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Yifan Zhang, Yunfei Liu, Jingjing Wang, Nuozhou Huang

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Yifan Zhang

China Institute for Smart Justice,
Shanghai Jiao Tong University,
Shanghai, 200030, China
Email: zhangyifan@sjtu.edu.cn

Yunfei Liu

International School of Law and Finance,
East China University of Political Science and Law,
Shanghai, 200042, China
Email: 2011150371@ecupl.edu.cn

Jingjing Wang

School of Automotive,
Tongji University,
Shanghai, 200092, China
Email: 20104@tongji.edu.cn

Nuozhou Huang*

Shanghai Intellectual College of Intellectual Property,
Tongji University,
Shanghai, 200092, China
Email: hhnz448@163.com
*Corresponding author

Abstract: The purpose of this article is to analyse the impact of government subsidies on investments in research and development (R&D) and the innovative performance of Chinese patent-intensive industries. Patent-intensive industries listed on the Shenzhen and Shanghai Stock Exchanges from 2013 to 2019 were chosen as the research samples, and the study methods included univariate linear regression and exponential regression analyses. The principal results were as follows: 1) government subsidies had a direct positive effect on firms' innovative performance, and R&D investment played a mediating role; 2) this facilitation effect was greater in state-owned enterprises; 3) the facilitation was also higher in the Greater Bay Area. Accordingly, the government should increase innovation R&D subsidies for patent-intensive enterprises, while enterprises should improve their R&D capabilities, thereby boosting their efficiency of innovation transformation.

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Keywords: government subsidies; R&D investment; innovative performance.

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Biographical notes: Yifan Zhang is an Assistant Professor/Postdoctoral in the Koguan School of Shanghai Jiaotong University in China. Her research interests include the area of finance policy, innovation performance, and circular economy. Her most recent research attends to the carbon finance and innovation performance.

Yunfei Liu is a graduate student at the School of International Finance, East China University of Political Science and Law, with research interests including the fields of intellectual property law and policy.

Jingjing Wang is a Lecturer and currently working as the Secretary of the Youth League Committee in Automotive Studies at Tongji University. She finished her Bachelor's and Master's degrees in College of Arts and Media at Tongji University and her research mainly focused on new media, media communication and network ideological and political education. She has claimed several awards including Excellent Ideological Worker of Tongji University and Excellent League Cadre of Shanghai Communist Youth League.

Nuozhou Huang is currently a Doctoral student at the International Intellectual Property School of Tongji University in Shanghai. His major field of study is intellectual property management. Most of his current research focuses on how to improve patent quality and efficiency and how to layout patent navigation in universities. His research group has also done several research projects, including coal chemicals, digital twinning and magnesium-based materials.

1 Introduction

Technological progress and the innovation revolution in the industry have shifted the engine of economic growth away from resources and capital toward technology and intellectual property rights, with the latter becoming a leading driver of economic growth (Kim et al., 2012). Developed countries now place greater value on the leadership role of intellectual property rights in generating economic prosperity. Related studies in the US and the European Union have shown that patent-intensive industries are critical for economic growth and for maintaining a competitive edge, while future economic and social development is heavily reliant on patent-intensive industries (Lin et al., 2021). Compared with those in developed countries, Chinese patent-intensive industries make a smaller contribution to social development and national prosperity. Intellectual property (IP)-intensive industries in the US accounted for 41% of domestic economic activity or output in 2019. IP-intensive industries created a total of 63 million jobs, or 44% of all US jobs, and collectively contributed nearly USD8 trillion to GDP (US Patent and Trademark Office, 2020). IP-intensive industries generated nearly 45% of the total EU GDP in 2019 and 16% of the total EU GDP (European Patent Office and European Union Intellectual Property Office, 2020). The added value from China's patent-intensive industries in 2020 was about USD12.13 trillion, contributing only 11.97% of the total GDP (National Bureau of Statistics of China, 2021). The economic benefits brought by patent-intensive industries in China remain insufficient compared to other countries; therefore, how to enhance the innovation potential of such enterprises in China formed the focus of our research. There are also certain anomalies, in terms of the specific types of industries and structures, compared with developed countries (Shao, 2020). This requires going back to basics and exploring the inner mechanisms that drive China's economic restructuring and industrial development. Through effective government policy support and planning guidance, it would be possible to establish a better institutional environment for the blossoming of patent-intensive industries, representing a core driving force for upgrading China's economy and the best route toward building an economically resilient country (Sweet and Eterovic, 2019).

With the rapid economic development and progressive industrialisation, patent-intensive industries, as one of the critical issues in China's 13th Five-Year Plan[1], have been added to the list of key industries supported by the Sci-Tech Innovation Board. Industries associated with environmental protection, medical and pharmaceutical products, and intelligent manufacturing have become highly valued. In less than four months, from September to December 2019, nine companies were included on the Sci-Tech Innovation Board. Utilising this board, the Chinese Government can give more opportunities to companies that are courageous enough to address current social governance issues and that possess core technological competence, breaking the old commercial expansion company model and spurring Chinese patent-intensive industries to 'break through the wall' (Zhou et al., 2020). Therefore, a reasonable and effective subsidy policy for patent-intensive enterprises would aid in the recruitment of more patent-intensive enterprises to the board, accelerate the growth of regional economies, and strengthen the integration of intellectual property and economic prosperity. At the same time, this policy would advance the technological development in patent-intensive fields and increase international cooperation in science and technology (Mao et al., 2022).

The existing domestic and foreign studies and empirical literature have mainly focused on the societal benefits of patent-intensive enterprises or on the enterprises themselves. In terms of the factors influencing enterprise innovative performance, the existing studies primarily explored these dimensions from the perspectives of industrial heterogeneity (Mansfield, 1986; Harhoff and Hall, 2007), innovation efficiency (Albert and Ivan, 2012), and input-output analyses. In terms of research on enterprise performance, most scholars concluded that the injection of external funds, such as government subsidies, is conducive to motivating enterprise research and development (R&D) innovation and has a facilitating effect on enterprise R&D investment, thus boosting enterprise innovation outputs and financial performance (Lee, 2011; Wu et al., 2020; Bronzini and Piselli, 2016; Mardones and Velásquez, 2021). Other scholars have conducted research on patent protection. Some scholars studied the impact of different combinations of patent policies and R&D policies on firm innovation (Jeon, 2019; Chu and Cozzi, 2018), and various other scholars also suggested that the government should increase their protection of technological innovation to stimulate improvements in firms' capacity for innovation (Liu et al., 2021; Maskus et al., 2019). In addition, studies discovered that, when firms have heterogeneous property rights, state-owned enterprises (SOEs) have better resource endowment conditions and that government subsidies can significantly promote R&D investment in SOEs, while this relationship is less significant in non-SOEs (Luo et al., 2011; Liang et al., 2012). It was also argued that non-SOEs attach more importance to R&D innovation at the top level, and hence, R&D investment significantly enhances their innovative performance, while the R&D input-output efficiency is lower in SOEs (Li et al., 2021; Szücs, 2020). Differences in firms' geographical characteristics also affect the impact of government subsidies, with a more efficient use of R&D subsidies in more market-oriented regions, whose firms have stronger internal management systems (Pu et al., 2020).

The study of patent-intensive industries can not only aid in the more effective utilisation of government subsidies in this sector but also help to build a green-economy society (Lin et al., 2021). At present, while the government is substantially subsidising patent-intensive enterprises, there is still a gap between the intensity of R&D input and international standards, hence the critical need to conduct extensive research in this area. Considering these points, this study investigated the impact of government subsidies on the stimulation of R&D inputs and the innovative performance of Chinese patent-intensive enterprises when they are constrained by their interior and exterior environments, thus filling this research gap.

The aim of this paper was to reveal the process by which government subsidies affect firms' innovative performance, through the lens of the impact of macroeconomic policies on microeconomic firm behaviour. The existing studies on innovative performance mainly took a macro-regional perspective, but it is necessary to conduct research from the firms' perspective because innovation is the primary driver of firm development. In addition, this paper considers the regional heterogeneity and enterprise heterogeneity of innovative performance and explores the impact of different regulatory instruments on enterprises, which may contribute to the improvement of related systems in China.

The remainder of this article is composed as follows: Section 2 includes relevant hypotheses, considering existing research results; Section 3 introduces the variable selection and model design of this study; Section 4 lists the results of the empirical analysis; Section 5 is the discussion section of this paper, which provides relevant suggestions for the future innovative development of patent-intensive enterprises through industrial policies; and the final section gives the paper's conclusions.

2 Hypotheses

2.1 Government innovative subsidies can foster the innovative performance of patent-intensive enterprises

In recent years, academia has paid increasing attention to the correlation between government subsidies and firms' innovative performance (Chen and Li, 2021). There is a wider debate about whether these two factors promote or inhibit each other. For example, Choi and Lee (2017) argued that government subsidies have a direct promotive influence on innovation in patent-intensive firms. Yu et al. (2021) stated that subsidies make a direct and significant contribution to firm performance. Conversely, Yu and Guo (2016) suggested that government subsidies inhibited innovation in patent-intensive enterprises. Du and Mickiewicz (2016) stated that when companies receive subsidies, they squander them on unproductive activities that are not beneficial to society. Government innovative subsidies are aimed at enhancing firms' innovative performance, and whether this institutional purpose can be achieved is the subject of this paper's empirical evaluation. Regarding the mechanisms by which government subsidies can contribute to the innovative performance of firms, they are first used to compensate for the loss of economic benefits due to technological spillovers from firms conducting R&D activities. Second, they encourage certain firms to undertake R&D activities and promote the use of the results of advanced R&D in the capital market to generate greater profits. Finally, they allow firms that have not undertaken innovative R&D to start doing so and to gradually increase their investment in R&D, improving the technological innovation environment of the market as a whole, thus leading to increased innovative performance.

Based on the previous statement, we can put forward H1:

H1 Government subsidies can promote innovative performance.

2.2 R&D investment mediates between government innovative subsidies and the innovative performance of patent-intensive enterprises

At present, scholars at home and abroad generally agree that government subsidies help enterprises to innovate technologically, which means that subsidies can reduce firms' R&D risks, while encouraging them to put more resources into R&D (Kleer, 2014; Dimos and Pugh, 2016). In addition, Bonte (2004) argued that the connection between R&D investment and government subsidies should be U-shaped and that too many subsidies would be counterproductive. Considering the role of government subsidies in promoting the R&D investment of enterprises, the government directly invests financial resources in enterprises, to channel social capital into enterprises. Certain riskier R&D projects can face the problem of insufficient investment funds. Under such circumstances, enterprises that wish to engage in R&D and innovation projects may abandon them due to a lack of R&D funds. In addition, a high level of investment in R&D and an inability to accurately measure returns on that investment in the short term further discourage companies from undertaking R&D. Government subsidies for R&D projects can go some way to alleviating the financial pressure on companies to allow investment in R&D in the event of a shortage of funds.

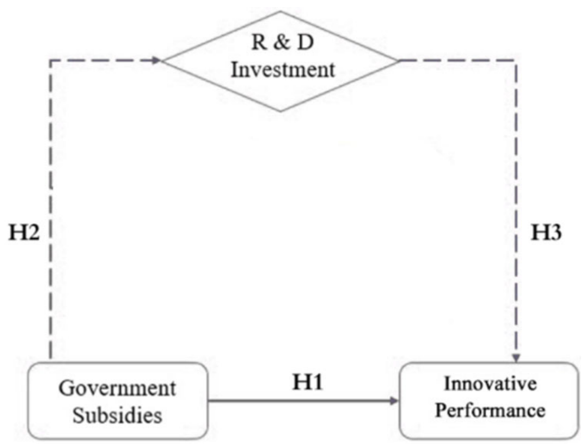
Thus, we propose Hypothesis 2.

H2 Government innovative subsidies can stimulate firms to increase R&D investment.

In the past two years, the academic community has paid particular attention to the character of enterprises' R&D investment, regarding the connection between government innovative subsidies and firms' innovative performance (Xu et al., 2021). Guo et al. (2020) found that innovation partly mediated the correlation between financial resources and firm performance. In addition, Catozzella and Vivarelli (2014) argued that government subsidies have a 'squeeze-out effect' on companies and that an increase in government subsidies can lead to companies reducing their R&D investment. Due to regulatory loopholes, firms also tend to exploit government subsidies for non-R&D purposes, such as production expansion (Chen et al., 2018). As regards the mechanism by which government subsidies can promote R&D investment, the funds invested by enterprises provide a basis for R&D activities. By carrying out R&D activities, enterprises can develop new inventions, technologies, etc. On the one hand, R&D investment promotes the improvement of the firm's processes; on the other hand, the firm's innovative performance is improved by the firm's R&D activities, which results in new patents. In addition, the improved innovative performance of the company also results in positive feedback for the company's R&D and the inflow of direct and indirect economic benefits to the company. These, in turn, encourage firms to continue their R&D activities and to invest in further R&D. Therefore, this paper argues that the role of government subsidies in innovative performance can be revealed by demonstrating that R&D investment mediates the relationship between government subsidies and firms' innovative performance. This leads us to Hypothesis 3.

H3 Corporate R&D investment has a mediating effect on government subsidies and firm innovative performance.

Figure 1 Research framework



3 Variable description

3.1 Data selection

In this study, 1,009 Chinese firms in patent-intensive industries and listed on the Shanghai and Shenzhen Stock Exchanges were taken as research subjects, and data from 2013 to 2019 were collected for analysis. A-share listed firms, companies that are incorporated and listed in China, were selected as the research sample. These firms are representative of Chinese realities. Since Chinese A-share listed companies are only listed on two stock exchanges, in Shanghai and Shenzhen, we selected these two exchanges. We screened and organised the raw data in a reasonable and standardised manner, in line with the following rules, to reduce the impact of invalid or anomalous data on the analysis results:

1 We deleted companies with incomplete data.

2 After screening and excluding ST[2] and *ST listed companies, 7,063 research samples were obtained.

Then, innovative performance indicators were selected from the statistical data of the Chinese Intellectual Property Office. The remaining data were obtained from the WIND database.[3] This paper analysed data using the statistical software MATLAB, and the study methods included univariate linear regression and exponential regression analyses.

3.2 Variables

3.2.1 Government subsidies for innovative R&D (ISUB)

ISUB was used as the explanatory variable. Given that the selected sample was from patent-intensive industries, it was reasonable to assume that all financial subsidies under government grants could be considered 'government innovative R&D subsidies'. Due to the large amount of data, the ratio of government innovative R&D subsidies to company operating income was used to represent ISUB in this study.

3.2.2 Innovative performance

In this study, the annual number of patent applications of firms (PAT) represented their innovative performance.

3.2.3 Innovative R&D investment (IRD)

In this study, IRD was used as an intermediary variable between government innovative subsidies and the innovative performance of patent-intensive enterprises, and a company's innovative R&D input was represented by the ratio of the firm's innovative R&D input to its operating income.

Table 1 System of indicators for variables

Category	*Variable name*	*Variable symbol*	*Variable definition*
Main variables	Innovative performance	PAT	Number of annual corporate patent applications
	Government innovation R&D subsidy	SUB	Government-funded innovative R&D subsidies as a percentage of operational income
	Enterprise innovative R&D investment	IRD	Corporate inventive R&D expenditure as a percentage of operating revenue

4 Empirical analyses

4.1 Full example analysis

4.1.1 SUB can promote an increase in PAT

The scatter plot of SUB and PAT in Figure 2 shows a nonlinear positive relationship between the two factors, while the scatter plot of SUB and log(PAT) in Figure 3 shows a linear positive relationship. Therefore, exponential regression was used.

$$Y = \alpha e^{\beta X}$$

Figure 2 Relationship between SUB and PAT (see online version for colours)

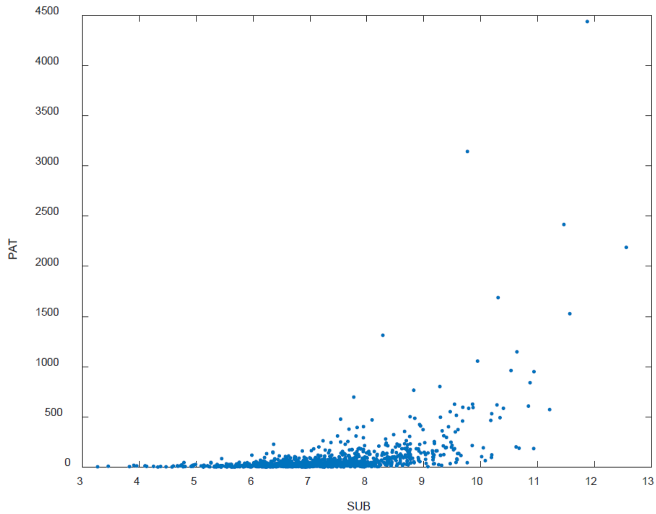
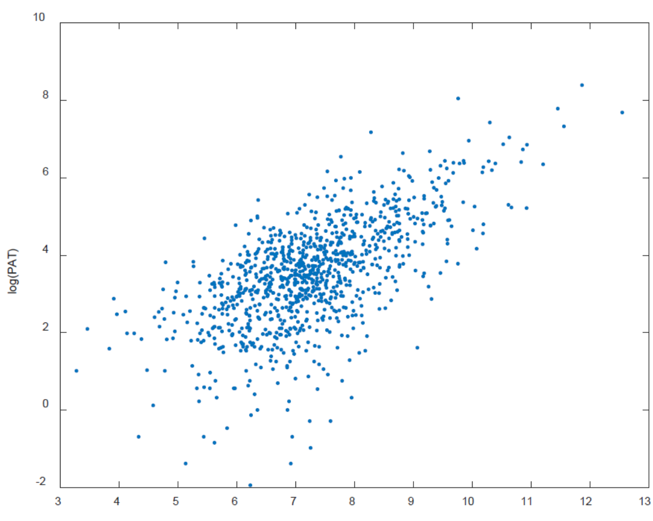


Figure 3 Relationship between SUB and log (PAT) (see online version for colours)



This formula was converted to an exponential model.

$$Y^* = \alpha^* + \beta X + \varepsilon$$

$$\ln Y = \ln \alpha + \beta X$$

X is the independent variable SUB, Y^* is the dependent variable ln(PAT), $\alpha^* = \ln\alpha$ and β are the regression coefficients, and ε is the random error term.

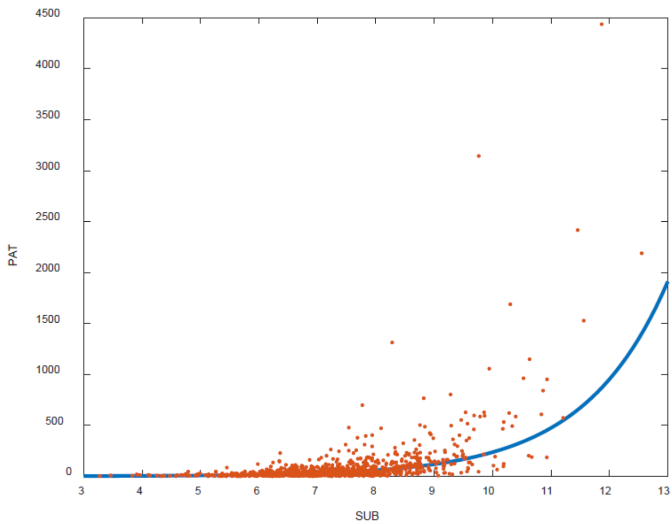
The regression coefficients were calculated using the least squares' criterion, giving $\alpha^* = -3.1019$ and $\beta = 0.7428$. The model was tested with $r^2 = 0.4776$, indicating that the model was valid; $p < 0.0001$, indicating that the variables were significantly linearly related.

The final model was obtained after transformation, as follows:

$$Y = 0.2202\, e^{0.6976X}$$

Figure 4 shows that SUB and PAT were exponentially related. The higher the SUB, the more obvious the promotional effect on PAT. Hypothesis 1 was thus verified.

Figure 4 Model for SUB and PAT (see online version for colours)



4.1.2 SUB can promote an increase in IRD

As shown in Figure 5, the scatter plot of SUB and IRD shows that there was a linear relationship between the two, while their correlation coefficient was 79.09%, which indicated that SUB and IRD were strongly correlated.

Therefore, a one-dimensional linear regression model was used:

$$Y = \beta_0 + \beta_1 X + \varepsilon$$

where Y is IRD and X is SUB, β_0 and β_1 are the regression coefficients, and ε is the random error term. Using the least squares criterion to calculate the regression coefficients, β_0 is 3.221 and β_1 is 0.7892. The model was obtained as follows:

$$Y = 3.221 + 0.7892\ X$$

In Figure 6, the r^2 value of the model is 0.6255, which indicates that the model is valid. In addition, the p-value of the model is less than 0.0001, which indicates a significant linear relationship between the variables. An increase in SUB led to an increase in IRD. Hypothesis 2 was thus verified.

Figure 5 Relationship between SUB and IRD (see online version for colours)

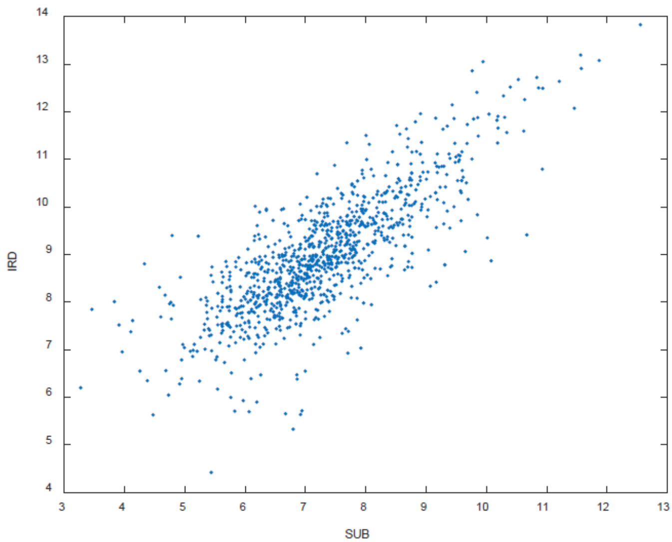
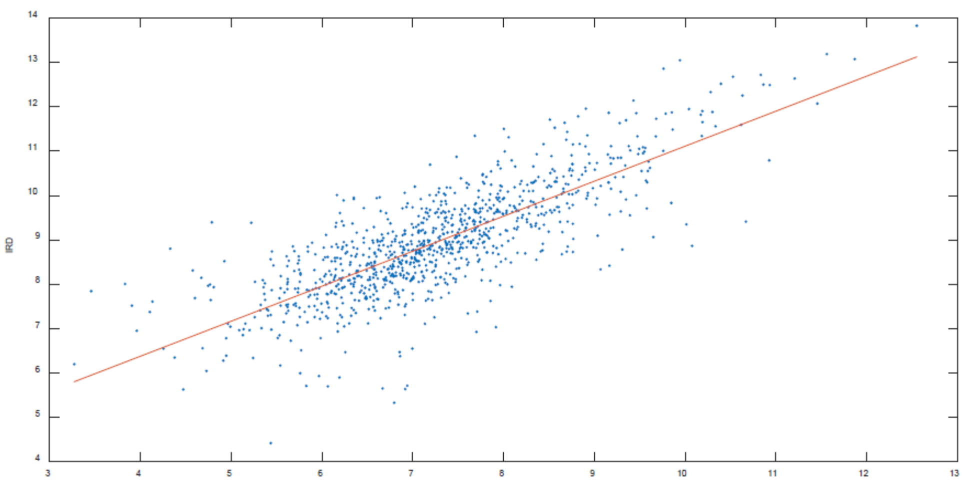


Figure 6 Model for SUB and IRD (see online version for colours)



4.1.3 IRD can promote an increase in PAT

As shown in Figure 7, PAT and IRD were nonlinearly and positively proportional, whereas, in Figure 8, IRD and log (PAT) are linearly and positively proportional. Therefore, exponential regression was used.

$$Y = \alpha e^{\beta X}$$

Figure 7 Relationship between IRD and PAT (see online version for colours)

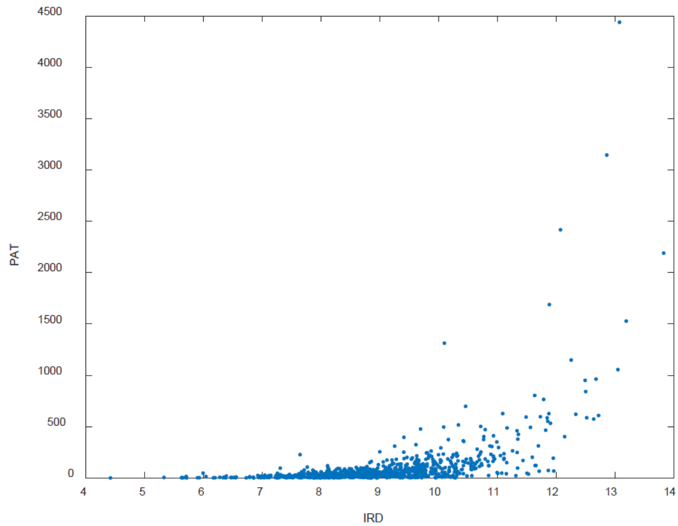
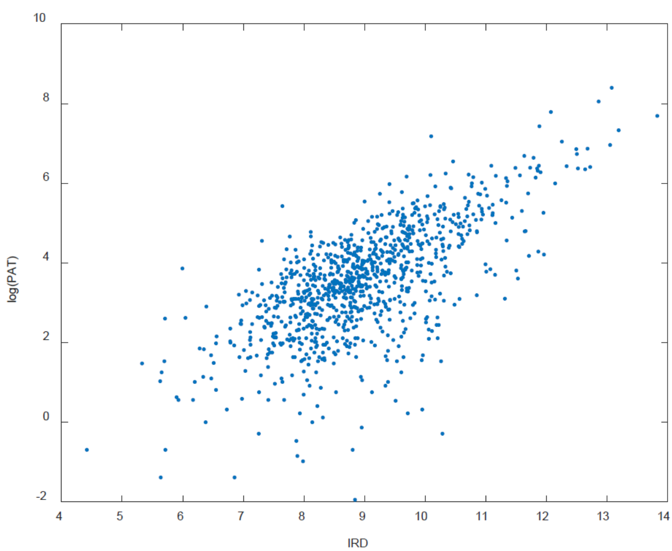


Figure 8 Relationship between IRD and log (PAT) (see online version for colours)



The above model was converted into a one-dimensional linear regression model.

$$Y^* = \alpha^* + \beta X + \varepsilon$$

$$\ln Y = \ln \alpha + \beta X$$

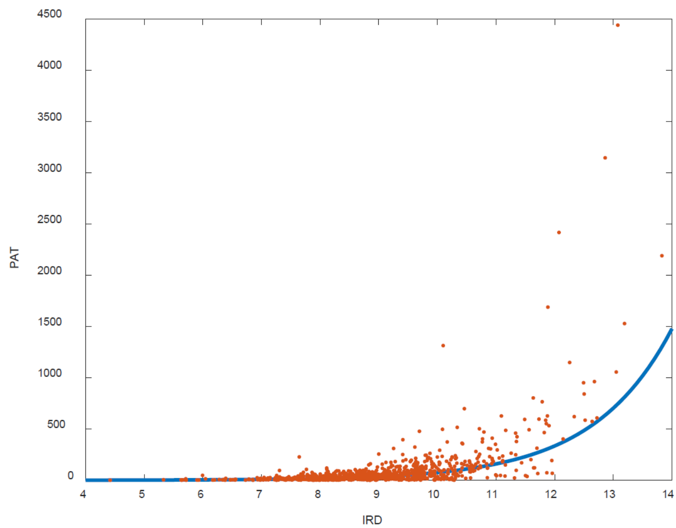
X is the independent variable IRD, y^* is the dependent variable ln(PAT), $\alpha^* = \ln\alpha$ and β are the regression coefficients, and ε is the random error term.

The regression coefficients were calculated using the least square criterion, giving $\alpha^* = -3.1019$ and $\beta = 0.7428$. The model was tested with $r^2 = 0.4776$, indicating that the model was valid; $p < 0.0001$, indicating that the variables were significantly linearly related.

The final model was obtained after transformation, as follows:

$$Y = 0.045\, e^{0.7428X}$$

Figure 9 Model for IRD and PAT (see online version for colours)



This shows that IRD and PAT were exponentially related, and the higher the IRD, the more pronounced the promotion of PAT. Hypothesis 3 was thus verified.

4.2 Heterogeneity test

The aforementioned benchmark regressions provided a lot of empirical evidence for the relationship between SUB and PAT, but the starting point of this examination focused on the aggregate level, ignoring the heterogeneity in different contexts. We examined the heterogeneous effect of SUB on PAT in two dimensions: the nature of ownership, and the location of the firm.

4.2.1 Sub-samples of SOEs and non-SOEs

In terms of the Chinese context, there are two distinct types of enterprise: SOEs and non-SOEs, each with their own management models and decision-making mechanisms (Ji and Yi, 2022). Compared with SOEs, non-SOEs boast a higher market transparency and a greater drive for innovation, under the influence of fierce market competition and enterprise elimination mechanisms. They are more sensitive to the effect of government subsidies on innovation output, and subsidies contribute more to their innovative performance (Szücs, 2020; Choi and Lee, 2017). Based on this, we expected the contribution of SUB to PAT to be greater in non-SOEs.

4.2.1.1 Descriptive statistics

As shown in Table 2, PAT differed significantly between SOEs and non-SOEs, with the mean and median values showing that SOEs had a much higher PAT than non-SOEs. The difference between SOEs and non-SOEs was smaller for SUB and IRD.

Table 2 Descriptive statistics

Samples	*Variable*	*Mean*	*Median*	*Min*	*Max*	*Std.*
Full samples	SUB	7.26	7.17	3.27	12.55	1.22
	PAT	89.30	33.88	0	4,438	244.17
	IRD	8.95	8.85	4.42	13.83	1.22
SOEs	SUB	7.80	7.72	4.38	12.55	1.40
	PAT	161.61	57.75	0.25	4,438	391.90
	IRD	9.40	9.37	5.65	13.83	1.43
Non-SOEs	SUB	7.08	7.07	3.27	11.56	1.10
	PAT	64.91	30.06	0	3,143.63	160.37
	IRD	8.80	8.76	4.42	13.19	1.10

4.2.1.2 SUB can promote an increase in PAT

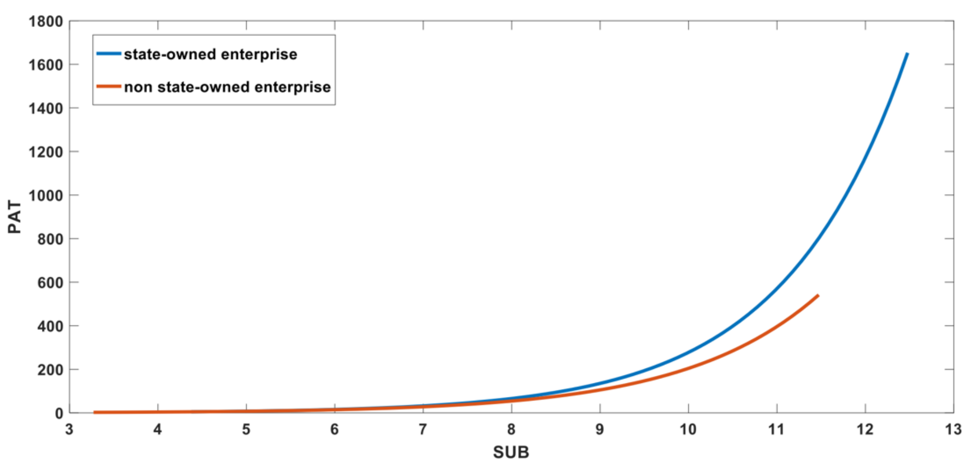
When the formulas for the full sample were inserted into the SOEs and non-SOEs, the following two formulas could be obtained, respectively:

$$Y_0 = 0.2076\, e^{0.7199 X_0}$$

$$Y_1 = 0.2726\, e^{0.6620 X_1}$$

As shown in Figure 10, SOEs received more SUB, and the contribution of SUB to PAT was greater in SOEs.

Figure 10 Model for PAT and SUB (SOEs and non-SOEs) (see online version for colours)



4.2.1.3 SUB can promote an increase in IRD

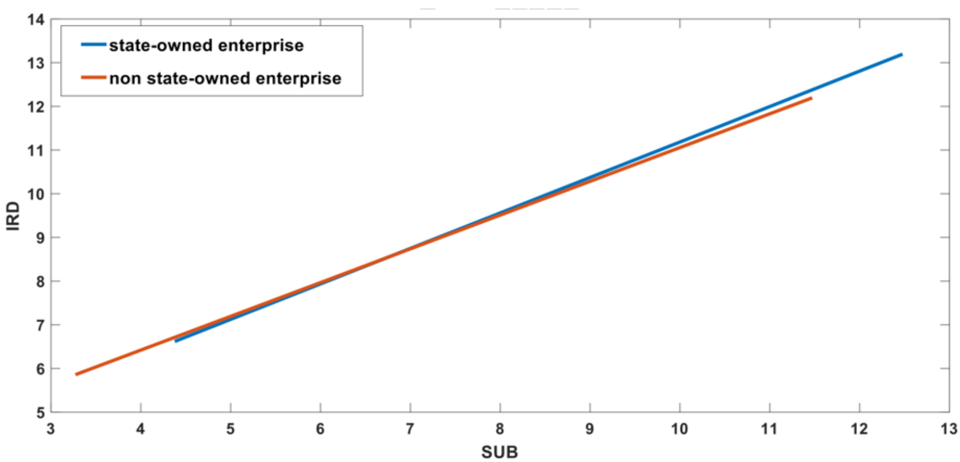
When the formulas for the full sample were inserted into the SOEs and non-SOEs, the following two formulas could be obtained, respectively:

$$Y_0 = 3.0667 + 0.8117X_0$$

$$Y_1 = 3.3309 + 0.7726X_1$$

As shown in Figure 11, the contribution of SUB to IRD did not differ significantly between SOEs and non-SOEs.

Figure 11 Model for IRD and SUB (SOEs and non-SOEs) (see online version for colours)



4.2.1.4 IRD can promote an increase in PAT

When the formulas for the full sample were inserted into the SOEs and non-SOEs, the following two formulas could be obtained, respectively:

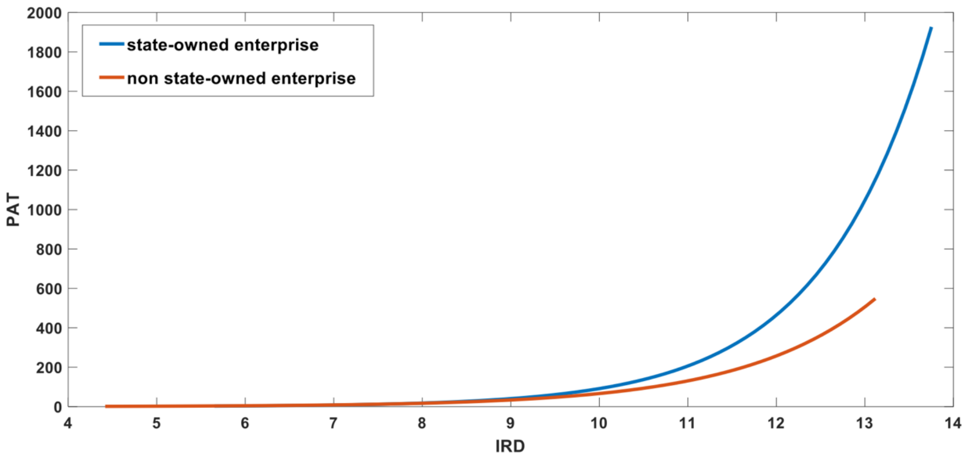
$$Y_0 = 0.0272\ e^{0.8121X_0}$$

$$Y_1 = 0.0767\ e^{0.6577X_1}$$

As shown in Figure 12, SOEs received more IRD, and the contribution of IRD to PAT was higher in SOEs

This result differed from our expectations. For patent-intensive industries, SOEs were better able to use government subsidies for innovation. This may have been because the government directed various resources towards SOEs. SOEs rarely face financial pressures in their day-to-day operations and, therefore, invest the government subsidies they receive in their R&D projects to the greatest extent possible and in accordance with their requirements. Therefore, they perform better than non-SOEs.

Figure 12 Model for IRD and SUB (SOEs and non-SOEs) (see online version for colours)



4.2.2 Sub-samples by area

Due to differences in factors such as economic base, there was regional variability in innovation policies, with government subsidies leading to better performance in regions with better institutional environments (Tian et al., 2016). The three major urban areas, Beijing-Tianjin-Hebei Area, Yangtze River Delta, and the Greater Bay Area, as the most important economic centers of China, contributed significantly to the high-level urban agglomerations and socio-economic development (Yang et al., 2021). Compared with other cities, the three major urban agglomerations had better achievements regarding their quality, efficiency, and dynamic change in their regional economic development (Wang and Yang, 2020). It was expected that the contribution of SUB to PAT of the listed patent-intensive enterprises would be better in these three major policy-supported regions. We labelled the Beijing-Tianjin-Hebei area as Area_1, the Yangtze River Delta as Area_2, the Greater Bay Area as Area_3, and other regions as Area_4.

4.2.2.1 Descriptive statistics

In Area_1, PAT was much higher than in the other three categories, but there was a strong bifurcation. SUB and IRD varied less between areas.

4.2.2.2 SUB can promote an increase in IRD

When the formulas for the full sample were inserted into the four areas, the following four formulas could be obtained, respectively:

$$Y_1 = 0.1951\, e^{0.7111 X_1}$$

$$Y_2 = 0.2860\, e^{0.6595 X_2}$$

$$Y_3 = 0.1341\, e^{0.7923 X_3}$$

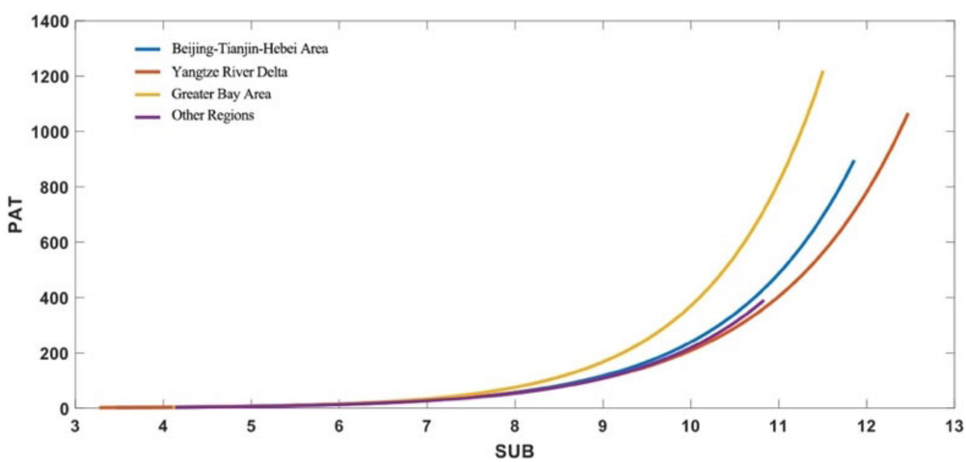
$$Y_4 = 0.2070\, e^{0.6964 X_4}$$

As shown in Figure 13, when SUB was not high (below 7), the effect of IRD on the promotion of PAT was essentially the same in the different regions. When SUB was high (above 7), SUB made a stronger contribution to PAT in the Greater Bay Area, with little difference in the other three categories.

Table 3 Descriptive statistics

Sample	*Variable*	*Mean*	*Median*	*Min*	*Max*	*Std*
Full samples	SUB	7.26	7.17	3.27	12.55	1.22
	PAT	89.30	33.88	0	4,438	244.17
	IRD	8.95	8.85	4.42	13.83	1.22
Area_1	SUB	7.44	7.38	3.46	11.87	1.37
	PAT	128.86	33.69	0	4,438	409.87
	IRD	9.41	9.21	5.90	13.08	1.20
Area_2	SUB	7.25	7.16	3.27	12.55	1.20
	PAT	79.76	33.31	0.14	2,416.13	200.01
	IRD	8.92	8.82	5.64	13.83	1.21
Area_3	SUB	7.19	7.15	4.10	11.56	1.12
	PAT	85.11	40.94	0.25	1,527.5	153.31
	IRD	8.96	8.89	4.42	13.19	1.08
Area_4	SUB	7.24	7.11	4.13	10.93	1.23
	PAT	85.44	29.63	0.25	3,143.63	233.06
	IRD	8.77	8.74	4.42	13.05	1.25

Figure 13 Model for PAT and SUB (different areas) (see online version for colours)



4.2.2.3 *SUB can promote an increase in PAT*

When the formulas for the full sample were inserted into the four areas, the following four formulas could be obtained, respectively:

$$Y_1 = 4.2193 + 0.6970X_1$$

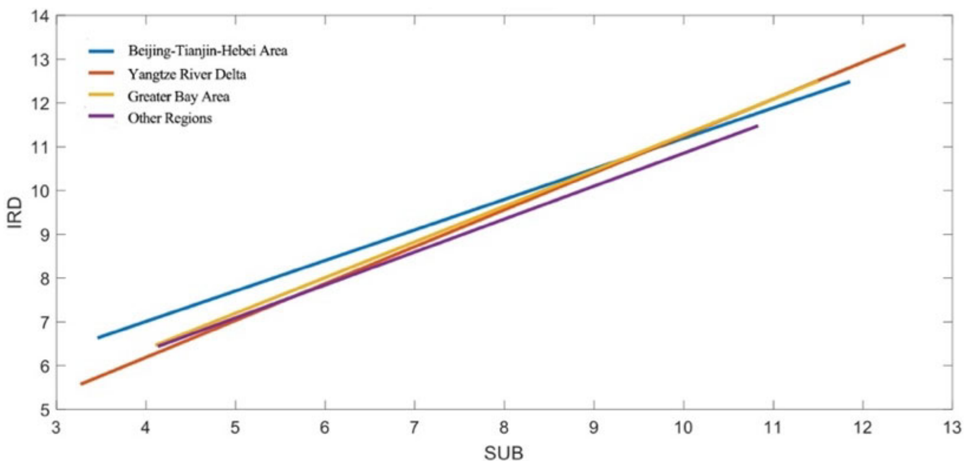
$$Y_2 = 2.8159 + 0.8428X_2$$

$$Y_3 = 3.1181 + 0.8152X_3$$

$$Y_4 = 3.3273 + 0.7524X_4$$

As shown in Figure 14, the contribution of SUB to IRD did not vary significantly across areas.

Figure 14 Model for IRD and SUB (different areas) (see online version for colours)



4.2.2.4 IRD can promote an increase in PAT

When the formulas for the full sample were inserted into the four areas, the following four formulas could be obtained, respectively:

$$Y_1 = 0.0168\, e^{0.8242X_1}$$

$$Y_2 = 0.1112\, e^{0.6409X_2}$$

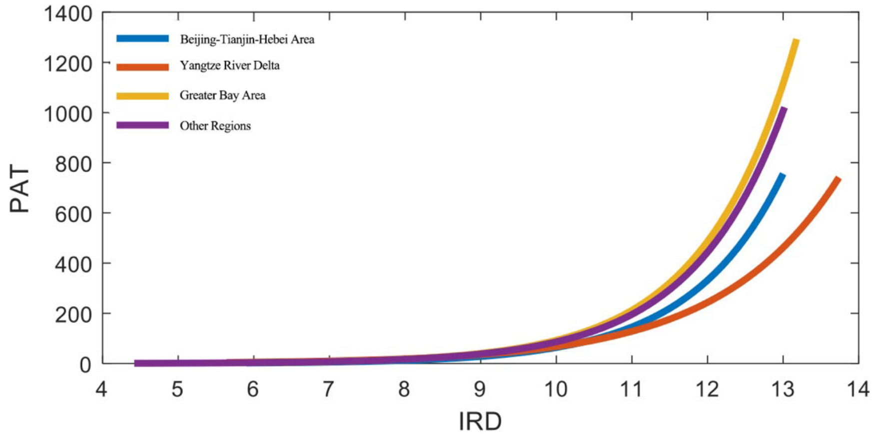
$$Y_3 = 0.0230\, e^{0.8299X_3}$$

$$Y_4 = 0.0240\, e^{0.1817X_4}$$

As shown in Figure 15, when the IRD was not high (below 10), IRD had essentially the same effect on the promotion of PAT in different regions; while, when the IRD was high (above 10), IRD had a stronger promotional effect on the PAT in the Greater Bay Area and other regions, being weakest in the Yangtze River Delta.

The above shows that companies located in the Greater Bay Area were the most capable of innovating using their subsidies. This is because the Greater Bay Area has introduced certain institutional innovations in the acquisition, protection, application, servicing, and financing of intellectual property rights. The government has continued to promote the creation of high-value intellectual property and the development of enterprises through patent transformation. As a result, these enterprises have a greater incentive to develop and innovate after receiving government subsidies.

Figure 15 Model for IRD and PAT (different areas) (see online version for colours)



5 Discussion

This research discovered that, although government innovative subsidies do not make a direct and significant contribution to the innovative performance of patent-intensive enterprises, the innovative R&D investment of patent-intensive enterprises positively mediates between government innovative subsidies and firms' innovative performance, while government subsidies make an enormous contribution to firms' investment in R&D. Therefore, Hypotheses 1, 2, and 3 were verified. For this reason, the Chinese Government should further increase innovative subsidies for patent-intensive enterprises, to supplement the funds required for their investment in innovative R&D and to promote the efficient operation of their innovation activities, thereby improving their level of innovation and innovative performance. In addition, the government should establish an assessment mechanism for firms' investments, to fully promote the intermediary role of firms' investments and to minimise market interventions, while maximising the benefits of free competition and R&D innovation.

With the progressive strengthening of the rule of law, especially in public finance and social supervision, the government has begun to be able to evaluate specific public policies in economic and social governance, based on the concept and position of public management, and thus can decide to adjust or withdraw them. However, there is a lack of independent and clear processes for the formation of normative documents for subsidies. The government should make the industry understand that subsidies are not arbitrary, that there are purposes and criteria for entry and exit, and that they can anticipate changes in the targeting of subsidies in relation to the government's orientation. On this basis, the government should also increase the investigation of subsidy fraud and ensure suitable civil, administrative, or criminal consequences for those organisations and individuals found guilty.

Furthermore, government innovative subsidies contribute significantly to both R&D investment and innovative performance in SOEs. Based on this fact, the government should increase its subsidies to SOEs, since increasing subsidies for such enterprises can enhance their innovative performance in a very short period of time. Non-SOEs should also optimise their subsidy efficiency to maximise the effect of government subsidies on their innovation and financial performance, as non-SOEs are more flexible than SOEs in their internal management and are more economically efficient. Furthermore, the emergence of the three major urban agglomerations mirrors China's economic development to a certain stage. Compared with other cities and regions, the three major urban agglomerations boast more prominent achievements in qualitative development, efficiency improvements, and changes in the power structure of regional economic development. This is particularly evident in the Greater Bay Area. It is vital to strengthen the coordination and integration of subsidy policies in these three strategic areas by combining the geographical advantages of these regions and enterprise development patterns and by optimising the strategy of regional integration.

6 Conclusions

It is becoming increasingly apparent that patents now play a more important role in economic development, as a factor in production and as the fourth industrial revolution progresses at a remarkable pace. Developed regions such as the US and Europe place great value on the role of patents in economic development. The results of this study can be used as a reference to maximise the role of intellectual property-intensive industries in achieving a competitive advantage and for economic development. Considering the direction of global transformation, China must fully exploit patent-intensive industries to gain competitive advantages and to further enhance its economic development and national status. China should place more value on the protection of intellectual property rights in this field, and the government should further expand innovative subsidies for patent-intensive enterprises, considering the region and the nature of the enterprise. In addition, enterprises should also increase their investments in R&D to boost innovative results.

This paper provides an innovative contribution to this field by constructing a theoretical framework for how government subsidies promote the technological innovation of enterprises and by conducting an empirical study, thus adding to the theory on subsidy policies and company technological innovation. Based on past research, this paper found that studies have mainly concentrated on the mechanism of subsidies, in terms of the enterprise size, market demand, type of R&D input, industry peculiarities, etc. while there have been few theories dedicated to patent-intensive industries. This paper develops an analysis framework for government subsidies, from a property right heterogeneity and regional heterogeneity perspective. Thus, relevant suggestions for the development of patent-intensive industries were put forward. Furthermore, as there have also been few studies on the connection between subsidies and innovative performance in patent-intensive industries, this paper also tried to elucidate this issue. The three major policy-supported regions had not previously been used as a sample in research on patent-intensive industries, and the existing research is largely geographically partitioned into the east and west (Shao and Fang, 2021; Guan and Chen, 2010). This research, therefore, fills the gap represented by the above aspects.

There are also some shortcomings to this article. It studied the effect of government subsidies on technological innovation solely from an input-output perspective, even though various other factors, such as enterprise size, profitability, etc. can also affect the function of government subsidies. In terms of its variable measurement, this paper chose the indicator that could most accurately reflect the current status, while ignoring the other indicators available for measuring innovative performance. In summary, this article could be further improved in the areas described above.

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References

Albert, G.Z. and Ivan, P.L. (2012) 'Patent rights and economic growth: evidence from cross-country panels of manufacturing industries', *Social Science Electronic Publishing*, Vol. 65, No. 3, pp.675–698 [online] https://doi.org/10.1093/oep/gpt011.

Bonte, W. (2004) 'Spillovers from publicly financed business R&D: some empirical evidence from Germany', *Research Policy*, Vol. 33, pp.1635–1655 [online] https://doi.org/10.1016/j.respol.2004.09.009.

Bronzini, R. and Piselli, P. (2016) 'The impact of R&D subsidies on firm innovation', *Research Policy*, Vol. 45, No. 2, pp.442–457 [online] https://doi.org/10.1016/j.respol.2015.10.008.

Catozzella, A. and Vivarelli, M. (2014) 'The catalysing role of in-house R&D in fostering complementarity among innovation inputs', *The Journal of Industry and Innovation*, Vol. 21, No. 3, pp.179–196 [online] https://doi.org/10.1080/13662716.2014.910890.

Chen, J., Heng, C.S., Tan, B.C.Y. and Lin, Z. (2018) 'The distinct signaling effects of R&D subsidy and non-R&D subsidy on IPO performance of IT entrepreneurial firms in China', *Research Policy*, Vol. 47, No. 1, pp.108–120 [online] https://doi.org/10.1016/j.respol.2017.10.004.

Chen, X. and Li, Q. (2021) 'Environmental regulation, subsidy and underperforming firms' R&D expenditure: evidence from Chinese listed companies', *International Journal of Technology Management*, Vol. 85, Nos. 2–4, pp.190–211 [online] https://dx.doi.org/10.1504/IJTM.2021.115265.

Choi, J. and Lee, J. (2017) 'Repairing the R&D market failure: public R&D subsidy and the composition of private R&D', *Research Policy*, Vol. 46, No. 8, pp.1465–1478 [online] https://doi.org/10.1016/j.respol.2017.06.009.

Chu, A.C. and Cozzi, G. (2018) 'Effects of patents versus R&D subsidies on income inequality', *Review of Economic Dynamics*, Vol. 29, pp.68–84 [online] https://doi.org/10.1016/j.red.2017.12.006.

Dimos, C. and Pugh, G. (2016) 'The effectiveness of R&D subsidies: a meta-regression analysis of the evaluation literature', *Research Policy*, Vol. 45, No. 4, pp.797–815 [online] https://doi.org/10.1016/j.respol.2016.01.002.

Du, J. and Mickiewicz, T. (2016) 'Subsidies, rent seeking and performance: being young, small or private in China', *Journal of Business Venturing*, Vol. 31, No. 1, pp.22–38 [online] https://doi.org/10.1016/j.jbusvent.2015.09.001.

European Patent Office and European Union Intellectual Property Office (2020) *IPR-Intensive Industries and Economic Performance in the European Union*, Alicante [online] https://euipo.europa.eu/tunnel-web/secure/webdav/guest/document_library/observatory/documents/IPContributionStudy/IPR-intensive_industries_and_economicin_EU/WEB_IPR_intensive_Report_2019.pdf (accessed 20 April 2022).

Guan, J. and Chen, K. (2010) 'Measuring the innovation production process: a cross-region empirical study of China's high-tech innovations', *Technovation*, Vol. 30, Nos. 5–6, pp.348–358 [online] https://doi.org/10.1016/j.technovation.2010.02.001.

Guo, F., Zhang, X., Bo, Q. and Li, K. (2020) 'Financial slack and firm performance of SMMEs in China: moderating effects of government subsidies and market-supporting institutions', *International Journal of Production Economics*, Vol. 223, p.107530 [online] https://doi.org/10.1016/j.ijpe.2019.107530.

Harhoff, D. and Hall, B. (2007) 'The strategic use of patents and its implications for enterprise and competition policies', *European Commission: Technology Report* [online] https://doi.org/10.1111/radm.12193.

Jeon, H. (2019) 'Patent protection and R&D subsidy under asymmetric information', *International Review of Economics & Finance*, Vol. 62, pp.332–354 [online] https://doi.org/10.1016/j.iref.2019.04.001.

Ji, J. and Yi, Y. (2022) 'Value variations of political ties in the acquisition of R&D capabilities: the roles of non-SOEs and dysfunctional competition', *Industrial Marketing Management*, Vol. 101, pp.1–11 [online] https://doi.org/10.1016/j.indmarman.2021.11.012.

Kim, Y.K., Lee, K., Park, W.G. and Choo, K. (2012) 'Appropriate intellectual property protection and economic growth in countries at different levels of development', *Research Policy*, Vol. 41, No. 2, pp.358–375 [online] https://doi.org/10.1016/j.respol.2011.09.003.

Kleer, R. (2014) 'Government R&D subsidies as a signal for private investors', *Research Policy*, Vol. 39, No. 10, pp.1361–1374 [online] https://doi.org/10.1016/j.respol.2010.08.001.

Lee, C. (2011) 'The differential effects of public R&D support on firm R&D: theory and evidence from multi-country data', *Technovation*, Vol. 31, No. 5, pp.256–269 [online] https://doi.org/10.1016/j.technovation.2011.01.006.

Li, M., Lien, J.W. and Zheng, J. (2021) 'Optimal subsidies in the competition between private and state-owned enterprises', *International Review of Economics & Finance*, Vol. 76, pp.1235–1244 [online] https://doi.org/10.1016/j.iref.2019.11.011.

Liang, X., Lu, X. and Wang, L. (2012) 'Outward internationalization of private enterprises in China: the effect of competitive advantages and disadvantages compared to home market rivals', *Journal of World Business*, Vol. 47, No. 1, pp.134–144 [online] https://doi.org/10.1016/j.jwb.2011.02.002.

Lin, J., Wu, H. and Wu, H. (2021) 'Could government lead the way? Evaluation of China's patent subsidy policy on patent quality', *China Economic Review*, Vol. 69, p.101663 [online] https://doi.org/10.1016/j.chieco.2021.101663.

Liu, W., Song, Y. and Bi, K. (2021) 'Exploring the patent collaboration network of China's wind energy industry: a study based on patent data from CNIPA', *Renewable and Sustainable Energy Reviews*, Vol. 144, p.110989 [online] https://doi.org/10.1016/j.rser.2021.110989.

Luo, Y., Zhao, H., Wang, Y. and Xi, Y. (2011) 'Venturing abroad by emerging market enterprises', *Management International Review*, Vol. 51, No. 4, pp.433–459 [online] https://doi.org/10.1007/s11575-011-0087-y.

Mansfield, E. (1986) 'Patents and innovation: an empirical study', *Management Science*, Vol. 32, pp.173–181 [online] https://doi.org/10.1287/mnsc.32.2.173.

Mao, G., Han, Y., Liu, X., Crittenden, J., Huang, N. and Ahmad, U.M. (2022) 'Technology status and trends of industrial wastewater treatment: a patent analysis', *Chemosphere*, Vol. 288, No. 2, p.132483 [online] https://doi.org/10.1016/j.chemosphere.2021.132483.

Mardones, C. and Velásquez, A. (2021) 'Macroeconomic, intersectoral, and environmental effects of R&D subsidies in Chile: an input-output approach', *Technological Forecasting and Social Change*, Vol. 173, p.121112 [online] https://doi.org/10.1016/j.techfore.2021.121112.

Maskus, K.E., Milani, S. and Neumann, R. (2019) 'The impact of patent protection and financial development on industrial R&D', *Research Policy*, Vol. 48, No. 1, pp.355–370 [online] https://doi.org/10.1016/j.respol.2018.09.005.

National Bureau of Statistics of China (2021) *Bulletin on the Value-added Data of National Patent Intensive Industry in 2020*, Beijing [online] http://www.stats.gov.cn/english/PressRelease/202112/t20211231_1825790.html (accessed 20 April 2022).

Pu, L., Wang, X., Tan, Z., Wang, H., Yang, C. and Wu, J. (2020) 'Is China's electricity price cross-subsidy policy reasonable? Comparative analysis of eastern, central, and western regions', *Energy Policy*, Vol. 138, p.111250 [online] https://doi.org/10.1016/j.enpol.2020.111250.

Shao, Q. (2020) 'Nonlinear effects of marine economic growth and technological innovation on marine pollution: panel threshold analysis for China's 11 coastal regions', *Marine Policy*, Vol. 121, p.104110 [online] https://doi.org/10.1016/j.marpol.2020.104110.

Shao, X. and Fang, T. (2021) 'Performance analysis of government subsidies for photovoltaic industry: based on spatial econometric model', *Energy Strategy Reviews*, Vol. 34, p.100631 [online] https://doi.org/10.1016/j.esr.2021.100631.

Sweet, C. and Eterovic, D. (2019) 'Do patent rights matter? 40 years of innovation, complexity and productivity', *World Development*, Vol. 115, pp.78–93 [online] https://doi.org/10.1016/j.worlddev.2018.10.009.

Szücs, F. (2020) 'Do research subsidies crowd out private R&D of large firms? Evidence from European Ffamework programmes', *Research Policy*, Vol. 49, No. 3, p.103923 [online] https://doi.org/10.1016/j.respol.2020.103923.

Tian, Q., Holland, J.H. and Brown, D.G. (2016) 'Social and economic impacts of subsidy policies on rural development in the Poyang Lake Region, China: insights from an agent-based model', *Agricultural Systems*, Vol. 148, pp.12–27 [online] https://doi.org/10.1016/j.agsy.2016.06.005.

US Patent and Trademark Office (2020) *Intellectual Property and the U.S. Economy*, 3rd ed., Washington [online] https://www.uspto.gov/sites/default/files/documents/uspto-ip-us-economy-third-edition.pdf (accessed 20 April 2022).

Wang, J. and Yang, L. (2020) 'Does factor endowment allocation improve technological innovative performance? An empirical study on the Yangtze River Delta region', *Science of the Total Environment*, Vol. 716, p.137107 [online] https://doi.org/10.1016/j.scitotenv.2020.137107.

Wu, Y., Gu, F., Ji, Y., Guo, J. and Fan, Y. (2020) 'Technological capability, eco-innovative performance, and cooperative R&D strategy in new energy vehicle industry: evidence from listed companies in China', *Journal of Cleaner Production*, Vol. 261, p.121157 [online] https://doi.org/10.1016/j.jclepro.2020.121157.

Xu, X., Zhang, W., Wang, T., Xu, Y. and Du, H. (2021) 'Impact of subsidies on innovations of environmental protection and circular economy in China', *Journal of Environmental Management*, Vol. 289, p.112385 [online] https://doi.org/10.1016/j.jenvman.2021.112385.

Yang, C., Xia, R., Liu, H., Shi, T. and Wu, G. (2021) 'Comparing hillside urbanizations of Beijing-Tianjin-Hebei, Yangtze River Delta and Guangdong-Hong Kong-Macau Greater Bay Area urban agglomerations in China', *International Journal of Applied Earth Observation and Geoinformation*, Vol. 102, p.102460 [online] https://doi.org/10.1016/j.jag.2021.102460.

Yu, F. and Guo, Y. (2016) 'The impact of government subsidies and enterprises R&D investment: a panel data study from renewable energy in China', *Energy Policy*, Vol. 89, No. 6 [online] http://dx.doi.org/10.1016/j.enpol.2015.11.009.

Yu, H., Chang, X. and Liu, W. (2021) 'Cost-based subsidy and performance-based subsidy in a manufacturing-recycling system considering product eco-design', *Journal of Cleaner Production*, Vol. 327, p.129391 [online] https://doi.org/10.1016/j.jclepro.2021.129391.

Zhou, W., Gu, R. and Lu, S. (2020) 'Penetrating the real performance of SSE STAR enterprises: a double-market investigation', *Finance Research Letters*, Vol. 37, p.101346 [online] https://doi.org/10.1016/j.frl.2019.101346.

Notes

1 The 13th Five-Year Plan refers to the outline of the 13th Five-Year Plan for the national economic and social development of the People's Republic of China. The Five-Year Plan, an important part of China's national economic plan, is a long-term plan, mainly for planning major national construction projects, productivity distribution, and important proportional relationships of the national economy, etc. as well as for setting goals and directions for the national economic development.

2 ST means the firm had been running in the red for two years in a row; *ST refers to running in the red for three years in a row.

3 WIND is a supplier of financial data and analysis tools from China.