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Do R&D Tax Credits Incentivize Radical or Incremental Innovation? Evidence from China

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Abstract: Many countries use R&D tax credits to promote firm innovation. Using the data of A-share listed companies from 2012 to 2019, we use a fixed effects model to examine the heterogeneity effect of the R&D tax credit in China on radical and incremental innovation based on the perspective of firm property rights, scale, and age under the framework of heterogeneity. The results show that the R&D tax credit significantly stimulates radical and incremental innovation, but the incentive effect on radical innovation is weak. Further heterogeneity analysis shows that the incentive effects of enterprises with different complementary resources and innovation capabilities are different. Specifically, we find that the R&D tax credit has a stronger impact on incremental innovation of state-owned enterprises and radical innovation of non-state-owned enterprises. Compared with small firms and start-ups, it has a stronger incentive effect on the radical and incremental innovation of large-, medium-sized, and incumbent firms. Finally, the results are consistent and robust using the Heckman two-step method, core indicator substitution method, and change lag period. This paper deepens the theoretical research on the heterogeneity effect of tax incentives on firm innovation, while also providing insights on how to design R&D tax credits to raise radical innovation for emerging economies.

Keywords: R&D tax credit; radical innovation; incremental innovation

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1. Introduction

Innovation plays a crucial role for the sustainable and competitive development of a country [1]. To a certain extent, national competition is manifested as the competition of frontier major core technologies. In recent years, with the expansion of China's strategic scientific and technological forces, firms have significantly improved their capacity for independent innovation. However, the situation where China relies on developed countries for key core technologies in industrial fields such as high-end chips, high-end professional manufacturing equipment, high-end medical equipment, and numerical control manufacturing has not changed. As the main body of innovation, firms play a key role in the process of realizing radical innovation; therefore, how to effectively stimulate firm radical innovation has become the focus of Chinese scholars and policymakers in recent years.

Compared with incremental innovation, radical innovation is more likely to lead to market failure because of its higher risks and costs, longer R&D cycle, higher degree of information asymmetry, and stronger dependence on basic research. Market failures lead to under-investment in R&D and innovation, which is rooted in the imperfect availability of returns to innovation and financial constraints exacerbated by asymmetric information [2,3]. Subsidies and tax incentives are widely accepted measures to reduce R&D uncertainty and fill the optimal private and social gap of R&D investment by governments around the world [4]. Compared with subsidies, tax incentives are more neutral and market-oriented and better able to reduce asymmetric information of R&D activities. Tax incentives can effectively and timely reduce the tax burden [5,6], and the probability of policy failure is low [7]. It is an important measure of the government's "tax reduction and burden reduction".

Since 2009, in the face of the global financial crisis, China has introduced tax cuts to boost domestic demand. Subsequently, the government introduced more than 100 preferential tax policies for entrepreneurship, employment, and key sectors. Tax incentives for enterprises' R&D activities are usually divided into R&D tax credit, accelerated depreciation of R&D fixed assets, and preferential tax rates for high-tech enterprises. In this paper, we are interested in the R&D tax credit, which has a particularly prominent impact on innovation and has gradually become an important part of innovation incentive policies [8,9]. According to statistics, during the 13th Five-Year Plan period (2016–2020), the amount of the R&D tax credit increased from CNY 72.6 billion to CNY 360 billion; therefore, the analysis and evaluation of the innovation incentive effect of the R&D tax credit is of great significance for policymakers.

Despite the increasing studies that have investigated the effects of R&D tax credits on enterprise innovation, there is no consensus, particularly in the context of developing and emerging economies. Most scholars consider that R&D tax credits may reduce the R&D cost, increase cash flow, stimulate innovation vitality, and thus increase R&D and innovation investment [5,10,11]. However, some scholars propose the opposite view that rent-seeking behavior may exist in the market because of the imperfect disclosure of China's information system and other reasons, which affects the effect of tax incentives. In addition, only a few studies distinguish radical innovation from incremental innovation. Cappelen et al., (2012) based on the background of SkatteFUNN, find that tax credits have a positive impact on the development of new production processes (incremental innovation), but has limited impact on new products and patents (radical innovation) [12]; however, the heterogeneous impact of R&D tax incentives on radical and incremental innovation in China almost blank. Moreover, some scholars are committed to studying the influence factors of tax credits on innovation, focusing on macro or industrial heterogeneity factors such as market size and competition structure of different economies. Only a few studies focus on the heterogeneity analysis at the micro level of enterprises, and no systematic heterogeneity framework has been formed. There is also a lack of discussion on the theoretical mechanism of tax considering enterprise factors.

To sum, based on the data of Chinese A-share listed firms from 2012 to 2019, we examined the heterogeneity effect of the R&D tax credit on radical and incremental innovation in the framework of heterogeneity from the perspective of the property rights, size, and age of firms. This paper has the following contributions: First, few previous studies have examined the heterogeneous impact of innovation policy on radical and incremental innovation, especially on emerging economies. Based on China's R&D tax credits, we distinguish radical and incremental innovation to enrich the theoretical research on the impact of tax incentives on innovation. Second, most of the related studies focus on macro-level heterogeneity. Although a few studies focus on heterogeneity at the firm level, a systematic research framework is lacking. In this paper, we focus on more firm-level heterogeneity factors, which are of practical significance to reasonably evaluate the effect of China's R&D tax credits and thus improving policy targeting.

The rest of paper is organized as follows: Section 2 presents the evolution of Chinese R&D tax credits. Section 2 reviews the literature and presents hypotheses. Section 3 introduces our methods. Section 4 shows our results, and Section 5 concludes the paper.

2. Background and Hypotheses

2.1. R&D Tax Credit in China

With the gradual acceleration of economic globalization, emerging economies have entered a stage of rapid development. The international status of emerging economies has also changed significantly. In particular, China as the representative of emerging economies has attracted much more attention. By 2021, China's R&D spending reached CNY 2.79 trillion, accounting for 2.44% of its GDP, ranking 12th in the world. In order to stimulate the enthusiasm of enterprises for innovation, China introduced a technological innovation policy with tax incentives and financial subsidies as the core. Among them, the R&D tax credit is one of the measures with great intervention strength in China, and has gradually become an important part of innovation incentive policies [8,9]. The scheme, exclusively offered by the Ministry of Finance and the Ministry of Taxation, allows firms to deduct a given percentage of their R&D expenditures from their corporate tax liability. Since the implementation of the R&D tax credit in 1996, the scope of application, the contents of R&D expenses, and the deduction rate of R&D activities have undergone many reforms.

Specific reform measures are as follows: Firstly, the scope of application is expanding. In 1996, it was limited "state-owned enterprises and collective industrial firms"; with China's reform and opening up and the increase in foreign-invested enterprises, by 2003, it was non-discriminatorily available to "all industrial enterprises of various ownership with sound financial accounting systems, auditing and levying corporate income tax." In 2006, it was expanded to include "resident enterprises that meet accounting standards, conduct audits and accurately collect R&D expenses." In 2015, it adopted a "negative list" method to determine the scope of the policy, which stipulates that except for seven industries, such as tobacco manufacturing, accommodation and catering, real estate, wholesale and retail, etc., can apply for preferential policies as long as they meet the regulations. This means that the scope was further expanded and the threshold was further lowered for enterprises to receiving tax incentives.

Secondly, the contents of R&D expenses are more detailed than before. Before 2008, it was vague. In 2008, only expenses related to R&D activities in the specified list could be eligible for deduction. In 2015, the contents were further expanded; specifically, labor costs for external employees, insurance premiums for high-tech R&D, travel expenses directly related to R&D, and conference expenses were included in the contents of R&D expenses. This is conducive to the specific operation of accounting personnel and tax collection personnel and the implementation of policies.

Thirdly, the deduction rate has been increasing. In 1996, 50% of the actual amount of "technology development fees" was deducted from taxable income. In 2017, the rate of technology-based small and medium-sized firms was increased to 75%. In 2018, the rate for all firms except those specified in the negative list was increased to 75%. In 2021, the rate of manufacturing firms was increased from 75% to 100%, and that of non-manufacturing enterprises was increased to 75%. The adjustment increased the ratio of R&D tax credit of technology-oriented SMEs to 100%. The multiple changes in the policy have undoubtedly demonstrated to the public the government's strong support for firm innovation.

2.2. Literature Review

With the prevalence of tax incentives, more attention has been paid to the debate on whether or not R&D tax credits stimulate innovation. Most of the studies consider that R&D tax credits increase firms' investment in R&D by reducing the R&D cost of firms, increasing the cash flow of firms, and stimulates the innovation vitality of firms. For instance, Rao (2016) considered that the R&D tax credit has a positive impact on the R&D expenditure of US firms [13]. Czarnitzki et al., (2011) empirically showed that tax credits promote the number of new products, sales revenue of new products, and original innovation of Canada [5]. Ivus et al., (2021) noted that tax credits programs stimulate the number of patent applications of Indian firms [14]. Zhang and Guan (2018) found that tax incentives have a positive impact on enterprise innovation performance based on the data of enterprises in Beijing Zhongguancun Science and Technology Park [15]. Li et al., (2019) found that the additional deduction for R&D expenses significantly promoted firm R&D investment by using the data of Chinese listed firms [8]. Jin et al., (2022) showed that the additional deduction of R&D expenses increased enterprise innovation input and innovation output [16]. However, some scholars also have different views. For instance, Labeaga et al., (2021) considered that Spanish manufacturing firms using tax credits regularly are likely to aim at innovating, while an occasional tax credits firm user may aim at reducing the tax burden, not innovating [17]. Dai and Chapman (2022) noted that tax stimulates R&D investment and patent growth, but greater incentives may induce R&D crowding out [18]. Laplante et al., (2019) noted the existence of the phenomenon of "strategic R&D classification", that is, firms use the inherent ambiguity in tax reports to classify indirect costs as R&D expenditures to achieve the purpose of obtaining R&D tax credits, resulting in low tax incentive effects [19]. Chen et al., (2020) showed that R&D tax credits have no significant impact on the quality of Chinese firm technological innovation [20].

Existing studies generally suggest that R&D tax credits have an incentive effect on enterprise innovation investment, new product sales revenue, and patent number, but few literatures distinguish radical and incremental innovation. The distinction between radical and incremental innovation helps policymakers better position policy objectives [21,22]. For instance, Beck et al., (2016) empirically tested the heterogeneous impact of public R&D subsidies on radical and incremental innovation against the background of Swiss fund policies. The results show that public R&D spending only has a significant effect on radical innovation [23]. Cappelen et al., (2012) based on the research background of SkatteFUNN, found that tax credits have a positive impact on the development of new production processes, but have a limited impact on new products and patents [12]. Damsgaard et al., (2017) showed that government subsidies increase enterprises' R&D investment, but do not affect enterprises' choice of radical or incremental innovation projects [24]. In contrast, tax incentives make enterprises more inclined to choose incremental innovation projects.

In addition, a general limitation of the existing literature on R&D tax credits is that most studies are under the framework of homogeneity. Until recently, studies have focused on the impact of heterogeneity on innovation; some papers focus on the heterogeneity factors at the macro level, such as examining the different impact of tax policies on enterprise innovation in different economies. Freitas et al., (2017) used the samples of Norway, Italy, and France and found that the impact of tax incentives on the innovation output of enterprises in their respective countries is very different [25]. Some literatures focus on the heterogeneity of industries and suggest that the different effects of policy incentives are due to the differences in market competition degree, technological opportunities, and the strength of knowledge diffusion and spillover effect. Paff (2004) investigated the impact of standard tax credits and alternative incremental credit (AIC) in the US, highlighting substantial differences between the high-tech and low-tech sectors, which is also supported by research by Paff (2005) and Rao (2016) [13,26,27]. Yang et al., (2012) considered that R&D tax credits have a stronger promotion effect on firms in the electronic industry than in other industries in Taiwan [10]. Castellacci and Lie (2015) considered that R&D tax credits have a strong incentive effect on enterprises in service industry and low-technology industry [28]. However, very few studies focus on heterogeneity factors at the firm level. Castellacci and lie (2015) found that the effect of R&D tax credits on small and medium-sized firms is different from that of large enterprises [28]. He et al., (2020) conducted an investigation on Chinese enterprises and found that R&D tax credits have a stronger incentive effect on the innovative output of non-state-owned firms and large-scale firms [29].

Through the review of the above literature, we found that the existing literature has the following limitations: First, the difference between radical and incremental innovation is not considered enough in previous the literature, and most of the studies focus on developed countries, with little evidence offered for developing countries. Second, most of studies have been conducted at the macro level across countries or industries, with little research on different types of enterprises. The systematic heterogeneity framework is not formed, and the corresponding theoretical mechanism is also lacking. In addition, from the innovation-driven perspective, R&D tax credits enable enterprises to gain benefits from innovation, while complementary resources or innovation capacity are also key factors [30]. It is necessary to consider complementary resources and innovation capability as heterogeneity factors in the research on the impact of R&D tax credits. As a consequence, we examined the heterogeneous effects of R&D tax credits on radical and incremental innovation in China. Furthermore, under the heterogeneous framework of complementary assets and innovation capability of firms, we empirically examined the impact of R&D tax credits on the innovation of different types of firms from the perspective of property rights, firm scale, and firm age.

2.3. Hypotheses

2.3.1. R&D Tax Credit and Firm Innovation

R&D tax credits promote firm innovation through the following mechanisms: Firstly, R&D tax credits indirectly alleviate financing constraints by reducing the marginal cost of R&D and innovation, and thus stimulate additional R&D and innovation investment [5,11]. Secondly, they reduce the income tax payable by enterprises and allows firms to maintain additional capital liquidity. This means that the solvency and anti-risk ability of enterprises are enhanced, which has a positive impact on R&D investment. Thirdly, the deductible R&D expenses include the related expenses of R&D personnel, which help reduce the labor cost of the enterprise, thereby increasing the investment in the scarce production factor of "talent". Fourthly, as important policy tools to stimulate the development of enterprises' innovation ability, R&D tax credits send signals to external investors that enterprises actively respond to the government's strategic guidance and relevant enterprise quality information. This can alleviate the information asymmetry between enterprises and external investors to help firms to obtain external financing.

In addition, radical innovation has a longer R&D cycle, higher cost, and higher risk than incremental innovation, which leads to the difference in innovation incentive effects of R&D tax credits on them. First of all, R&D tax credits as a universal policy directly reduces the R&D cost of enterprises through tax deduction and more easily leads to the output increase in incremental innovation. Czarnitzki et al., (2011) proposed that enterprises obtaining tax credits may focus on short-term promising projects. Secondly, the number of enterprises obtaining R&D tax credits increases year by year, while the proportion is still low [20]. Therefore, some enterprises may classify indirect costs as R&D expenditures by taking advantage of the inherent ambiguity in tax reports through "strategic R&D classification" in order to obtain R&D tax credits [19]. This is clearly not conducive to encouraging enterprise innovation, especially radical innovation. Based on the above analysis, this paper proposes hypotheses:

Hypotheses 1 (H1). *R&D tax credits have a positive effect on radical and incremental innovation, but the incentive effect on radical innovation is weak.*

2.3.2. Enterprise Heterogeneity Factors

In the context of China's special economic system, the impact of R&D tax credits on state-owned and non-state-owned enterprises is differences because of different resource conditions, financing channels and governance structures. First of all, most senior executives of state-owned enterprises have the attribute of "quasi officials", which makes the business decision-making objectives of enterprises generally consistent with the multiple political objectives of the government, such as stabilizing employment, promoting growth, adjusting structure, and benefiting people's livelihood [29]. Meanwhile, senior executives have a strong motivation for promotion and tend to pay attention to short-term results. Second, the state-owned background enables them to have obvious advantages in the political system, which enables them to survive even at a lower level of innovation. As a result, state-owned enterprises may lack sufficient enthusiasm and motivation for technological innovation, and their behaviors tend to be short-term [31], which contradicts the long cycle of radical innovation. Thirdly, the government's supervision of state-owned enterprises may be inadequate due to the principal-agent problem.

In contrast, non-state-owned enterprises are at a disadvantage in terms of access to government finance and resources. When faced with fierce market competition, they are more motivated to develop new products and new patents. They tend to choose radical innovation projects in order to take a leading position in the market. On the other hand, non-state-owned enterprises can quickly adjust to the market environment and make strategic decisions for radical innovation because of their flexible internal management mechanism. In addition, non-state-owned enterprises have strong financing constraints. When R&D tax credits are adopted, the financing constraints of non-state-owned enterprises can be effectively alleviated. We thus expect the following hypothesis:

Hypotheses 2 (H2). *In contrast, R&D tax credits have stronger incentive for incremental innovation of state-owned enterprises and radical innovation of non-state-owned enterprises.*

Compared with small enterprises, large- and medium-sized enterprises have obvious advantages in complementary resources and innovation ability. Large- and medium-sized enterprises have the ability to have a large market share through product innovation and monopolize the market so they can usually afford huge short-term or long-term R&D expenses. R&D tax credits can save more operating funds for them and encourage them to increase in R&D investment. In contrast, small enterprises have weak innovation ability, low market share, low and unstable profits, difficult and expensive financing, and other problems, all of which lead to their limited R&D investment. R&D tax credits help enterprises save less funds and their impact is weak. In addition, the disadvantage of small firms in areas such as intellectual property and patent litigation discourages R&D activities, which weakens the incentive effect. Third, small enterprises have fewer core technologies and rely more on incremental innovation by imitating external technologies. Due to the limitation of innovation ability, there is a higher probability of no returns for more radical innovation compared with incremental innovation. We thus expect the following:

Hypotheses 3 (H3). *Compared with small enterprises, R&D tax credits have a stronger incentive effect on incremental and radical innovation of large- and medium-sized enterprises.*

With the accumulation of time, complementary resources, knowledge, and skills of the enterprise, the innovation ability is enhanced. Incumbents have advantages in complementary resources and innovation capacity. In particular, incumbents have a richer experience in resource planning, integration, and reallocation, and a stronger ability to resist risks than start-ups, which has a positive impact on R&D input and innovation output [18]. McCaffrey (2018) also noted that dynamic capability and risk taking propensity have a positive impact on radical innovation [32]. In contrast, the agency cost and information asymmetry faced by start-ups are more obvious. External investors' cognitive barriers to the innovation ability and development potential of start-ups lead to difficulties in obtaining external financing, and thus inability to undertake a huge R&D investment. Therefore, we suggest that the above reasons weaken the innovation incentive effect of R&D tax credits on start-ups. We propose the following hypothesis:

Hypotheses 4 (H4). *Compared with start-ups, R&D tax credits have a stronger incentive effect on incremental and radical innovation of incumbent firms.*

3. Methodology

3.1. Model

Following Lennox et al. (2018) [33], we constructed a fixed effect model as a benchmark model for empirical research to test the heterogeneous impact of R&D tax credits on radical and incremental innovation. The model is specified as following:

$$\mathrm{Inov}_{\mathrm{it\_n}} = \alpha + \beta \mathrm{Incen}_{\mathrm{it}} + \gamma \mathrm{controls}_{\mathrm{it}} + \mu_{\mathrm{t}} + \mu_{\mathrm{s}} + \mu_{\mathrm{h}} + \varepsilon_{\mathrm{it}}\ (\mathrm{n} = 1{,}2) \tag{1}$$

where i represents the enterprise and t represents the year. $\mathrm{Inov}_{\mathrm{it\_n}}$ is the innovation level of enterprise i in t year; when n = 1, $\mathrm{Inov}_{\mathrm{it}}$ is the radical innovation of enterprise i in t year; when n = 2, $\mathrm{Inov}_{\mathrm{it\_2}}$ is the incremental innovation level of enterprise i in t year. In particular, since the citation and authorization of patents have delayed effects, we refer to the practice of most literatures to express the innovation level of enterprise i in t year by the innovation level of t + 1 period. $\mathrm{Incen}_{\mathrm{it}}$ is the preferential amount of R&D tax credits of enterprise i in year t. Coefficient β is used to identify the effect of R&D tax credits on radical and incremental innovation. $\mathrm{controls}_{\mathrm{it}}$ includes control variables that influence enterprise innovation. In addition, the model includes year fixed effects (μ_t), regional fixed effects, (μ_s) and industry fixed effects (μ_h). $\varepsilon_{\mathrm{it}}$ is the random error term. In addition, the standard deviation of the coefficient is adjusted by clustering at the enterprise level.

3.2. Samples and Data

Our paper is based on a sample of Chinese A-share listed companies from 2012 to 2019. We selected 2012 as the initial year because of the low implementation rate of the R&D tax credits prior to that date [34]. The data for this study are constructed from two sources: the firm data come from China Economic and Financial Research Database (CSMAR) and patent application data from China research data service platform (CNRDS). The principles of data cleaning are as follows: (a) We excluded industries that do not apply to R&D tax credits, such as tobacco manufacturing, leasing and catering, wholesale and retail, real estate, services and entertainment, etc. (b) We eliminated ST companies and companies with serious data gaps. In addition, the main variables were winsorized by 5% in order to exclude the influence of extreme values. We finally obtained 13,797 observations.

3.3. Key Varibles

3.3.1. Dependent Variables

Current research has not reached a consensus on the measurement of radical and increment innovation. Patent citation data are used by most scholars to identify radical innovations. Among them, patent forward citation data are regarded as an indicator which can best reflect the patent value and strategic significance [35]. The more times it is cited, the greater value of the patent is, which means that it contains more cutting-edge or generic technical knowledge. However, the value of patents is highly skewed and very few are considered radical innovations [36,37]. Therefore, according to Wu et al., (2019), this paper considers the top 3% of patent forward citation as radical innovation and the rest as incremental innovation [38]. The variables were processed as follows: First, we calculated the number of forward citations excluding self-citations for each patent granted by the company each year within 6 years. Second, we calculated the number of radical innovation and incremental innovation patents per year by the company. We lagged the explained variables by one term.

3.3.2. Independent Variables

In constructing R&D tax credits, we followed Zheng (2006) and Guo et al., (2020) [9,39]. The specific method is as follows: first, we calculated the cost reduced by enterprises obtaining the R&D tax credits, that is, cost reduction = R&D investment $\times$ deduction rate $\times$ corporate income tax rate, and then we divided it by the total assets for standardization.

3.3.3. Control Variables

According to relevant research, we controlled the variables related to firm innovation. Among them, the control variables at the enterprise level specifically include enterprise size (Lnsize), enterprise age (Age), enterprise leverage (Leverage), enterprise property rights (Ownship), enterprise return on assets (ROA), and shareholding ratio of major shareholders (Top1). Provincial-level control variables include university density (University_density). In addition, we also controlled the year dummy variable (Year), region dummy variable (Province), and Industry dummy variable (Industry) in order to obtain more robust regression result.

3.4. Descriptive Analysis

Table 1 reports the statistical results of grouped variables. As can be seen from Panel A-C, state-owned enterprises, large- and medium-sized enterprises, and incumbent enterprises have a stronger innovation ability, which is manifested by a higher average radical and incremental innovation quantity. On the other hand, Panel D presents the average number of radical and incremental innovation with higher R&D tax credits, which is also higher. Furthermore, the correlation test between core variables is shown in Table 2. The results show that the preferential intensity of R&D tax credits has a significant positive relationship with the radical and incremental innovation.

Table 1. Group descriptive statistical analysis results.

Panel A: Group by Property Rights

Variables	**Non-State-Owned Enterprises**		**State-Owned Enterprises**	
	Mean	**Sd**	**Mean**	**Sd**
$Inov_{it}$	0.416	0.738	0.714	1.114
$Inov_{it\_2}$	0.776	0.937	1.244	1.340
$Incen_{it}$	0.104	0.117	0.0943	0.110
ROA	0.0461	0.0424	0.0313	0.0352
Age	15.54	5.692	17.99	5.152
Leverage	0.294	0.227	0.427	0.229
Top1	0.238	0.179	0.324	0.171
Lnsize	17.64	8.774	22.10	4.363
University_density	0.0168	0.00619	0.0157	0.00801

Panel B: Group by Firm Scale

Variables	Small Firm		Medium-Sized Firm		Large Firm	
	Mean	Sd	Mean	Sd	Mean	Sd
$Inov_{it}$	0.233	0.525	0.444	0.691	0.903	1.224
$Inov_{it\_2}$	0.482	0.699	0.862	0.883	1.501	1.426
$Incen_{it}$	0.0877	0.118	0.120	0.117	0.0921	0.107
ROA	0.0475	0.0461	0.0405	0.0383	0.0347	0.0361
Age	15.22	5.851	16.53	5.380	17.46	5.449
Leverage	0.183	0.207	0.361	0.192	0.480	0.215
Top1	0.185	0.190	0.294	0.150	0.326	0.173
Ownship	0.143	0.350	0.329	0.470	0.585	0.493
Lnsize	12.83	10.28	21.29	3.633	23.39	2.393
University_density	0.0167	0.00646	0.0166	0.00652	0.0159	0.00769

Panel C: Group by Firm Age

Variables	Incumbents		Start-Ups	
	Mean	Sd	Mean	Sd
$Inov_{it}$	0.518	0.892	0.532	0.951
$Inov_{it\_2}$	0.941	1.111	0.925	1.165
$Incen_{it}$	0.101	0.115	0.0960	0.114
ROA	0.0405	0.0404	0.0447	0.0427
Age	17.54	4.889	7.700	2.297
Leverage	0.350	0.236	0.264	0.229
Top1	0.273	0.178	0.231	0.196
Ownship	0.374	0.484	0.157	0.363
Lnsize	19.50	7.502	16.88	9.651
University_density	0.0166	0.00679	0.0153	0.00762

Panel D: Group by the Amount of Tax Credits

Variables	Low R&D Deduction		High R&D Deduction	
	Mean	Sd	Mean	Sd
$Inov_{it}$	0.384	0.779	0.695	1.006
$Inov_{it\_2}$	0.698	0.989	1.249	1.194
$Incen_{it}$	0.0450	0.0805	0.173	0.113
ROA	0.0386	0.0417	0.0441	0.0391
Age	16.32	5.704	16.50	5.536
Leverage	0.324	0.254	0.361	0.210
Top1	0.251	0.190	0.291	0.167
Ownship	0.360	0.480	0.335	0.472
Lnsize	17.94	9.076	20.80	5.436
University_density	0.0164	0.00713	0.0164	0.00659

Table 2. Correlation coefficient matrix.

	Inov$_{it}$	**Inov$_{it_2}$**	**Incen$_{it}$**	**Lnsize**	**Leverage**	**Ownship**	**Age**	**Top1**	**Univer~y**	**ROA**
Inov$_{it}$	1									
Inov$_{it_2}$	0.782 ***	1								
Incen$_{it}$	0.056 ***	0.138 ***	1							
Lnsize	0.158 ***	0.242 ***	−0.144 ***	1						
Leverage	0.134 ***	0.169 ***	−0.159 ***	0.459 ***	1					
Ownship	0.158 ***	0.200 ***	−0.154 ***	0.272 ***	0.255 ***	1				
Age	−0.070 ***	−0.0130	0	0.275 ***	0.105 ***	0.207 ***	1			
Top1	0.075 ***	0.074 ***	−0.046 ***	0.178 ***	0.027 ***	0.161 ***	−0.098 ***	1		
University~y	−0.072 ***	−0.051 ***	−0.047 ***	0.027 ***	0.024 **	0.068 ***	0.058 ***	0.026 **	1	
ROA	−0.00100	−0.025 ***	0.203 ***	−0.371 ***	−0.395 ***	−0.230 ***	−0.111 ***	0.080 ***	−0.0120	1

Note: The statistics in parentheses are based on robust standard errors clustered at the firm level. **, and *** indicate statistical significance at the 5%, and 1% levels, respectively.

4. Results

4.1. Regression Results

Table 3 shows the results of the heterogeneous impact of R&D tax credits on radical and incremental innovation. Columns (1) and (3) control only year, province, and industry fixed effects, while Columns (2) and (4) contain all control variables. Table 3 presents that the coefficient estimates of the R&D tax credits significantly stimulate radical and incremental innovation. In particular, from the coefficient in Column (2) and Column (4), we can see that R&D tax credits have a weak promotion effect on radical innovation; Hypothesis 1 is verified. We suggest that R&D tax credits should be based on the characteristics of radical innovation, such as high R&D cost, long R&D cycle, difficult to overcome, and high probability of failure. The government should provide more support to enterprises engaged in radical innovation projects so as to enhance the tolerance of enterprises' risk and cultivate radical innovation ability.

Table 3. The impact of the R&D tax credit on enterprise innovation.

Variables	**(1)**	**(2)**	**(3)**	**(4)**
	Inov$_{it}$	**Inov$_{it}$**	**Inov$_{it_2}$**	**Inov$_{it_2}$**
Incen$_{it}$	1.7444 ***	0.6968 ***	1.0146 ***	0.3111 **
	(0.154)	(0.150)	(0.128)	(0.129)
ROA		3.0880 ***		2.5262 ***
		(0.345)		(0.283)
Age		−0.0061 *		−0.0062 **
		(0.004)		(0.003)
Lnsize		0.0329 ***		0.0231 ***
		(0.003)		(0.003)
Leverage		0.6250 ***		0.3666 ***
		(0.090)		(0.071)
Ownship		0.4422 ***		0.2852 ***
		(0.051)		(0.040)
Top1		−0.4048 ***		−0.3042 ***
		(0.136)		(0.111)
University_density		−1.8262		−1.6736
		(1.454)		(1.370)
Constant	0.7633 ***	−0.0180	0.4174 ***	−0.0728
	(0.023)	(0.067)	(0.018)	(0.054)
Industry	YES	YES	YES	YES
Province	YES	YES	YES	YES
Year	YES	YES	YES	YES
Observations	13,797	13,797	13,797	13,797
R-squared	0.225	0.332	0.204	0.275

Note: The statistics in parentheses are based on robust standard errors clustered at the firm level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

4.2. The Impact of R&D Tax Credits on Heterogeneous Firm Innovation

The different complementary resources and innovation capacity of enterprises inevitably leads to the different incentive effects of the R&D tax credits. In the framework of impacts of R&D tax credits, we added three heterogeneous factors, namely the nature of property rights, scale, and age of the firm, to indirectly analyze the differential policy effect of enterprises with different complementary resources and innovation capabilities.

4.2.1. The Property Rights of Enterprises

According to the property rights of enterprises, we divided the sample into state-owned and non-state-owned enterprises for regression analysis. The estimated results are shown in Table 4. From Columns (1) and (2), we can see that R&D tax credits have a significant promoting effect on non-state-owned enterprises' radical innovation, while the incentives on state-owned enterprises' radical innovation is insignificant. From Columns (3) and (4), we find that R&D tax credits have a slightly stronger incentive effect on incremental innovation of state-owned enterprises; Hypothesis 2 is verified. Possible reasons for the above results: (a) The flexible management mechanism and system of non-state-owned enterprises are conducive to rapid innovation decisions. (b) The disadvantage of non-state-owned enterprises in obtaining government financial resources makes them more motivated to carry out radical innovation in the face of encouraging market competition. The above reasons strengthen the incentive effect of R&D tax credits on radical innovation of non-state-owned enterprises to a certain extent. However, the lack of supervision caused by the principal-agent problem of state-owned enterprises makes the tax credits unable to stimulate radical innovation.

Table 4. Analysis on the heterogeneity of property right.

Variables	(1)	(2)	(3)	(4)
	Non-State-Owned	State-Owned	Non-State-Owned	State-Owned
	$Inov_{it}$	$Inov_{it}$	$Inov_{it\_2}$	$Inov_{it\_2}$
$Incen_{it}$	0.3467 ***	0.2666	0.6855 ***	0.7485 **
	(0.127)	(0.280)	(0.151)	(0.310)
ROA	2.0285 ***	3.7536 ***	2.6873 ***	4.1126 ***
	(0.294)	(0.653)	(0.364)	(0.772)
Age	0.0006	−0.0244 ***	0.0026	−0.0307 ***
	(0.003)	(0.007)	(0.003)	(0.009)
Lnsize	0.0129 ***	0.0601 ***	0.0218 ***	0.0783 ***
	(0.002)	(0.008)	(0.003)	(0.010)
Leverage	0.3994 ***	0.2886 **	0.6880 ***	0.4952 ***
	(0.076)	(0.116)	(0.103)	(0.140)
Top1	−0.0270	−0.6428 ***	−0.1371	−0.7819 ***
	(0.099)	(0.202)	(0.130)	(0.237)
University_density	0.2048	−2.9666	0.3375	−4.2093 *
	(1.670)	(2.354)	(1.846)	(2.439)
Constant	−0.0647	−0.1872	−0.0194	−0.0264
	(0.054)	(0.170)	(0.068)	(0.217)
Industry	YES	YES	YES	YES
Province	YES	YES	YES	YES
Year	YES	YES	YES	YES
Observations	8981	4816	8981	4816
R-squared	0.219	0.378	0.281	0.433

Note: The statistics in parentheses are based on robust standard errors clustered at the firm level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

4.2.2. The Scale of Enterprises

We divided the total sample into small-, medium-, and large-sized enterprises for regression analysis based on the scale of enterprises; the results are shown in Table 5. We found that R&D tax credits have a stronger incentive effect on radical innovation of large- and medium-sized enterprises, while the incentive effect on small enterprises is not obvious. The incentives of R&D tax credits to firm incremental innovation are also heterogeneity, which shows that the larger the scale, the stronger the incentive effect; Hypothesis 3 is verified. The possible reason is that enterprises of different scale differ in R&D resources, motivation, production efficiency, and industry position. The larger the scale of enterprises, the higher their innovation ability and innovation output. In addition, they pay more attention to the long-term development of enterprises, thus strengthening the role of the R&D tax credits in the process of enterprise innovation.

Table 5. Analysis on the heterogeneity of enterprises scale.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Small	**Medium-Sized**	**Large**	**Small**	**Medium-Sized**	**Large**
	$Inov_{it}$	**$Inov_{it}$**	**$Inov_{it}$**	**$Inov_{it\_2}$**	**$Inov_{it\_2}$**	**$Inov_{it\_2}$**
$Incen_{it}$	−0.0062	0.6342 ***	0.8061 **	0.3180 **	1.0936 ***	1.6048 ***
	(0.121)	(0.159)	(0.319)	(0.159)	(0.200)	(0.345)
ROA	0.7680 ***	1.7926 ***	4.2522 ***	1.2636 ***	2.4923 ***	4.5265 ***
	(0.240)	(0.385)	(0.792)	(0.339)	(0.494)	(0.916)
Age	−0.0018	−0.0058	−0.0112	−0.0000	−0.0070	−0.0081
	(0.003)	(0.004)	(0.008)	(0.004)	(0.005)	(0.010)
Leverage	0.1217 **	0.0285	0.4163 ***	0.4298 ***	0.2153 **	0.6229 ***
	(0.056)	(0.068)	(0.126)	(0.091)	(0.101)	(0.151)
Ownship	−0.0657	0.1490 ***	0.4006 ***	−0.0174	0.2757 ***	0.5117 ***
	(0.042)	(0.043)	(0.082)	(0.065)	(0.060)	(0.102)
Top1	0.1118	0.2282 **	−0.3782 **	0.1327	0.2842 **	−0.3601
	(0.084)	(0.104)	(0.192)	(0.109)	(0.136)	(0.228)
University_density	−1.0391	0.8418	−3.9943	2.2955	−4.0755	−3.1544
	(1.889)	(2.260)	(2.818)	(2.344)	(2.549)	(2.537)
Constant	0.2084 ***	0.2512 ***	0.6291 ***	0.2557 ***	0.5607 ***	0.9059 ***
	(0.053)	(0.079)	(0.189)	(0.075)	(0.106)	(0.226)
Industry	YES	YES	YES	YES	YES	YES
Province	YES	YES	YES	YES	YES	YES
Year	YES	YES	YES	YES	YES	YES
Observations	4494	4963	4340	4494	4963	4340
R-squared	0.143	0.244	0.396	0.186	0.291	0.445

Note: The statistics in parentheses are based on robust standard errors clustered at the firm level. ** and *** indicate statistical significance at the 5% and 1% levels, respectively.

4.2.3. The Age of Enterprises

We divided the sample into start-ups and incumbents based on the time of establishment. Following Wu and Zhang (2021), we defined enterprises that have been established for less than 12 years as start-ups, that is, enterprises established after 2006 [40]. From the Columns (1) and (2) of Table 6, the results show that R&D tax credits have a significant positive effect on the radical innovation of incumbent enterprises, but the incentive effect on the radical innovation of start-ups is not significant. The results in Columns (3) and (4) show that R&D tax credits have a stronger incentive effect on incumbent firms in terms of encouraging incremental innovation; Hypothesis 4 is verified. Start-ups lack experience in resource planning, integration, and reallocation, and external financing is weak. So, it is difficult for start-ups to undertake innovative projects with higher research and development risks. In addition, many hidden barriers are difficult to break through, which greatly affects the innovation ability of start-ups. The above reasons weaken the incentive effect of R&D tax credits on the innovation of start-ups.

Table 6. Analysis on the heterogeneity of enterprises age.

Variables	(1)	(2)	(3)	(4)
	Start-ups	Incumbents	Start-ups	Incumbents
	$Inov_{it}$	$Inov_{it}$	$Inov_{it\_2}$	$Inov_{it\_2}$
$Incen_{it}$	0.1788	0.3299 **	0.4360	0.7217 ***
	(0.341)	(0.139)	(0.321)	(0.162)
ROA	1.0284	2.6671 ***	1.5964 **	3.2254 ***
	(0.638)	(0.308)	(0.750)	(0.376)
Leverage	0.0199 ***	0.0221 ***	0.0254 ***	0.0318 ***
	(0.006)	(0.003)	(0.007)	(0.003)
Lnsize	0.0394	0.4053 ***	0.3892 *	0.6576 ***
	(0.232)	(0.069)	(0.232)	(0.091)
Ownship	0.6893 ***	0.2418 ***	0.9447 ***	0.3903 ***
	(0.202)	(0.040)	(0.242)	(0.052)
Top1	0.1530	−0.3013 **	0.2100	−0.3894 ***
	(0.232)	(0.117)	(0.250)	(0.146)
University_density	11.4591 ***	−3.3626 **	5.2050	−2.6885 *
	(3.025)	(1.485)	(3.225)	(1.594)
Constant	−0.1959 **	−0.1478 ***	0.0039	−0.1083 **
	(0.078)	(0.043)	(0.093)	(0.049)
Industry	YES	YES	YES	YES
Province	YES	YES	YES	YES
Year	YES	YES	YES	YES
Observations	1610	12,187	1610	12,187
R-squared	0.521	0.269	0.618	0.324

Note: The statistics in parentheses are based on robust standard errors clustered at the firm level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

4.3. Robustness Test

4.3.1. Heckman Two-Step

From the interaction logic between obtaining R&D tax credits and enterprises' innovation activities, enterprises with strong innovation ability are more likely to obtain policy preferences, which may lead to errors in the estimation results. To solve this problem, we used the Heckman two-step method for estimation. First, we chose the equation to estimate the probability that the firm obtained R&D tax credits and obtained the inverse Mills ratio (Lambda). Second, we used the obtained Lambda as a control variable into the regression equation of the second stage to control the sample selection bias, and simultaneously controlled for year, province, and industry fixed effects. The regression results are shown in Table 7. The lambda regression results of the second stage of R&D tax credit are significant, which proves that the conclusion has good robustness.

Table 7. The estimated results of the Heckman two-step method.

Variables	(1)	(2)
	$Inov_{it}$	$Inov_{it\_2}$
$Incen_{it}$	0.5584 ***	1.0844 ***
	(0.145)	(0.177)
Lambda	4.4788 ***	7.3044 ***
	(0.383)	(0.501)
ROA	1.0111 ***	1.2546 ***
	(0.267)	(0.339)
Lnsize	0.4868 ***	0.7920 ***
	(0.041)	(0.053)
Leverage	−0.9116 ***	−1.4644 ***
	(0.118)	(0.154)

Table 7. *Cont.*

Variables	(1)	(2)
	$Inov_{it}$	**$Inov_{it\_2}$**
Ownship	−0.4178 ***	−0.6842 ***
	(0.062)	(0.084)
Top1	0.1331	0.3054 **
	(0.101)	(0.125)
University_density	40.3293 ***	64.0808 ***
	(3.880)	(4.889)
Constant	−13.2746 ***	−21.5266 ***
	(1.136)	(1.481)
Industry	Yes	Yes
Province	Yes	Yes
Year	Yes	Yes
Observations	11,826	11,826
R-squared	0.317	0.403

Note: The statistics in parentheses are based on robust standard errors clustered at the firm level. ** and *** indicate statistical significance at the 5% and 1% levels, respectively.

4.3.2. Alternative Variable Method

In order to test the sensitivity of relevant conclusions to explained variables, we measured radical and incremental innovation by the number of invention patents (RI_{it}) and non-invention patents (II_{it}) granted by enterprises, respectively. All of them are logarithmic and lag one stage. The results are shown in Columns (1) and (2) of Table 8. We found that R&D tax credits have a significant effect on both the radical and incremental innovation of enterprises at the 1% level, and has a stronger promotion effect on incremental innovation, which is consistent with the regression results of Table 3. In addition, we defined "whether the enterprise obtains R&D tax credits" as a dummy variable ($Treattax_{it}$): when the enterprise obtains R&D tax credits, the dummy variable takes the value of 1, otherwise it is 0. Dummy variables are used as explanatory variables for regression. As shown in Columns (3) and (4) of Table 8, we found that the results are consistent with the above.

Table 8. Estimated results of alternative variable.

Variables	(1)	(2)	(3)	(4)
	RI_{it}	**IIit**	**$Inov_{it}$**	**$Inov_{it\_2}$**
$Incen_{it}$	0.9567 ***	2.9698 ***		
	(0.175)	(0.410)		
$Treattax_{it}$			0.1028 ***	0.2042 ***
			(0.038)	(0.039)
ROA	1.3136 ***	1.0667	1.1808 ***	1.0924 ***
	(0.406)	(0.903)	(0.263)	(0.325)
Lnsize	0.3508 ***	0.9608 ***	0.5289 ***	0.8034 ***
	(0.043)	(0.106)	(0.041)	(0.052)
Leverage	−0.6456 ***	−1.5169 ***	−1.0110 ***	−1.4731 ***
	(0.145)	(0.335)	(0.117)	(0.152)
Ownship	−0.3420 ***	−0.7109 ***	−0.4572 ***	−0.6903 ***
	(0.078)	(0.196)	(0.062)	(0.082)
Top1	0.3466 ***	0.7506 **	0.1755 *	0.3297 ***
	(0.127)	(0.323)	(0.097)	(0.118)
University_density	24.5999 ***	59.5190 ***	40.6668 ***	62.6999 ***
	(4.775)	(11.853)	(3.828)	(4.826)
Constant	−9.2452 ***	−25.2883 ***	−14.3973 ***	−21.8562 ***
	(1.215)	(2.972)	(1.136)	(1.447)
Industry	YES	YES	YES	YES
Province	YES	YES	YES	YES
Year	YES	YES	YES	YES
Observations	13,797	13,797	13,797	13,797
R-squared	0.132	0.148	0.324	0.406

Note: The statistics in parentheses are based on robust standard errors clustered at the firm level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

4.3.3. Replacement Lag

Considering the high risk and long cycle of R&D activity, especially radical innovation, we followed Jiang et al., (2017) and Wang and Wang (2021) to select the innovation output at T + 2 stage and T + 3 stage as the explained variable for T stage [41,42]. The specific results are shown in Table 9. We found that after considering the long cycle of the innovation process, R&D tax credits have a positive impact on firm radical and incremental innovation, and a greater impact on incremental innovation. This confirms the conclusions in Table 3.

Table 9. Regression results of replacement lag.

Variables	T + 2 Stage		T + 3 Stage	
	$Inov_{it}$	$Inov_{it\_2}$	$Inov_{it}$	$Inov_{it\_2}$
$Incen_{it}$	0.6402 ***	1.1864 ***	0.5396 ***	1.1818 ***
	(0.146)	(0.185)	(0.156)	(0.201)
ROA	2.3020 ***	3.3698 ***	2.1436 ***	3.1981 ***
	(0.287)	(0.366)	(0.283)	(0.366)
Lnsize	0.6051 ***	0.9826 ***	0.5213 ***	0.8679 ***
	(0.069)	(0.089)	(0.067)	(0.090)
Leverage	0.2861 ***	0.4625 ***	0.2666 ***	0.4373 ***
	(0.039)	(0.053)	(0.038)	(0.053)
Ownship	0.0123	0.0744	0.0146	−0.0012
	(0.090)	(0.115)	(0.086)	(0.118)
Top1	0.6750	−0.5681	−0.7469	−1.8427
	(1.602)	(1.626)	(2.015)	(1.803)
University_density	0.1042 *	0.2797 ***	0.1673 ***	0.3919 ***
	(0.055)	(0.070)	(0.056)	(0.070)
Constant	0.6402 ***	1.1864 ***	0.5396 ***	1.1818 ***
	(0.146)	(0.185)	(0.156)	(0.201)
Industry	YES	YES	YES	YES
Province	YES	YES	YES	YES
Year	YES	YES	YES	YES
Observations	11,826	11,826	9855	9855
R-squared	0.264	0.317	0.267	0.318

Note: The statistics in parentheses are based on robust standard errors clustered at the firm level. * and *** indicate statistical significance at the 10% and 1% levels, respectively.

5. Conclusions

There is a consensus of governments to implement tax incentives for enterprise R&D activities. As early as the 1960s, India, Japan, the United States, France, Canada, and other countries began to use tax incentives to encourage enterprises to conduct R&D activities. At present, many countries (OECD or not) use different degrees of R&D tax credits. We conducted our inquiry in the context of China for two reasons: (i) In the past, most of the relevant research used developed countries, but few used developing countries. As the largest developing country, China deserves further study. (ii) Because China contributes a larger share of global R&D expenditures, the incentive effect of R&D tax credits is worth exploring. The results show that R&D tax credits have an incentive effect on radical and incremental innovation, but it has a weak incentive effect on radical innovation. Furthermore, we found that the impacts of tax credit for different types of enterprises is heterogeneity; specifically, it has a stronger incentive effect on non-state-owned enterprises' radical innovation and state-owned enterprises' incremental innovation. Compared with small enterprises and start-ups, the incentive effect of incremental and radical innovation on large- and medium-sized enterprises and incumbents is stronger. Further, the results are robust based on a series of robustness tests.

Based on the research results, we propose the following policy recommendations: On the one hand, it is necessary to clarify the difference between radical and incremental innovation, which is conducive to improving the pertinence and effectiveness of policies. The government should encourage enterprises to engage in radical innovation activities by providing more support. On the other hand, the government should adopt different and targeted policy arrangements for different types of enterprises. First, the supervision mechanism and performance evaluation mechanism of state-owned enterprises should be improved to overcome the dilemma of state-owned enterprises in the efficiency of asset management. We encourage non-state-owned enterprises to play a leading role under the policy of R&D tax credits. Second, the government clearly defines the different functions and roles of enterprises of different sizes in the process of achieving radical innovation. Specifically, we should provide full play to the supporting role of R&D tax credits for radical innovation of large- and medium-sized enterprises. Small enterprises play an important role in China's economic and social development, but their disadvantages in profitability, innovation resources, lack of high-end talents, and other aspects seriously restrict their innovative development. This means that the combination of the R&D tax credits and other policy measures is needed to stimulate the innovation potential of small firms. Third, the government should guide start-ups to enhance their ability to plan, integrate, and reconfigure resources, while increasing external financing channels for start-ups. The government should further explore diversified policy instruments to encourage new enterprises. In addition, the government should provide complementary resources and innovation capability advantages of incumbent enterprises and encourage them to cooperate with other types of enterprises to achieve radical innovation. Finally, policies should focus on cross-field and cross-sector cooperation and provide policy support for enterprises' innovation and development from fiscal and tax subsidies, financial policies, innovative services, international cooperation, and other aspects.

Although this study achieved certain research results, there are some limitations. Firstly, we used forward patent citation to measure radical innovation, which can reflect the ability of core technology to influence subsequent technologies and lead the forefront of technology development, but lacks the measurement of commercial value in the transformation process from invention to innovation to some extent. Therefore, future research on the measurement indicators of radical innovation must be considered in many aspects. We only considered the impact of R&D tax credits on the two types of innovation, without more comprehensive consideration of the heterogeneous impact of different forms of tax incentive policies on enterprise innovation, which will also be an important aspect of our future research. Third, we empirically tested the effectiveness of the impact on radical innovation only from the perspective of R&D tax credits. Future research should explore a variety of policy tools to strengthen the research on radical innovation technology policy systems and policy measures.

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