test. The first type error rate of coefficient difference test is significantly higher than that of the coefficient product test (probably much higher than 0.05), so it is lost to the coefficient product test. A coefficient product test can be divided into an indirect test and a direct test. The sequential test used in this study belongs to the category of indirect test, while the Sobel test, bootstrap method, and MCMC (Markov chain Monte Carlo) method are direct test methods. Although the suggestion has been made to use the bootstrap method to directly test the product coefficient, many application workers still use the sequential test. The reason why sequential testing is popular is that the method is simple, easy to understand and easy to explain. It is understandable that methodological scholars do not recommend sequential testing, because the test power of a sequential test is the lowest among various methods (Fritz & MacKinnon, 2007). That is to say, it is difficult to obtain the result of the significant mediating effect by using a sequential test. However, if researchers have already obtained significant results with the sequential test, then the low test power is not a problem. In this case, the result of a sequential test is better than that of a bootstrap test. Thus, we exclude the problem of model selection in mechanism testing and use a sequential test to investigate the mechanism of government subsidies on enterprise innovation.

The theoretical analysis indicates that the relief of financing constraints is an important channel through which government subsidies affect the innovation of high-tech enterprises. Innovative investment projects cannot provide detailed information to the outside world, since this would breach commercial confidentiality. As a result, it is difficult to obtain sufficient external financing. The injection of government subsidies can alleviate financing difficulties and promote enterprise innovation. To test this theoretical mechanism, Models (2), (3), and (4) were used for regression analysis, the results of which are presented in Table 4. Columns (1), (3), and (5) are general OLS. Columns (2), (4), and (6) are BE panel regression. The results of the two methods are similar.

This study mainly uses ordinary OLS results to explain the mechanism of financing constraints. The coefficient of SUBQD β_1 in Column (1) of Table 4 is 0.4523, which is significant at a level of 5%. This meets the requirements of the mediating effect test. In Column (3), the coefficient of SUBQD γ_1 is -13.4000 , which is significant at a level of 1%. This shows that government subsidies are negatively correlated to the degree of financing constraints. The coefficient of SUBQD θ_1 in Column (5) is significantly positive and its absolute value decreases with respect to β_1 . The coefficient of financing constraints on enterprise innovation (SA) θ_2 is -0.0032 , which is significant at a level of 10%. Also, $\gamma_1 \times \theta_2$ has the same sign as θ_1 . These results indicate that financing constraints play an intermediary role, i.e., these results are consistent with Kou et al. (2020), who suggested that government subsidies stimulate enterprise innovation by easing financing constraints. Thus, Hypothesis 2 is proved.

Table 4. Intermediary effect test of financing constraints.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	BE	OLS	BE	OLS	BE
	Enterprise innovation		Financing constraints		Enterprise innovation	
SA					-0.0032*	-0.0038*
					(-1.72)	(-1.65)
SUBQD	0.4523**	1.0211*	-13.4000***	-4.9827*	0.4096**	-0.3435**
	(2.24)	(1.85)	(-2.94)	(-1.73)	(2.02)	(-2.03)
PER	0.0001	0.0004	-0.0001	0.0040	0.0000	0.0000
	(0.19)	(0.16)	(-0.42)	(0.59)	(0.16)	(0.05)
ROA	-0.0825	-0.0687	6.4563***	0.6223	-0.0619	-0.0264
	(-1.41)	(-0.38)	(4.89)	(0.80)	(-1.04)	(-0.58)
LEV	-0.0357***	-0.0371	3.5671***	1.2642***	-0.0243*	-0.0175
	(-2.82)	(-1.19)	(12.50)	(5.53)	(-1.71)	(-1.29)
CF	-0.0729**	-0.1296	1.0382	0.0362	-0.0696**	-0.0224
	(-2.59)	(-1.41)	(1.64)	(0.10)	(-2.47)	(-1.03)
Q	0.0038***	0.0055	-0.2250***	-0.1447***	0.0031**	0.0011
	(3.00)	(1.43)	(-7.86)	(-8.59)	(2.32)	(1.04)
Cons	0.0450***	0.0390*	2.1135***	3.1753***	0.0517***	0.0583***
	(5.35)	(1.76)	(11.16)	(20.47)	(5.59)	(5.33)
N	576	576	576	576	576	576
R2	0.0663	0.0710	0.3577	0.3082	0.0712	0.0329

The table shows the results obtained for different methods of estimation of our main Models (2), (3), and (4). The main dependent variable is enterprise innovation; the main independent variable is government subsidies (SUBQD); the intermediary variable is financing constraints (SA). See Table 1 for the definition of variables. Columns (1), (3), and (5) are general OLS. Columns (2), (4), and (6) are BE panel regression. Also, *, **, and *** indicate significant correlation at the levels of 0.10, 0.05, and 0.01, respectively; t values are in parentheses.

Source: Authors.

As a non-profit organisation, the government can inject funds into qualified enterprises for the sake of public interests. Those funds can alleviate the financing constraints in scale and structure, thus promoting enterprise innovation. In terms of total amount, although government subsidies are smaller, a subsidy can become a powerful supplement to market financing channels and can also guide social capitalists to increase investment when market capitalists do not prefer to invest in high-risk innovative projects. In terms of structure, debt is still the dominant financing channel, due to the underdevelopment of China's capital market. Government subsidies can optimise the capital structure of R&D projects, relieve debt pressure and provide new lending space. Even the phony high-tech enterprises who want to get government subsidies can benefit from the financing constraint effect, which will help to increase innovation in the context of China's anti-corruption policies and practices. To sum up, government subsidies remove a series of obstacles to enterprise innovation activities from the perspective of financing constraints. The regression results presented in Column (3) of Table 4 support this conclusion.

However, the ways in which government subsidies ease the financing constraints of enterprises' innovation activities can be divided into direct mitigation and indirect mitigation. Direct mitigation is realised by the direct injection of government subsidies into enterprises' innovation activities, while indirect mitigation is realised by the guidance of government subsidies to external funds. In the latter case, government subsidies act as a signal. In order to study the effect of government subsidies on enterprise innovation, numerous scholars have started from the financing constraint channel; many other studies start from the signal transmission channel. However, few studies consider the two mechanisms simultaneously. This study attempts to put the

two mechanisms in the same research framework by further studying the impact of government subsidies on enterprise innovation through the signal transmission channel.

5.4. The intermediary effect test of signal transmission

Because of the particularity of the government's attributes, it can be inferred that a government subsidy has the function of signal transmission. To test this hypothesis, Models (2), (5), and (6) are regressed, and the results are reported in Table 5. Columns (1), (3), and (5) are general OLS. Columns (2), (4), and (6) are BE panel regression. The results of the two methods are similar.

This study also mainly uses ordinary OLS results to explain the mechanism of information transmission. The regression results of Model (2) in Column (1) of Table 5 meet the test condition of the mediating effect. In Column (3), the coefficient of the effect of government subsidies on information asymmetry γ_1 is -0.0065 , which is significant at a level of 5%. This indicates that government subsidies are negatively correlated with information asymmetry. In Column (5), the coefficient θ_1 is significantly positive, and its absolute value decreases with respect to β_1 . The coefficient of the effect of information asymmetry on enterprise innovation θ_2 is -10.0621 , which is significant at a level of 1%. In addition, $\gamma_1 \times \theta_2$ has the same sign as θ_1 . These results are consistent with Zhao and Ziedonis (2020), which indicates that information asymmetry plays a mediating role. Therefore, government subsidies promote the innovation activities of high-tech enterprises by transmitting positive signals, which verifies Hypothesis 3.

Serious information asymmetry exists between enterprises and external investors for innovation projects. The corresponding confidentiality measures do not allow enterprises to disclose project information freely. In this context, the government, as a participant outside the market, can audit the information of innovation projects and then provide subsidies for eligible projects. Consequently, successful access to government subsidies will send a positive and reliable signal to the outside world about the prospects of the project. This helps enterprises to obtain funds, talents, industry-university-research cooperation and other resources. Moreover, government subsidies also help to strengthen the supervision of potential venture fund investors, so as to encourage enterprises to focus more on innovation. This is the mechanism whereby government subsidies affect enterprise innovation under the signalling transmission channel.

5.5. Robustness test

Government subsidies can promote the innovation of high-tech enterprises, which is the precondition for testing the existence of the two mediating mechanisms. Therefore, we need to focus on the robustness of the empirical results of Model (2). For the concerns about variable measurement, an alternative enterprise innovation variable was used to test the relationship between government subsidies and enterprise innovation activities. This alternative variable uses the ratio of R&D expenditure

Table 5. Intermediary effect test of signal transmission.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	BE	OLS	BE	OLS	BE
	Enterprises innovation		Degree of information asymmetry		Enterprises innovation	
ILL					-10.0621*** (-3.61)	-21.1449** (-2.33)
SUBQD	0.6439*** (3.52)	1.0961** (2.30)	-0.0065** (-2.40)	-0.0096* (-1.91)	0.5786*** (3.18)	0.8924* (1.88)
PER	-0.0002 (-0.31)	-0.0012 (-0.54)	-0.0000 (-0.47)	0.0000 (0.53)	-0.0002 (-0.38)	-0.0009 (-0.43)
ROA	-0.0534 (-1.02)	-0.0578 (-0.35)	-0.0003 (-0.44)	-0.0011 (-0.62)	-0.0568 (-1.10)	-0.0806 (-0.50)
LEV	-0.0270** (-2.32)	-0.0352 (-1.22)	0.0001 (0.72)	0.0004 (1.40)	-0.0257** (-2.24)	-0.0262 (-0.92)
CF	-0.0667** (-2.53)	-0.1407* (-1.69)	0.0002 (0.60)	0.0004 (0.41)	-0.0644** (-2.47)	-0.1331 (-1.63)
Q	0.0012 (1.09)	0.0017 (0.49)	-0.0000 (-0.66)	0.0001 (1.44)	0.0011 (1.00)	0.0029 (0.82)
Cons	0.0415*** (5.45)	0.0470** (2.30)	0.0013*** (11.85)	0.0011*** (4.92)	0.0549*** (6.53)	0.0695*** (3.13)
N	585	585	585	585	585	585
R2	0.0525	0.0630	0.0160	0.0140	0.0734	0.101

The table shows the results obtained for different methods of estimation of our main Models (2), (5), and (6). The main dependent variable is enterprise innovation; the main independent variable is government subsidies (SUBQD); the intermediary variable is the degree of information (ILL). See Table 1 for the definition of variables. Columns (1), (3), and (5) are general OLS. Columns (2), (4), and (6) are BE panel regression. Also, *, **, and *** indicate significant correlation at the levels of 0.10, 0.05, and 0.01, respectively; t values are in parentheses.

Source: Authors.

to the total assets as a measure of the innovation activity of high-tech enterprises. According to the regression results presented in Table 6, the coefficients of government subsidies in univariate and multivariate regression are 0.2887 and 0.2156, respectively, both of which are significant. The empirical results in Table 3 illustrate the role of the government in terms of R&D expenditure, while these results again illustrate the role of government subsidies in stimulating enterprise innovation in terms of R&D expenditure as a share of total assets.

6. Conclusion

In the long run, encouraging independent R&D strengthens the foundation of the economy. Government subsidies are an important way to promote innovation and the development strategy in China. This study uses the high-tech companies listed at the Shanghai Stock Exchange and the Shenzhen Stock Exchange, from 2013 to 2018, as samples. The intermediary effect test method is used to deeply explore the promotion effect of government subsidies on high-tech enterprise innovation. This includes the intermediary effect of financing constraints and signal transmission.

This study draws the following three conclusions: First, government subsidies significantly promote the innovation of high-tech enterprises, which can in turn help the government to achieve policy objectives. Government subsidies directly inject external funds for enterprises and further release positive signals, so as to alleviate the high cost of innovation and to correct the positive externality of innovation results brought about by market failure. A one-standard-deviation increase in government

Table 6. Robustness test: alternative measure of enterprise innovation.

Variable	(1) Enterprises innovation	(2) Enterprises innovation
SUBQD	0.2887** (2.53)	0.2156* (1.82)
PER		-0.0000 (-0.12)
ROA		-0.0022 (-0.07)
LEV		-0.0105 (-1.42)
CF		-0.0425** (-2.56)
Q		0.0012 (1.58)
Cons	0.0174*** (14.01)	0.0219*** (4.51)
N	665	607
R2	0.0096	0.0300

The table shows the results obtained for estimation of our main Model (2). An alternative enterprise innovation variable was used for robustness. The dependent variable is enterprise innovation, measured by the ratio of R&D expenditure to the total assets. The main independent variable is government subsidies (SUBQD), measured by the ratio of government subsidies to the total assets of enterprises at the beginning of the same year. General OLS is used in both Columns (1) and (2). Also, *, **, and *** indicate significant correlation at the levels of 0.10, 0.05, and 0.01, respectively; t values are in parentheses.

Source: Authors.

subsidies, as measured by SUBQD, is associated with an increase of 9.30%¹ of a standard deviation in the innovation of high-tech enterprises.

Second, one of the channels through which government subsidies can promote the innovation of high-tech enterprises is by easing their financing constraints. Government subsidies, as a segment of external capital sources and a powerful way to guide social capital, not only make up part of the total investment amount, but they also optimise the external financing structure of enterprises. Moreover, the influence of rent-seeking behaviour is limited. Under the anti-corruption pressure of the Chinese government in recent years, the rent-seeking cost of pseudo high-tech enterprises has increased, and the driving force of innovation has been strengthened. Statistically, 9.48%² of the promotion of government subsidies on innovation activities of high-tech enterprises is realised through the alleviation of financing constraints.

Third, signal transmission is the second channel through which government subsidies can promote the innovation of high-tech enterprises. Innovation financing often faces problems associated with information asymmetry. The government's behaviour of subsidising eligible projects undoubtedly sends a positive and reliable signal and also implies a request to the public to strengthen supervision of the market. Therefore, investors become more confident about providing funds to innovation enterprises. The mediating effect of this signal transmission reaches 10.16%³ of the total effect of government subsidies on the innovation investment of high-tech enterprises.

In fact, under the background of an imperfect market mechanism, the impact of government subsidies is far-reaching and broad. There is great space for further study on the relationship between government subsidies and enterprise innovation. For example, future research could distinguish between the different types of high-tech

enterprises, or make comparative analysis with medium- and low-tech enterprises and other enterprises. In addition, more reasonable and targeted subsidies could be explored, in order to maximise the efficiency of subsidy allocations. Unfortunately, these ideas require more space and a larger framework and therefore could only be explored in the next study.

The presented findings of this paper have a number of implications for policy-makers. Firstly, China's economic transformation is being accompanied by market failure, so the government should adhere to the policy of innovation subsidies to relieve the market failure problem. Secondly, the government should pay attention to the signal function of subsidies and improve the pertinence and accuracy of subsidies. It is suggested that the government should classify and grade subsidies for different enterprises, in order to provide accurate and effective information to the market. Thirdly, we should use the signal transmission of subsidies to leverage the market. It is suggested that the government should establish a public information platform. The platform could not only help reduce the degree of information asymmetry between enterprises and external investors, but could also improve the credibility of the government.

Notes

1. $0.4243 \times 0.0082 / 0.0374 = 9.30\%$.
2. $13.4000 \times 0.0032 / 0.4523 = 9.48\%$.
3. $0.0065 \times 10.0621 / 0.6439 = 10.16\%$.

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