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R&D tax credits and firm innovation: Evidence from China☆

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ABSTRACT

Scholars currently have a limited understanding of the role of R&D tax credit in developing countries. To help fill this gap, this article examines the allocation logic and innovative consequences of R&D tax credit in China. Using a panel data set of listed companies in China from 2010 to 2012, we show that the local institutional contexts, such as government transparency, market development, and industrial policies, promote the allocation of R&D tax credit. The fiscal capacity of local governments constrains the implementation of tax credit policy. Furthermore, this article estimates the causal effect of R&D tax credit on firm innovation. We find that R&D tax credit significantly increases firms' innovative input and output. The results are consistent and robust using various specifications. Yet the stimulation effect is heterogeneous across industries and scale. R&D tax credit only evidently promotes innovation in manufacturing firms and large firms.

1. Introduction

R&D tax credits and subsidies are two most popular instruments for governments to support R&D activities (Hall and Van Reenen, 2000). As a horizontal policy with market-oriented features (Czarnitzki et al., 2011), tax credit apparently calls more applause from the practitioners of advanced economies.

However, the effectiveness of tax credits is not guaranteed in any institutional contexts. The institutional context is vital for innovation efficiency (Guan and Chen, 2012). Previous studies have mainly focused on developed economies, with little evidence offered for developing and emerging countries (Zúñiga-Vicente et al., 2014). For instance, research shows that R&D tax credits can stimulate firm innovation in OECD countries (Bloom et al., 2002), the United States (Paff, 2005; Wu, 2005), Japan (Kobayashi, 2014) and Canada (Czarnitzki et al., 2011). As tax administration plays a crucial role in effective state institutions (Bird and de Jantscher, 1992), developing countries face great challenges in the establishment of efficient and effective tax systems, and have a limited capacity of tax administration (Tanzi and Zee, 2000). Therefore, the impact of R&D tax credits on innovation investment and performance in developing countries are quite suspicious (Crespi et al., 2016). Developing countries may have distinct allocation mechanisms of R&D tax credits.

As the biggest developing country, China provides an appropriate and unique setting for examining the allocation mechanisms and policy effectiveness of R&D tax credits. China has experienced a great boom in R&D input and output in the past decades. Despite the substantial market transition, the political institution in China is still centralized (Xu, 2011). The government plays a crucial role in the national innovation system and has advocated policy mixes involving tax credits, technological standard setting, and enforcement of intellectual property rights (Boeing, 2016). The role of government policies on the innovation boom is still under-examined.

China has formally adopted a nationwide R&D tax credit policy since 2008. In the R&D tax credit policy design, resident enterprises can deduct 150% of qualified R&D expenses from the corporate income tax. It suggests that R&D tax credit policy can reduce firm's income tax by about 7.5% to 12.5% of R&D expenditure.[1] In practice, the proportion of R&D tax credit was about 4% of total R&D expenditure from 2010 to 2014 (Fig. 1). The practical policy implementation is under the optimal policy design.

There have been few examinations of allocation mechanisms and consequences of R&D tax credits in China. The only exception is Guan and Yam (2015) and Zhang and Guan (2018), which provide important insights about R&D tax credit policies, and indicate that tax credit stimulates innovation in Beijing. Due to data availability, it is unknown

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[1] In tax law of China, the corporate income tax rate is 25%, and the tax rate of high-tech companies is 15%. In theory, R&D tax credit policy can reduce tax for about 7.5% to 12.5% of R&D investment.

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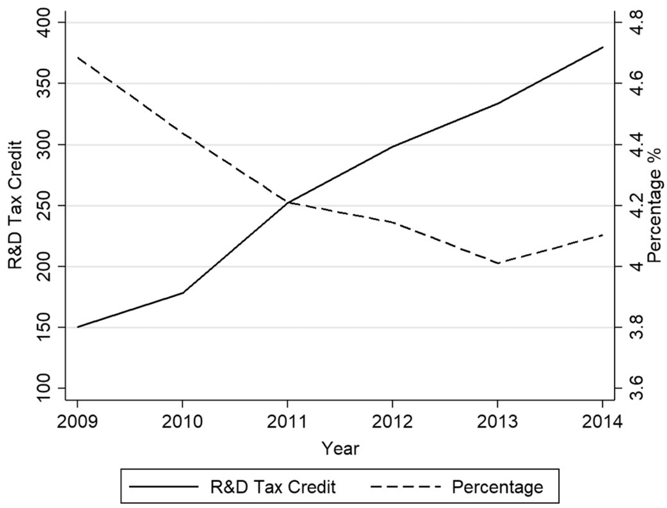

Fig. 1. R&D tax credit and its percentage in R&D expenditure.

whether nationwide R&D tax credit policy promotes firms innovation across various contexts.

To help fill this gap, we use a panel data of listed companies in China from 2010 to 2012 to estimate the consequence of R&D tax credit. To our knowledge, our data is the first firm-level micro data in China including self-reported R&D tax credit information. Our results show that the likelihood of receiving R&D tax credits is shaped by local institutional contexts. Firms in policy-preferred industries have an advantage in the receipt of R&D tax credit. Government transparency and local market development significantly raise the probability of receiving tax credits. Firms with a high managerial stockholding have stronger motivations to apply for R&D tax credit. The implementation of R&D tax credit policy is constrained by government fiscal capacity.

Moreover, we evaluate the influence of R&D tax credit on firm innovation. We find that R&D tax credit evidently increase R&D investment and patents. The results are consistent and robust across different specifications including entropy balancing method and instrumental variable estimation. Yet the stimulation effect is heterogeneous. It is more evident in the manufacturing industry and large firms. A variety of studies show that R&D tax credit has a larger effect in SMEs in developed countries (Baghana and Mohnen, 2009; Corchuelo and Martinez Ros, 2009; Kobayashi, 2014; Rao, 2016). The article provides unique evidence that R&D tax credit may be more salient in larger firms, which will enrich our understanding of R&D tax credit in different institutional context.

2. R&D tax credit and firm innovation

Innovation plays a critical role in the process of improving productivity rates and boosting economic growth. Particularly, R&D activities are the crucial engine of technology progress (Griliches, 1992; Howitt and Aghion, 1998; Rivera-Batiz and Romer, 1991). However, R &D programs face financial constraints in an incomplete capital market, and many firms treat the lack of external financial support as the main barrier to R&D activities (David et al., 2000; Harhoff and Körting, 1998). R&D investment is a part of fixed costs, and market structures are easily concentrated and imperfectly competitive, with a consequence of allocation inefficiency and asymmetric information (Hall, 2002; Spence, 1984). Policy instruments including R&D subsidies and tax credit are employed to reduce R&D uncertainty and fill the optimal private and social gap of R&D investment (Arrow, 1962; Nelson, 1959).

Tax credits leave the decisions of R&D programs to enterprises and reduce the discretionary decisions in the selection process of R&D subsidies (Czarnitzki et al., 2011; Yang et al., 2012). Tax credit is more neutral and market-oriented and better able to reduce asymmetric information of R&D activities than R&D subsidies. It is designed in a bottom up fashion and less subject to policy inefficiencies, while R&D subsidies are more likely to lead to policy failure (Castellacci and Lie, 2015). Hall and Van Reenen (2000) examine the pre-2000 literature and conclude that tax credits significantly increase R&D expenditure. The majority of literature supports the positive impact of R&D tax credits on R&D expenditure across many countries and areas (Bloom et al., 2002; Czarnitzki et al., 2011; Yang et al., 2012).

Institutional context is critical for the evaluation of R&D tax credits. Specifically, the design of the R&D tax system varies widely across space and time. Different R&D tax credit designs may have distinct effects on firms' innovative incentives.[2] For example, a deadweight loss is associated with volume-based R&D tax incentives rather than incremental tax credits (Baghana and Mohnen, 2009; Lokshin and Mohnen, 2012). In addition, institutional context may shape the impact of R&D tax credit. The consequence of R&D tax credits might be limited in areas with low concentrations of R&D activities and weak innovation culture (Howells, 2005). Moreover, institutional characteristics, such as institutional credibility and expected return, are critical for the effectiveness of R&D tax credit. The uncertainty of institutional credibility might impede firms from forming durable expectations of government support, and firms are not sensitive to the tax credits. Stable tax incentives are more effective over time (Becker, 2015).

Moreover, tax credits might be less effective in stimulating projects with high social return and investment in exploratory projects and development of research infrastructure (David et al., 2000; Hall and Van Reenen, 2000). In a long-term, The R&D demands of firms respond slowly over time to changes in the user cost of R&D expenditure (Harris et al., 2009). The effectiveness of tax credit can be constrained in the short term.

The effect of R&D tax credit may be heterogeneous in firms' size and sectors. Sector has specific technological opportunities, market competition, knowledge diffusion and constraints, shaping how firms organize innovative activities (Castellacci and Lie, 2015; Dosi, 1982; Pavitt, 1984). The influence of tax credit may be contingent on sectoral characteristics. In addition, the effect of tax credit may be different between SMEs and large firms. A set of works show that R&D tax credit has a larger impact for SMEs in countries such as US (Rao, 2016), Canada (Baghana and Mohnen, 2009), Spain (Corchuelo and Martinez Ros, 2009), and Japan (Kobayashi, 2014).

The empirical evidence from developing and emerging countries is limited. It is still unclear how the effect of R&D tax credits varies across industries, and how institutional contexts shapes the allocation of R&D tax credit. To help fill the literature gap, we use China as a typical case, and estimate the effects of volume-based R&D tax credit on firms innovation.

3. R&D tax credit in China

The evolution of China's R&D tax credit policies has three stages. The first state is the reform experiments. The R&D tax credit policy was experimentally adopted in China in the 1990s. Only firms in high-tech zones or science and technology parks were eligible to deduct tax for their R&D expense. The tax credit was dispersive in different policy programs and unclear in categories and rate of tax reduction. The second stage is the nationwide implementation. Since 2008, China has formally adopted a nationwide volume-based R&D tax credit policy to stimulate firms' R&D activities. China mainly provides the tax deduction for firms with the Technologically Advanced Service Company and the High-New Technology Enterprise status and industries including

[2] There are two main tax credit designs: incremental and volume based tax credits. Incremental tax credit applies to additional amount of R&D investment above a specific base amount, volume tax credit applies to all qualified R&D investment.

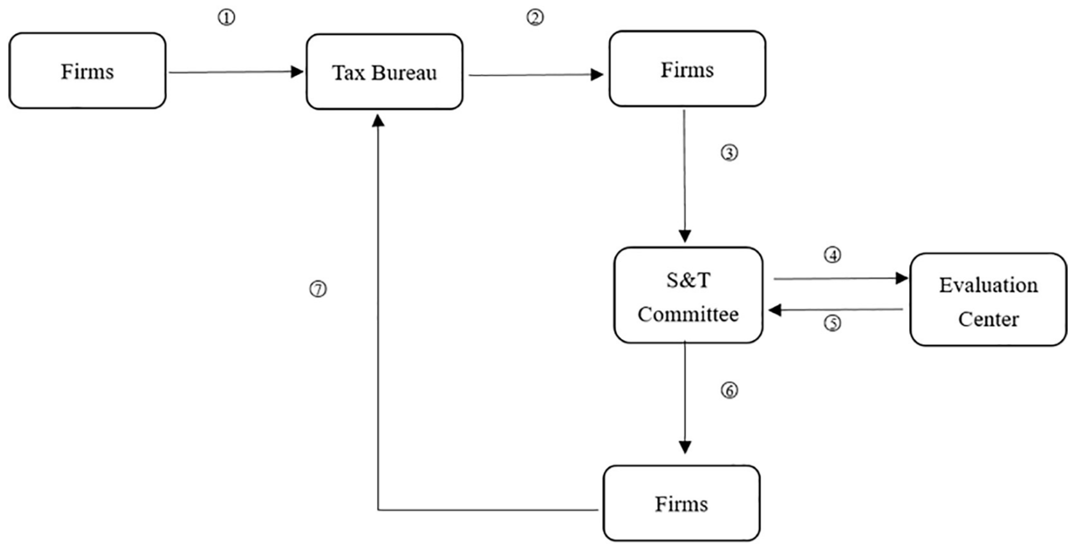

Fig. 2. Procedures of applying R&D tax credit for firms.

electronic, biological medicine, new materials, new energy, and aerospace technology. The third stage is the policy adjustment since 2015. To directly stimulate more innovative activities, several industries such as real estate, retail sales, and entertainment are restricted to receive R&D tax credit.

Based on the policy design, firms can deduct 150% of qualified R&D expenses from the corporate income, and pay income tax at the tax rate of 15% to 25%. It reveals that R&D tax credit policy can reduce firm's income tax by about 7.5% to 12.5% of R&D expenditure. China has no thresholds or ceilings for R&D tax credit, and has a larger reduced tax rate than many developed countries such as the United States, Japan, Canada, and France. Yet the design and implementation of the tax credit policy are at the initial stage, and the institutions and regulations are not explicit.

Chinese firms need to accomplish several procedures to obtain R&D tax credits (Fig. 2). First, firms need to get application forms from local tax bureau, and then submit materials including application forms, R&D budget, contacts, project proposals and reports to Science and Technology (S&T) Committee of local government. S&T Committee then delegates the third-party evaluation center to authenticate the scope and amount of R&D cost. The evaluation center provides expertise reports about verified R&D cost. After S&T Committee approves the score and amount of R&D cost, firms submit all the related materials to local tax bureau for R&D tax credit.

In general, firms receive the tax credit for previous year's R&D expenditure. The complicated process involves several government institutes' coordination and information exchange. As a result, the receipt of R&D tax credit may be contingent on government transparency and efficiency. The implementation of R&D tax credit policy partly relies on the discretion of local government.

4. Data and variables

We employ data from the "Corporates' Restructuring and Upgrading" survey conducted by the China Association for Public Companies and Shenzhen Stock Exchange (SZSE) in 2013. The survey includes R&D tax credits and expenditure information on 1256 listed companies in the SZSE from 2010 to 2012.[3] To the best of our knowledge, the data is the first firm-level survey data in China including nationwide self-reported R&D tax credit information. The SZSE is one of two stock exchanges in mainland China. The Small and Medium-sized Enterprise (SME) Board was launched in 2004, and the ChiNext Board was launched in 2009 aiming to attract innovative high-tech firms. The SZSE has become China's major stock exchange for SMEs and high-tech firms; 58.49% of firms applied for at least one patent and 83.60% of firms are in manufacturing and information technology industries. The sample can well represent China's high-tech firms. The key characteristic variables of companies are obtained from the China Stock Market and Accounting Research database.

R&D expenditure only captures firms' innovative input, we further adopt the number of patents to proxy innovative output. The patent data is obtained from the patent search platform of the State Intellectual Property Office of China, which records firms' domestic and international patent information.[4]

Our analysis includes key independent variables that might shape the distribution and effects of R&D tax credits.

Scale and Listed age. Studies such as González and Pazó (2008) show that more experienced firms are more likely favored by subsidies. The founding year of some firms is incomplete in the database or disordered as the result of merger or restructuring. We choose the listed age as a proxy of firms' experience. As most Chinese firms have been founded since the 1980s, the difference between the founded year and listed age is comparatively small. The average listed age is 6.22 years, and most firms were listed in the past 10 years.

Debt-to assets ratio. Firm's innovative behavior is constrained by financial conditions. A deficient debt-to-assets ratio constrains the investment intensity of R&D activities, and partly reflects the financial condition of firms. The debt-to-assets ratio is thus included in the model.

Corporate governance. The structure of corporate governance or property rights is crucial for R&D policy-making and the incentives of the R&D program application and operation. Yi et al. (2017) indicate that regulatory institutions such as state ownership shape firm's innovation performance. State ownership may have negative effects on firm's R&D activities (Lin et al., 2010). Foreign R&D investment in China might confront barriers such as human resource management, bureaucracy, and concerns about intellectual property rights protection (Gassmann and Han, 2004), which weaken the motivations for R&D activities. The long-term incentives and managers' characteristics

[3] Some of the firms were listed in 2011 or 2012, and thus no related information is available before the listed year.

[4] We use the name of each firm to search for the number of patents in specific year and then construct the patent variable. The link for the website is www.pss-system.gov.cn/sipopublicsearch/portal/index.shtml.

appear to be associated with firm innovation (Barker III and Mueller, 2002; Lerner and Wulf, 2007). Thus, we control the stock holding shares of state-owned enterprise (SOE) and stock holding share of managers to identify the types of property rights and managers' motivations.

Policy preferred industries. The R&D tax credit policy in China aims to stimulate innovation in key areas such as information and communication technology (ICT), biotechnology, and aerospace technology. To identify policy favored industries, we construct the policy-preferred industry dummy. If firms are in manufacturing, ICT and scientific research, and technical services, the dummy is given a value of 1, otherwise 0.

Government transparency. Transparency is a crucial element of good governance (Stiglitz, 2003). Government transparency could constrain power and make a credible commitment to citizens (Kolstad and Wiig, 2009; Wehner and De Renzio, 2013). In addition, government transparency may promote the information exchange between firms and government, and reduce the inefficiency of policy implementation. As a result, government transparency may reduce the policy uncertainty and make firms more likely to receive R&D tax credit. We adopt the provincial government information disclosure index to measure government transparent level and match government transparency information with firms' location.

Marketization level. R&D tax credit is a market-oriented policy tool, and the implementation of R&D tax credit could be shaped by local market environment. Areas with high marketization level have better institutional environment to protect intellectual property rights and well-developed innovation intermediaries (Aldrich and Fiol, 1994; Yi et al., 2017). We use the provincial-level marketization index from Fan et al. (2011) to measure local market environment. To reduce the endogeneity, we construct a marketization dummy. If the marketization index in a province is larger than the national average, it is identified as 1; otherwise is 0.

Fiscal revenue. The implementation of R&D tax credit may be contingent on local governments' fiscal capacity. Local government with high fiscal revenue tends to have more resources to support firms' innovative activities, while weak fiscal capacity constrains local governments to provide more R&D tax credit. We use prefecture governments' fiscal revenue as a proxy of fiscal capacity. The data is collected from China City Statistical Yearbook. In the sample, 73.91% of firms received R&D tax credits, which presents an increasing trend from 2010 to 2012. Firms' average R&D expenditure is 63.76 million yuan. Table 1 shows the descriptive statistics for key variables.

Table 1
Descriptive statistics.

Variable	*N*	Mean	SD
R&D expenditure	3274	6376.634	30,393.370
The number of patent	3274	27.907	196.049
R&D tax credit	3274	3363.340	12,821.160
Listed age	3274	6.331	5.881
Stock share of SOE	3274	0.046	0.132
Managerial stockholding proportion	3274	0.175	0.228
Employees	3274	2851.827	7377.118
Gross revenue (log)	3274	20.594	1.735
Debt-to-assets ratio	3274	0.379	0.681
Policy preferred industries	3274	0.837	0.369
Government transparency (province)	3265	0.703	0.153
Fiscal revenue (prefecture)	3274	3249.924	1740.968
Marketization level (province)	3274	0.878	0.328
Fiscal autonomy (prefecture)	3259	0.773	0.216

5. Empirical results

5.1. The allocation of R&D tax credit

We use the binary logistical model to estimate the allocation logics of R&D tax credit in China. The dependent variable is whether firms received R&D tax credits or not. The recipient of R&D tax credits is coded as 1, the non-recipient is coded as 0.

$$log\left(\frac{P_i}{1-P_i}\right) = \alpha X_{it} + \beta \gamma_i + \delta_I + \lambda_t \tag{1}$$

where P_i is the likelihood that firm i receives the R&D tax credit, X_{it} is time-variant determinants. γ_i is time-invariant factors. δ_I is industrial dummies, λ_t is year dummies.

Column (1) of Table 2 shows the baseline results. We plot the estimated likelihood of industries to receive R&D tax credit using results in Column (1). Fig. 3 presents that firms are more likely to obtain R&D tax credit in ICT, manufacturing, scientific research and technical services. We employ the prior period R&D expenditure and patents to capture firms' innovation activities. The estimated results in Column (2) present that previous R&D activity is the critical criterion for the allocation of R&D tax credit.

The R&D tax credit policy in China aims to stimulate innovation in key areas such as information and communication technology (ICT), biotechnology, and aerospace technology. The likelihood of receiving R&D tax credit varies in different industries. We further construct the policy-preferred industry dummy including manufacturing, ICT, and scientific research and technical services. Column (3) of Table 2 shows that firms in policy-preferred industries are more likely to receive R&D tax credits. The result is significant at 1% level. The distribution of R&D credit is consistent with the policy design. Fig. 3 depicts the estimated coefficients in Table 2. It further shows that ICT and manufacturing firms are more likely to obtain R&D tax credit.

We further investigate whether local institutional attributes shape the allocation of R&D tax credit. Column (4) of Table 2 shows that government transparency significantly improves firm's likelihood to receive R&D tax credit. Government transparency may reduce policy uncertainties, and enable firms to be more likely to apply and receive R&D tax credit. In addition, the results in Column (5) indicate that marketization level significantly increases the possibility of firms to receive R&D tax credits. The results prove that market development is critical in the allocation of R&D credit.

Local governments' fiscal capacity may constrain the implementation of R&D tax credit. Governments with strong fiscal resources possess more resources to support innovative activities. Column (5) of Table 2 confirms that high government fiscal revenue significantly promotes local firms' chance of receiving R&D tax credit. The implementation of R&D tax credit policy is constrained by local fiscal capacity.

Moreover, the estimated results show that young firms are more likely to obtain the R&D tax credit. A high managerial stockholding proportion tends to significantly increase the probability of receiving tax credits. When managers hold high stock shares, they might have strong incentives to promote the development of firms. Furthermore, SOEs in China enjoy a variety of policy favoritism. Wu (2017) indicates that state-owned enterprises have the advantage in receiving governments' subsidies. However, our results imply that stock share of SOEs does not increase the probability of receiving R&D tax credit. It implies that the allocation of R&D tax credit may have less ownership discrimination than the distribution of subsidies.

5.2. The impact of R&D tax credit

Our data contains rich information about the amount of R&D tax credit, and allows us to use the panel data analysis to examine the effect of R&D tax credit on firm innovation. Model (2) shows the specification:

Table 2
The distribution of R&D tax credits (logit model).

	(1)	(2)	(3)	(4)	(5)	(6)
R&D expenditure (*t*-1)		0.332***				
		(0.025)				
Patent (*t*-1)		0.162***				
		(0.047)				
Policy preferred industries			2.482***			
			(0.135)			
Government transparency				0.884**		
				(0.361)		
Marketization level					0.636***	
					(0.137)	
Government fiscal revenue						0.283***
						(0.041)
Listed age	−0.101***	−0.054***	−0.100***	−0.099***	−0.094***	−0.095***
	(0.010)	(0.014)	(0.010)	(0.010)	(0.010)	(0.010)
Stock share of SOE	−0.140	0.638	0.003	−0.088	−0.002	−0.157
	(0.350)	(0.491)	(0.327)	(0.351)	(0.349)	(0.349)
Managerial stock proportion	2.424***	2.257***	2.618***	2.397***	2.391***	2.324***
	(0.334)	(0.395)	(0.332)	(0.335)	(0.336)	(0.336)
Employees	0.276***	−0.073	0.255***	0.275***	0.260***	0.296***
	(0.045)	(0.064)	(0.041)	(0.045)	(0.047)	(0.047)
Gross revenue	−0.019	−0.048	−0.023	−0.017	−0.014	−0.008*
	(0.027)	(0.036)	(0.025)	(0.028)	(0.027)	(0.029)
Debt-to-assets ratio	0.133***	0.044	0.108**	0.132***	0.141***	0.140***
	(0.044)	(0.135)	(0.044)	(0.043)	(0.042)	(0.043)
Year fixed	Y	Y	Y	Y	Y	Y
Industry fixed	Y	Y	N	Y	Y	Y
Pseudo R^2	0.329	0.426	0.309	0.330	0.335	0.343
N	3258	2363	3274	3249	3258	3243

Notes: Robust standard errors in parentheses. Employees, R&D expenditure and gross revenue are logarithmic values. Constants are not reported.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

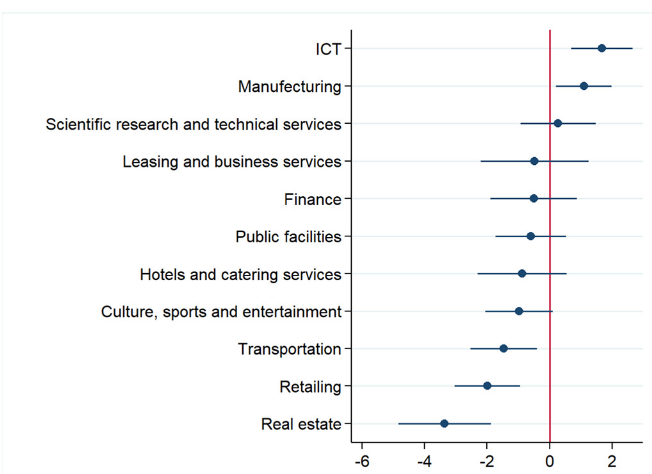

Fig. 3. The likelihood of obtaining R&D tax credits across industries.

$$R_{it} = \beta Tax\ Credit_{it} + \alpha X_{it} + \lambda_i + \rho_t + \varepsilon_{it} \tag{2}$$

where R_{it} is the logarithmic value of R&D expenditure and patent. $Tax\ Credit_{it}$ refers to the logarithmic value of R&D tax credits firm i obtained. In the model, we control current period of R&D tax credits. As shown in Fig. 2, there are several procedures for firms to obtain R&D tax credits. It takes time for firms to finish these steps. Any clogs may prolong the time to obtain the tax credit. As a result, the current amount of tax credit can reflect the actual tax credit in the previous year. X_{it} is a vector of control variables. λ_i indicates firm fixed effect to capture firm-specific time-invariant factors that might affect firm innovation; ρ_t is year fixed effect, and captures year specific policy dynamics. ε_{it} is the error term.

In general, the empirical results indicate that R&D tax credit stimulates firm innovative input and output. In particular, Column (1) of Table 3 shows that the elasticity of R&D expenditure with respect to the R&D tax credit is 0.246 and statistically significant at the 1% level.[5] Column (1) of Table 4 demonstrates that the elasticity of patent with respect to the R&D tax credit is 0.027 and statistically significant at the 10% level. R&D tax credit tends to have a larger facilitation effect in R&D expenditure than in patent.

The effect of R&D tax credit may be heterogeneous across industries. As shown in Columns (2) to (9) in Table 3, we find that tax credit only significantly promotes R&D investment in manufacturing, public facilities and culture, sports and entertainments. It fails to promote R&D investment in remaining industries such as information and communication technology (ICT) and scientific research and technical services. Similarly, Table 4 shows the influence of R&D tax credit on firms' patent. Columns (2) to (9) indicate that tax credit only increases the number of patents in manufacturing firms. In sum, R&D tax credit consistently promotes innovative input and output in manufacturing. Yet the stimulation effect is limited in other industries. In the allocation of tax credit, local governments evidently prioritize several industries such as ICT, manufacturing and scientific research and technical services. However, R&D tax credit only significantly stimulates innovative input and output in manufacturing. The allocation of R&D tax credit has certain mismatch.

Furthermore, the influence of R&D tax credit may vary in the size of firms. Large sized firms are generally measured by > 249 employees, small firms have employees < 50, and the number of employees in medium-sized firms is between50 and 249 (Bayona et al., 2001). Based on the criteria, 94.11% of firms in our sample is large firms. Columns

[5] We also use the random effect model for estimation and the results are similar. The *p*-value for the Hausman test is < 0.001, indicating that the fixed effect model is more proper.

Table 3
R&D tax credit and R&D expenditure (industry).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All	Manufacturing	ICT	Real estate	Retailing	Transportation	Facilities	Culture	Science
Tax credit	0.246***	0.144***	−0.019	−1.137	0.337	0.881	0.693**	1.131***	0.073
	(0.016)	(0.015)	(0.045)	(23.031)	(0.897)	(0.843)	(0.311)	(0.051)	(0.478)
Listed age	0.162***	0.123***	0.175**	0.505**	0.123	0.191	0.174	0.575**	1.565
	(0.031)	(0.028)	(0.075)	(0.252)	(0.232)	(0.267)	(0.171)	(0.246)	(1.082)
Stock share of SOE	0.255	0.414*	−0.203	−0.025	−4.947	−0.377	0.501	1.107	1.775
	(0.232)	(0.235)	(0.550)	(1.265)	(3.247)	(0.941)	(0.642)	(1.269)	(5.298)
Managerial stock proportion	0.156	0.059	−1.085*	6.389**	−3.471	−0.062	2.263	66.771*	1.786
	(0.282)	(0.240)	(0.600)	(3.182)	(6.388)	(2.373)	(4.595)	(33.655)	(8.933)
Employees	0.100**	0.105**	0.894***	0.153	0.152	0.134	−0.236	−0.049	−2.100
	(0.050)	(0.052)	(0.139)	(0.226)	(0.349)	(0.782)	(0.444)	(0.210)	(4.242)
Gross revenue	−0.002	−0.007	0.251	−0.018	−0.020	0.448	−0.014	−0.097	1.910
	(0.016)	(0.021)	(0.163)	(0.168)	(0.052)	(0.678)	(0.018)	(0.577)	(2.837)
Debt-to-assets ratio	0.006	0.026	0.187	−0.081	0.018	−0.866	0.168	2.239	−7.226
	(0.026)	(0.099)	(0.640)	(0.266)	(0.042)	(2.410)	(0.301)	(2.569)	(24.868)
Firm fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	3274	2482	227	144	134	71	40	38	32
R^2	0.120	0.055	0.111	0.255	0.139	0.395	0.405	0.098	0.005

Notes: Robust standard errors in parentheses. Employees, R&D tax credits and gross revenue are logarithmic values. Constants are not reported.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 4
R&D tax credit and patents (industry).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All	Manufacturing	ICT	Real estate	Retailing	Transportation	Facilities	Culture	Science
Tax credit	0.027*	0.032*	0.003	1.197	0.224	−0.226	−0.030	0.005	−0.248
	(0.014)	(0.018)	(0.081)	(8.431)	(0.356)	(0.383)	(0.436)	(0.038)	(0.157)
Listed age	0.045	0.038	0.007	−0.111	0.073	0.015	0.508*	0.169	−0.063
	(0.028)	(0.033)	(0.134)	(0.092)	(0.092)	(0.121)	(0.241)	(0.184)	(0.356)
Stock share of SOE	0.235	0.318	1.804*	−0.074	−1.360	−0.431	0.776	−1.805*	−1.290
	(0.207)	(0.280)	(0.988)	(0.463)	(1.288)	(0.428)	(0.901)	(0.953)	(1.744)
Managerial stock proportion	−0.565**	−0.603**	0.208	0.071	0.677	−1.589	−3.832	−36.291	3.969
	(0.251)	(0.285)	(1.077)	(1.165)	(2.534)	(1.079)	(6.449)	(25.264)	(2.941)
Employees	0.118***	0.164***	0.133	0.015	−0.147	0.180	−0.130	0.208	2.389
	(0.044)	(0.062)	(0.250)	(0.083)	(0.138)	(0.356)	(0.623)	(0.158)	(1.397)
Gross revenue	0.009	0.026	0.125	0.032	0.013	0.067	−0.025	−0.138	0.915
	(0.015)	(0.025)	(0.292)	(0.061)	(0.020)	(0.308)	(0.025)	(0.433)	(0.934)
Debt-to-assets ratio	0.012	0.065	2.048*	0.039	−0.008	−0.030	0.167	0.808	−4.995
	(0.023)	(0.118)	(1.148)	(0.097)	(0.017)	(1.096)	(0.423)	(1.929)	(8.187)
Firm fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	3274	2482	227	144	134	71	40	38	32
R^2	0.003	0.024	0.003	0.001	0.023	0.220	0.408	0.150	0.037

Notes: Robust standard errors in parentheses. Employees, R&D tax credits and gross revenue are logarithmic values. Constants are not reported.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

(1) and (3) of Table 5 present the results for SME (small and medium-sized enterprises). R&D tax credit has no evident effect on SME's R&D expenditure and patent. However, Columns (2) and (4) show that R&D tax credit has a positive and significant influence on large firms' R&D investment and patents. It indicates that the facilitation effect of R&D tax credit is mainly driven by large firms.

6. Robustness test

6.1. Entropy balancing

The allocation of R&D tax credit is not random, and can be endogenous to a variety of firm characteristics. The endogeneity problem may undermine the validity of main arguments. To mitigate the concern, we adopt a novel entropy balancing method. Compared with propensity score matching (PSM), entropy balancing is more effective in balancing the covariants, as it employs a reweighting scheme that directly incorporates covariate balance into the weight function, and generates a more comparable control group (Hainmueller, 2012; Hainmueller and Xu, 2013). The covariants include firms' key characteristics, industry and year dummies.

The treatment variable is a binary variable that implies whether a firm receives R&D tax credit in that year. The treatment group indicates the receipt of R&D tax credit. Table 6 presents the means and variances for the treatment and control group. After the reweighting by entropy balancing, the means of covariants in the control group are equal to the means in treatment group, the variances of covariants in the control group are close to the means in treatment group. It indicates that the

Table 5
The effect of R&D tax credit (size).

	(1)	(2)	(3)	(4)
	R&D expenditure		Patent	
	SME	Large	SME	Large
Tax credit	0.012	0.273***	0.042	0.027*
	(0.045)	(0.017)	(0.033)	(0.015)
Listed age	0.162	0.170***	−0.075	0.056**
	(0.121)	(0.032)	(0.089)	(0.028)
Stock share of SOE	0.711	0.263	0.009	0.273
	(0.738)	(0.245)	(0.545)	(0.218)
Managerial stock proportion	−0.014	0.140	−2.366	−0.569**
	(2.931)	(0.286)	(2.163)	(0.255)
Gross revenue	0.141	−0.001	−0.028	0.008
	(0.212)	(0.017)	(0.156)	(0.015)
Debt-to-assets ratio	0.299	0.007	−0.197	0.013
	(0.647)	(0.026)	(0.478)	(0.023)
Firm fixed	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y
N	203	3081	203	3081
R^2	0.596	0.133	0.078	0.002

Notes: Robust standard errors in parentheses. Employees, R&D tax credits and gross revenue are logarithmic values. Constants are not reported.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table 6
Robustness check I: Covariates balance test for entropy balancing.

	Treat		Control (before)		Control (after)	
	Mean	Variance	Mean	Variance	Mean	Variance
Listed age	4.865	22.59	10.49	42.13	4.865	23.34
Stock share of SOE	0.039	0.0148	0.065	0.025	0.039	0.015
Managerial stock proportion	0.217	0.057	0.058	0.020	0.217	0.058
Employees (log)	7.242	1.122	6.980	2.244	7.242	1.300
Gross revenue (log)	20.550	2.087	20.710	5.612	20.550	2.375
Debt-to-assets ratio	0.343	0.445	0.480	0.506	0.343	0.268

Notes: Results of entropy balancing across the treatment group ($N = 2420$), and the control group ($N = 854$).

entropy balancing scheme successfully balances both the means and variances of covariants.

Table 7 presents the OLS results with reweighting. It begins with a baseline specification and then incorporates all covariants for robustness check. Columns (1) and (3) show the baseline results and demonstrate that the treatment evidently promotes firms' R&D expenditure and patent at 1% level. After adding covariants, the results in Columns (2) and (4) are similar and consistent. The robustness test further confirms that R&D tax credit significantly increases firm's innovative input and output.

6.2. Instrumental variable method

In the above section, we use entropy balancing method to balance the covariants. Matching methods usually assume the fully observed covariates. Yet the assumption is unlikely to hold. The treatment effect is likely to be driven by various unobserved covariants, which may bias the main results. Thus, we use the instrumental variable method to further estimate the main results.

We construct an instrument variable using the prefecture governments' fiscal autonomy:

$$\text{Autonomy}_{ijt} = \frac{\text{Budgetary Revenue}_{ijt}}{\text{Budgetary Expenditure}_{ijt}} \tag{3}$$

Table 7
Robustness check I: OLS models with entropy balancing weights.

	(1)	(2)	(3)	(4)
	R&D expenditure		Patent	
Treatment	1.397***	1.391***	0.603***	0.601***
	(0.169)	(0.146)	(0.097)	(0.093)
Listed age		−0.127***		−0.031***
		(0.018)		(0.009)
Stock share of SOE		−0.919		−0.600*
		(1.217)		(0.339)
Managerial stock proportion		0.595**		−0.170
		(0.270)		(0.238)
Employees		0.848***		0.388***
		(0.080)		(0.046)
Gross revenue		0.054		−0.004
		(0.045)		(0.025)
Debt-to-assets ratio		0.133		−0.017
		(0.119)		(0.032)
Industry fixed	N	Y	N	Y
Year fixed	N	Y	N	Y
N	3274	3274	3274	3274
R^2	0.063	0.254	0.035	0.119

Notes: Standard errors in parentheses. Employees, R&D tax credits and gross revenue are logarithmic values. Constants are not reported.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

where i, j, t refer to firm, prefecture and year, respectively. $Autonomy_{ijt}$ captures the extent of a prefecture government's fiscal autonomy where firms are located.[6]

There are several reasons why fiscal autonomy is a proper instrument variable for the tax credit. First, fiscal autonomy matters for the allocation of tax credit. Fiscal autonomy reveals that local governments have more fiscal resources and discretion for public goods provision and policy implementation. Specifically, severe fiscal pressure motivates governments to impose higher effective tax rates (Chen, 2017). Oppositely, weak fiscal pressure undermines local governments' tax enforcement efforts (Esteller-Moré, 2005). China is one of the most fiscally decentralized countries in the world, local governments have strong incentives to promote market development (Xu, 2011). High fiscal autonomy may allow local governments to conduct larger tax cut and stimulate economic development.

Moreover, fiscal autonomy may be exogenous to unobserved firm characteristics. In China's contexts, it is nearly unlikely for unobserved firm attributes to shape local governments' fiscal capacity. Tax credit may be the only channel through which fiscal autonomy affects the dependent variables. The exclusion restriction assumption can be satisfied.

The estimated results using instrumental variable method are shown in Table 8. In Panel B, the first stage results show that fiscal autonomy is positively and significantly related to the R&D tax credit at 1% level, which indicates that fiscal autonomy allows local government to have more tax credit. The Kleibergen-Paap LM test is significant at 1% level. It confirms the canonical correlation between the instrument variable and tax credit. The relevance assumption of instrumental variable estimation is met. The Cragg-Donald Wald F statistics are larger than 10 in all specifications. The weak instrument concern can be ruled out.

Panel A of Table 8 presents the second stage results. Column (1) shows that tax credit evidently stimulates firms' R&D expenditure. After adding more firm characteristics, the results are similar and consistent in Column (2). In addition, Column (3) estimates the consequence of tax credit on firms' patents. The coefficient of tax credit is positive and

[6] The local revenue and expenditure data is from *China City Statistical Yearbook* in 2011, 2012, and 2013.

Table 8
Robustness check II: Instrument variable method.

	(1)	(2)	(3)	(4)
	R&D expenditure		Patent	
Panel A: Second stage				
Tax credit	0.565***	0.563***	0.267***	0.341***
	(0.112)	(0.148)	(0.070)	(0.107)
Listed age		−0.048		0.024
		(0.031)		(0.023)
Stock share of SOE		−0.358		−0.094
		(0.543)		(0.340)
Managerial stock proportion		−0.609		−0.466
		(0.412)		(0.303)
Employees		0.537***		0.100
		(0.119)		(0.085)
Gross revenue		0.030		0.052**
		(0.041)		(0.024)
Debt-to-assets ratio		0.123*		−0.042
		(0.066)		(0.051)
Industry fixed	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y
N	3750	3259	3747	3259
Panel B: First stage				
Fiscal autonomy (prefecture)	2.885***	2.258***	2.891***	2.258***
	(0.488)	(0.491)	(0.488)	(0.491)
Controls	Y	Y	Y	Y
Industry fixed	Y	Y	Y	Y
Year fixed	Y	Y	Y	Y
Cragg-Donald Wald F statistic	103.217	57.681	103.304	57.681
Kleibergen-Paap LM statistic	32.944***	20.842***	32.921***	20.842***
N	3750	3259	3747	3259

Notes: Robust standard errors clustered at prefecture level are in parentheses. Employees, R&D tax credits and gross revenue are logarithmic values. Constants are not reported.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

significant at 1% level. The results remain significant controlling more firm covariants in Column (4). In sum, using instrumental variable estimation, the results are consistent and robust. Tax credit has an evident stimulation effect on innovative input and output. The stimulation effect is more salient for innovative input.

7. Conclusion

Technological innovation has become the main drivers of economic development and social change. Innovation policies are widely adopted to promote industrial development. As a popular innovation policy, R&D tax credit is critical for innovations with uncertain technological trajectories and social return. The evaluation of R&D tax credit in a changing institutional context can expand our understanding of R&D tax credit. The research uses China as a case to examine the allocation logics and the effect of R&D tax credit. We conclude that institutional conditions, including industrial policies, government transparency and market development, shape the allocation of tax credit. Fiscal capacity constrains the implementation of tax credit policy.

Moreover, policy-preferred industries are more likely to obtain the R&D tax credit. It indicates that the allocation of R&D tax credit is contingent on industrial policies. Yet the influence of R&D tax credit is only evident in the manufacturing firms. The allocation of R&D tax credit has certain mismatch. Firms in industries such as hotels and catering service, leasing and business services also receive R&D tax credit. Parts of R&D tax credit may flow to some non-productive industries. Government should restrict the scope of industries, and mainly allocate tax credit to innovation-driven enterprises.

We find that government transparency and local market development increase firms' chance to receive tax credit, while fiscal capacity constrains the provision of R&D tax credit. It demonstrates that market-supporting institutions are vital for the allocation of R&D tax credit. It is essential for governments to establish more market friendly environment, and allocate more policy attention and resources to support firm innovation.

Furthermore, the article indicate that the R&D tax credit only facilitates innovative activities in large firms. The result is inconsistent with previous research that R&D tax credit has a larger effect in SMEs in developed countries (Baghana and Mohnen, 2009; Corchuelo and Martinez Ros, 2009; Kobayashi, 2014; Rao, 2016). In developing countries, SMEs may confront more institutional barriers to innovate. For instance, firms need to prepare application forms, R&D budget, contacts, project proposals and reports for applying R&D tax credit. SMEs have comparatively weak financial accounting apartments, and may be reluctant to meet the requirements of applying R&D tax credit. The cost of applying tax credit can be higher for SMEs, which discount the facilitation effect of R&D tax credit. Government should reduce procedures of applying R&D tax credit for SMEs, reduce mismatch of tax credit, and ensure that SMEs have a fair chance to receive R&D tax credit.

This article has some limitations. We only use the data of listed companies. Thus, we should be cautious in applying the conclusion to the population of Chinese firms. Listed companies tend to have better corporate governance structures, stronger bargaining power, and richer sources for R&D activities. For instance, 87.63% of firms in our sample engaged in R&D activities, while only about 10% of industrial firms in China engaged in R&D activities from 2005 through 2007 (Chen and Dai, 2012). Future research may examine the consequence of tax credit among a wider range of firms. We mainly estimate the policy effects of R&D tax credit. However, Chen and Naughton (2016) point out that Chinese government gradually adopts a wide spectrum of policy instruments such as subsidies, funds, tax exemptions, and tax credit to facilitate technological progress. It is essential to estimate the effectiveness of multiple policy instruments in a framework.

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