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Study on the Incentive Effect of R&D Expense Plus Deduction on Innovation of Science and Technology-based SMEs

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Abstract

In the report of the 20th Party Congress in 2022, the core position of science and technology innovation is further emphasized, which also plays an important role in China's economic growth. Science and technology-based small and medium-sized enterprises (SMEs) in the survival and development of the road, facing financing difficulties and other heavy obstacles, need the government to actively play a function, with the help of fiscal and taxation policy means, for science and technology-based SMEs financing to provide strong support. As an important tax benefit, the additional deduction for R&D expenses aims to incentivize and support science and technology-based SMEs to strengthen technological innovation and enhance their independent R&D capability. On this basis, selected science and technology-based SMEs successfully listed on the China Growth Enterprise Market (GEM) during the period from 2018 to 2023 as a sample for empirical analysis, and utilized the fixed-effect model, a statistical method, to accurately explore the actual impact of the add-and-deduct policy on the innovation investment of science and technology-based SMEs. The study also takes the financing constraints suffered by enterprises as a mediating variable and analyzes whether it works through a signaling mechanism. The strength of R&D expense deduction and the intensity of innovation investment of SMEs in science and technology show a significant positive correlation. The study confirms that it works through a signaling mechanism to alleviate the financing constraints enterprises suffer. The effect of this policy is more prominent for those SMEs with high-tech enterprise status or in the "mature" stage of their life cycle. On this basis, the paper proposes a series of targeted strategic recommendations from the perspectives of both enterprises and the government.

Keywords: additional deduction for R&D expenses; financing constraints;, science and technology-based SMEs; corporate innovation.

1 | Introduction

Innovation is at the core of sustained economic growth, and the realization of high-quality economic development is deeply rooted in the soil of technological innovation and technological

creation. 2016 saw the official release of the Programmatic Document of the National Strategy for Innovation-Driven Development, reflecting China's unswerving stance and determination in this regard. In the program, innovation was established as a key driver of China's economic growth, as well as an important strategic support for enhancing the country's comprehensive strength. By 2022, in the report of the 20th Party Congress, the central position of science, technology, and innovation is further emphasized as playing an important role in China's economic growth. It aims to promote the overall development of the country, enhance the ability of scientific and technological innovation, optimize the mechanism of talent cultivation, and then achieve the overall prosperity and progress of the country. As the basic unit of social economy, science, and technology-based SMEs play an important role in promoting economic growth and scientific and technological progress. However, they face difficulties in capital mobilization, which is a global problem. The research and development process of SMEs is usually long and the return on investment is accompanied by significant uncertainty, while at the same time, they have to deal with multiple financing challenges such as narrow financing channels, high financing costs, and high financing risks. Together, these factors lead to financing difficulties and a lack of capital, which seriously constrain the progress of SMEs in R&D and innovation. The core challenge facing SMEs is how to break through the financing difficulties and enhance their innovation capability. Relying only on market mechanisms to address the financing challenges of SMEs in science and technology may result in the risk of market failure, so government intervention and macro-control are particularly necessary, and fiscal and tax measures need to be utilized to actively promote the financing process of this type of enterprise. Specifically, the implementation of tax incentives for additional deduction of R&D expenses is intended to incentivize and support SMEs in science and technology to strengthen technological innovation and enhance their independent R&D capabilities by lowering the level of tax burden on enterprises, alleviating their financing difficulties, and improving their financial liquidity. Further drive technological innovation and development. Improve China's innovative strength.

2 | Literature Review

2.1 Deduction of R&D expenses and firms' investment in innovation

Myers and Majluf (1984)[1] argued that when there is information asymmetry between external investors and insiders of enterprises, external investors may require enterprises to pay a premium when they raise external financing, which leads to an increase in the cost of external financing and creates financing constraints. Andrew C. Chang (2018) [2]found that after an empirical analysis of enterprises that enterprises' R&D investment is indeed affected by tax incentives, and this effect is still a positive promotion effect Guellec et al [3] analyzed the policy effect of tax incentives from the time dimension based on the panel data of OECD countries and found that

the intensity of tax incentives and the intensity of R & D investment show a significant positive correlation in both the short term and the long term. Bernstein and Jeffrey (1986)[4]Their research results show that the implementation of fiscal incentives such as tax breaks can significantly enhance the level of capital investment in R&D activities of enterprises. Brown (2016)[5] took 1990-2006 as the period, and analyzed the information data of 22 industries in 19 countries by using the double-difference model method, and concluded that the tax preference system brings a Bloom et al. (2002)[6] showed that tax incentives can effectively promote enterprise R&D investment and have a significant impact on their independent innovation, mainly in the form of long-term effects. Boeing's (2015)[7]empirical study based on data from China's A-share market shows that compared to state-controlled firms, private firms' R&D expenditure intensity is significantly higher after enjoying tax relief policies. However, some studies put forward a different point of view. Cumming (2004) [8]For high-tech enterprises in the start-up stage, the promotion effect of tax credit policy on their R&D investment is relatively limited, which may be related to the special operating conditions and risk characteristics of start-ups.Mansfield(1986)[9] based on the survey data of 110 U.S. firms in the period of 1981-1983 found that although the investment tax credit policy can stimulate the growth of R&D expenditures to a certain extent, its effect is not significant. These studies reveal the complexity of the effect of tax incentives from different perspectives, providing a multi-dimensional reference basis for policymaking.

Therefore, hypothesis I is proposed.

H1: The policy of adding a deduction for R&D expenses promotes innovation investment of science and technology-based SMEs

2.2 Analysis of the mediating effect of R&D expense Deduction and Enterprise Innovation Investment

Regarding the mechanism of tax incentives, academics have mainly explored the direct and indirect effects. Traditional research focuses on the path of tax incentives to directly increase R&D investment through the supply of funds, i.e., the "R&D additionality" effect, and Lerner (1999)[10]pioneered that tax incentives can send signals to the market through the government's certification mechanism to attract risk capital to participate in corporate innovation activities. Subsequent studies, through theoretical modeling (Kleer, 2010; Takalo and Tanayama, 2010)[11][12] and empirical research by Feldman and Kelley (2006)[13] have shown that when the governmental department that implements the subsidy possesses a high level of professionalism and a good level of scientific credibility, its process of vetting and evaluating firms' innovation projects tends to be more rigorous and credible. In this case, tax incentives not only reflect the government's recognition of an enterprise's innovation capability but also become an important quality certification signal. Research further shows that the amount of tax incentives received by an enterprise is positively correlated with the market competitiveness and development prospects

of its innovation project. This certification effect not only incentivizes firms to increase R&D investment but also enhances the confidence of external investors, thus attracting more social capital to participate in innovation investment. This finding reveals the important role of high-quality government assessment in innovation support policies and provides important insights for improving the policy implementation mechanism.

Therefore, hypothesis II is proposed.

H2: The R&D cost plus deduction policy can work through a signaling mechanism by using the financing constraints suffered by firms as the mediating variable.

A systematic review of the existing literature reveals that academics have accumulated a wealth of research results around the impact of tax incentives on innovation activities, which cover different economies, industrial sectors, and groups of enterprises with heterogeneous characteristics, providing an important theoretical foundation and experience for the research of this paper. Unlike the existing literature, which focuses on listed companies, manufacturing industries, and high-tech enterprises, this study extends the research perspective to SMEs, a more representative innovation subject, to make up for the shortcomings of the existing studies. By constructing a systematic theoretical framework and empirical model, this study aims to provide new analytical perspectives and methodological references for subsequent researchers, and at the same time to provide empirical evidence for improving innovation support policies.

3 | Research Design and Methods

3.1 Definition of variables and data sources

3.2.1 | Variable selection

1. Explained Variables

Existing literature usually assesses the innovation capability of enterprises from two dimensions: innovation input and innovation output. In terms of innovation inputs, scholars commonly use indicators such as the proportion of R&D expenditures to sales revenues, the ratio of R&D expenditures to operating revenues, and the proportion of R&D personnel. As far as innovation output is concerned, studies have mostly used the number of patent applications or patent grants as measurement indicators. Considering that R&D activities are characterized by high risk, long cycles, and uncertainty of returns, innovation inputs to outputs are affected by many factors. This study adopts the ratio of R&D expenditures to operating revenues as an indicator for measuring the level of innovation inputs of enterprises.

2. Explanatory variables

In this paper, we use the measurement method to express the intensity of the R&D cost plus deduction suffered as the following formula:

Intensity of preferential deduction for R&D expenses (Tax) = (R&D expenses x percentage of deduction x enterprise income tax rate)/total assets x 100 percent

3. Mediating variables

In existing studies, when measuring the degree of financing constraints faced by enterprises, academics generally adopt index systems such as the WW index, KZ index, and SA index. In this study, the SA index is selected as the core measurement index based on the following considerations: analyzed from the perspective of endogeneity, the formula of the SA index has only two exogenous variables, namely, enterprise size and the number of years of establishment, which effectively circumvents the endogeneity problem of the model. The public announcement is as follows:

SA=-0.737×Size+0.043×Size2-0.04×Age

4. Control variables

Firm Size (Size): firms with larger assets are usually more risk-resistant, as they can cushion external shocks in the face of market volatility or economic uncertainty by their abundant resources and capital reserves; Return on Equity (RoE): firms with higher levels of ROE are usually more attractive in the capital market, and can gain investors' favor at a lower cost, and thereby making it easier to raise capital. This financing advantage provides a sufficient source of funds for enterprises to increase their investment in R&D activities, which in turn promotes technological innovation and business development; gearing ratio (Roe): gearing ratio indicates the level of financial risk faced by enterprises. In the face of financing constraints, corporate management decision makers tend to adopt a prudent business strategy, which is mainly manifested in the tendency to avoid high-risk investment projects; the proportion of shares held by the first largest shareholder (Top1): equity concentration affects corporate innovation, and the concentration of equity makes the major shareholders tend to make private gains, which is also an important factor affecting the investment decision of corporate innovation; the proportion of independent directors (Indp): This indicator is a key parameter for measuring the independence and transparency of the corporate governance structure, reflecting the ability of the board of directors in supervising the company's management and ensuring the scientific nature of the company's decision-making; Firm Growth (Growth): High growth usually means that firms have strong competitiveness in the market and a high market share, which strengthens their expectations of future earnings and makes them more inclined to invest resources in R&D activities.

Table 1 Definition of variables

variant	variable name	variable symbol	Variable Definition
explanatory variable	Enterprise innovation inputs	Rd	R&D investment/revenue
explanatory variable	Intensity of deduction for R&D expenses	Tax	Deduction intensity of R&D expenses = (R&D expenses × deduction ratio × enterprise income tax rate)/total assets × 100%
intermediary variable	Financing constraints	SA	=-0.737×Size+0.043×Size2-0.04×Age
control variable	Enterprise size	Size	Ln (total assets at the end of the period)
	gearing	Lev	Total liabilities/total assets
	Proportion of independent directors	Indp	Number of independent directors/total number of board members
	Corporate Growth	Growth	(Total assets for the current period - total assets for the previous period)/total assets for the previous period
	Return on assets	Roe	Net profit/owners' equity
	shareholding concentration	Top1	The shareholding ratio of the largest shareholder

3.2.2 | Data sources

This study selects science and technology-based SMEs listed on GEM during 2018-2023 as the research sample. The data is obtained from diversified data sources mainly including the Cathay Pacific Database, Juchao Information Network, CNRDS, and Science and Technology-based SME Public Service Platform. The specific screening process is as follows: companies listed on GEM are subjected to the following treatment.

Based on the official certification database of the Science and Technology-based SME Service Platform, the study screened the sample enterprises that have obtained the qualification certification of Science and Technology-based SMEs.

Based on the provisions of the Negative List Management System, this study excludes specific industry samples, including enterprises in the tobacco manufacturing industry, accommodation and food service industry, wholesale and retail trade, real estate industry, leasing and business service industry, and entertainment industry.

Remove ST, *ST, and suspended firms from the data;

Sample firms with significant missing values or outliers in key variables are excluded; to further control the interference of extreme values on the results of empirical analysis, this study carries out Winsorize shrinkage treatment for all continuous variables at 1% and 99% quantile points to enhance the robustness and reliability of data. After data screening and organization, this study finally identifies 710 listed companies as the research sample and obtains a total of 4,199 valid observations. During the research process, the raw data were first preprocessed using Excel software, followed by data analysis and model estimation using Stata 18.0 statistical software.

Table 2 Data screening criteria

serial number	(an official) standard
1	Excluding companies labeled as ST or ST*, suspended companies
2	Excluding firms with significantly missing or abnormal values for key variables
3	Based on the provisions of the Negative List Management System, this study excludes specific industry samples, including enterprises in tobacco manufacturing, accommodation and food service, wholesale and retail trade, real estate, rental and business services, and entertainment industries.

3.2 Research Design

Firstly, the F-test is performed, and finally F(709,3482)=15.6 as well as F=0.0000, which indicates that the F-test is passed.

The statistical results based on Hausman's test show that the p-value of the test statistic is significant at a 1% level of significance. Therefore, for the main regression, this paper selects the fixed effect model. The specific model is as follows:

$$RDi,t = \alpha 0 + \alpha 1 Taxi,t + \alpha 2 \sum X i,t + \varepsilon i,t \quad (1)$$

$$SAi,t = \beta 0 + \beta 1 Tax\ i,t + \beta 2 \sum X\ i,t + \varepsilon i,t \quad (2)$$

$$RDi,t = \gamma 0 + \gamma 1 Tax\ i,t + \gamma 2 SA\ i,t + \gamma 3 \sum X\ i,t + + \varepsilon i,t \quad (3)$$

Among them, model (1) takes the R&D expense plus deduction policy as the core explanatory variable and enterprise innovation input as the explanatory variable, which is used to test the validity of hypothesis H1. Model (2) takes the degree of financing constraints faced by enterprises as the explanatory variable and systematically examines whether the tax incentive policy of R&D expense deduction affects enterprises' innovation input by alleviating their financing ability through empirical analysis methods. Model (3) plays its role by alleviating the financing constraints suffered by enterprises through a signaling mechanism. In the process of empirical analysis, the direct impact of the R&D expense deduction policy on enterprises' innovative activities is first assessed through the coefficient $\alpha 1$, and then through the comprehensive analysis of the coefficients $\alpha 1$, $\beta 1$, and $\gamma 1$, which is used to verify the hypothesis H2.

4 | Results and Discussion

4.1Results

4.1.1 | Descriptive statistics and correlation analysis

In this study, the Stata 18.0 statistical analysis tool was used to process the descriptive statistics of the panel data set of 710 sample listed companies, and the results of the relevant analysis are shown in Table 3.

Table 3 Descriptive statistics of variables

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
code	4,199	300,407	229.9	300,001	300,811
year	4,199	2,021	1.697	2,018	2,023
Rd	4,199	0.0749	0.0584	0.00387	0.315
Tax	4,199	0.00382	0.00272	0.000363	0.0155
SA	4,199	-3.861	0.203	-4.387	-3.405
Lev	4,199	0.368	0.179	0.0654	0.824
Size	4,199	21.72	0.892	20.02	24.48
Indp	4,199	0.386	0.0537	0.333	0.571

Top1	4,199	26.48	11.58	6.097	61.17
Roe	4,199	0.0335	0.166	-0.783	0.347
Growth	4,199	0.123	0.264	-0.474	1.366
Number of code	710	710	710	710	710

From the distribution characteristics of innovation investment (R&D), the mean value of R&D intensity of the sample enterprises is 0.0749, the standard deviation reaches 0.0584, and its value ranges from 0.00387 to 0.315, and the empirical data show that the science and technology-based SMEs in the sample present a big difference in R&D investment intensity. In terms of the distribution of the intensity of tax incentives, its extreme values are 0.0155 and 0.000363, respectively, and the standard deviation reaches 0.00272, this statistical feature indicates that there is a significant difference in the actual degree of benefit from tax incentives among different enterprises.

In terms of the statistical value of financing constraints, the maximum and minimum values of the SA index are -3.405 and -4.387 respectively, with a mean value of -3.861 and a standard deviation of 0.203, and this distributional feature reveals that China's science and technology-based SMEs are facing greater obstacles in obtaining external financing, and the overall financing environment is challenging.

In the statistical analysis of the control variables, the distribution characteristics of the gearing ratio indicator show the following features: its observation interval is [-0.783, 0.347], the arithmetic mean is 0.0335, and the standard deviation of the degree of dispersion is 0.166, reflecting that the sample enterprises have a large difference in their capital structure. This result indicates that the sample firms generally adopt conservative financial strategies and rely less on debt financing, which also reflects that it is more difficult for SMEs to obtain external debt financing. In addition, the value of the equity concentration indicator ranges from 0.333 to 0.571, with a mean of 0.386 and a standard deviation of 0.0537, indicating that there is a significant difference in the equity structure of the sample enterprises.

In summary, the results of descriptive statistics reveal significant differences among the sample firms in terms of R&D investment, tax incentives, financing constraints, and capital structure.

4.1.2 | Benchmark regression analysis

According to the results of the correlation coefficient matrix analysis in Table 6.4, in the baseline

regression model without introducing control variables, the tax incentive policy of additional deduction for R&D expenses exhibits a significant positive relationship with the intensity of enterprises' R&D investment. It is further found that the characteristics of enterprises' financial leverage, asset size, growth potential, board independence, and equity structure are all correlated with innovation investment intensity at the 1% significance level, a result consistent with theoretical expectations.

As far as the test of multidisciplinary is concerned, this study uses the variance inflation factor (VIF) method to diagnose the regression model of the R&D expense deduction policy and corporate innovation investment. The test results in Table 6.5 show that the VIF value is lower than 1.5. the result can be determined that the model does not have serious multidisciplinary problems.

Table 4 Correlation coefficient test between variables

Tax	Rd	SA	Lev	Size	Indp	Top1	
Tax	1						
Rd	0.699***	1					
SA	0.054***	0.045***	1				
Lev	-0.126***	-0.230***	-0.041***	1			
Size	-0.155***	-0.129***	-0.184***	0.334***	1		
Top1	-0.058***	-0.099***	0.051***	-0.073***	-0.074***	0.033**	1
Roe	-0.00400	-0.114***	0.054***	-0.318***	0.115***	-0.0240	0.198***
Growth	-0.059***	-0.066***	0.041***	0.061***	0.199***	-0.031**	0.089***

	Roe	Growth
Roe	1	
Growth	0.439***	1

Note: Standard errors in parentheses

*p<0.1,**p<0.05,***p<0.01

Table 5 Results of multiple covariance test

Variable	VIF	1/VIF
Roe	1.550	0.644
Lev	1.370	0.728
Growth	1.320	0.756
Size	1.240	0.807
Top1	1.060	0.944
Tax	1.040	0.961
Indp	1.010	0.992
Mean	VIF	1.230

The results of the base regression are shown in Table 6.

Table 6 Regression results

	(1)

	Rd
Tax	8.109***
	(0.280)
Lev	-0.027***
	(0.005)
Size	0.004***
	(0.001)
Indp	0.015
	(0.012)
Top1	-0.000***
	(0.000)
Roe	-0.060***
	(0.003)
Growth	0.001
	(0.002)
_cons	-0.023
	(0.026)
N	4199.000
r2	0.299
r2_a	0.155

Note: Standard errors in parentheses

*p<0.1,**p<0.05,***p<0.01

The results of the empirical regression analysis show that in the estimation results of model (1), the implementation strength of the R&D expense deduction policy is significantly and positively related to the innovation investment of enterprises, and this finding verifies the establishment of research hypothesis one.

4.1.3 | Robustness Test

1. Reduction of period

Due to the increase in the percentage of R&D cost deduction to 100% in 2022. Therefore, the data is shortened from 2018-2023 to 2018-2021 for the robustness test.

Table 7 Robustness test for shortened years

	(1)
	Rd
Tax	8.034***
	(0.344)
Lev	-0.016***
	(0.006)
Size	-0.000
	(0.002)
Indp	0.014
	(0.014)
Top1	-0.000***
	(0.000)
Roe	-0.052***
	(0.003)
Growth	0.005***
	(0.002)
_cons	0.062*
	(0.037)
N	2777.000
r2	0.315
r2_a	0.077

Note: Standard errors in parentheses

*p<0.1,**p<0.05,***p<0.01

The empirical results of the robustness test show that there is a significant positive correlation between the implementation strength of the R&D expense deduction policy and the firm's innovation investment, which further verifies hypothesis two.

2. One period lagged regression

This result suggests that the relevant policies not only had a significant boosting effect on firms' R&D expenditures at the initial stage of implementation but also that this incentive effect continued to be significant in the second year after the implementation of the policies. This finding further verifies that the R&D investment of SMEs in science and technology is indeed positively affected by the implementation of the policy, suggesting that the policy effect has a longer-term continuity and stability. Through this analysis, it can be concluded that the policy intervention can effectively stimulate the innovation vitality of enterprises in both the short and medium term, providing strong support for the technological upgrading and sustainable development of S&T SMEs.

Table 8 One-period lagged robustness results.

	(1)
	F.Rd
Tax	2.6886***
	(7.6861)
Lev	-0.0422***
	(-6.9847)
Size	0.0158***
	(10.1086)
Indp	-0.0110
	(-0.7269)
Top1	-0.0004***
	(-3.0191)
Roe	-0.0025

	(-0.6613)
Growth	-0.0086***
	(-4.2742)
_cons	-0.2468***
	(-7.0232)
N	3481
adj. R2	-0.168

Note: Standard errors in parentheses

*p<0.1,**p<0.05,***p<0.01

The results of the empirical analysis show that the implementation strength of the R&D expense deduction policy shows a significant positive correlation with the innovation investment of enterprises, and this finding verifies that the tax incentive policy has a significant role in promoting the innovation activities of enterprises, thus supporting the establishment of the research hypothesis H1.

Replacement of explanatory variable indicators

In this paper, the logarithm of the amount of R&D expense deduction (denoted as Tax1) is used to replace the original tax benefit variable (Tax) to eliminate the bias that may be caused by the difference in absolute values among enterprises. An in-depth analysis reveals that after the variable replacement, it passes the 5% significance test. It confirms that tax incentives have a significant role in promoting the innovative behavior of enterprises, which further validates the reliability of the results.

Table 9 Robustness test for substitution of explanatory variables

	(1)
	Rd
Tax1	0.001**
	(0.001)
Lev	-0.014***
	(0.005)

Size	0.001
	(0.001)
Indp	0.031**
	(0.013)
Top1	-0.000***
	(0.000)
Roe	-0.063***
	(0.003)
Growth	-0.006***
	(0.002)
_cons	0.040
	(0.030)
N	4185.000
r2	0.132
r2_a	-0.047

Note: Standard errors in parentheses

*p<0.1,**p<0.05,***p<0.01

4.1.4 | Heterogeneity test

1. Whether it qualifies as a high-tech enterprise

As S&T SMEs with high-tech enterprise qualifications are more sensitive to policy benefits, the incentive effect of the policy on them is more significant. To verify whether there is a difference in policy response among SMEs with high-tech enterprise qualifications, this paper conducted a group difference analysis by introducing an interaction term and conducting a Chow test. This method aims to test the heterogeneity of the policy effects of enterprises with different qualifications, to provide more targeted empirical evidence for policy optimization.

Through the above analysis, the coefficient of the interaction term (Tech*Tax) in the results is 0.559, which is significant at the 1% significance level and passes the Chow test at the 1% significance level, F(20,709)=16.35, p-value 0.010, and the results of the test of between-groups difference show that the tax incentive policy has a more significant role in promoting innovation in high-tech enterprises, and this finding reveals the differential character of the policy effect.

Table 10 Interaction term results1

	(1)
	Rd
Tax	8.053***
	(0.280)
Tech*Tax	0.559***
	(0.182)
Lev	-0.027***
	(0.005)
Size	0.004***
	(0.001)
Indp	0.015
	(0.012)
Top1	-0.000***
	(0.000)
Roe	-0.060***
	(0.003)
Growth	0.000
	(0.002)
_cons	-0.029
	(0.026)
N	4199.000
r2	0.301
r2_a	0.157

Note: Standard errors in parentheses

*p<0.1,**p<0.05,***p<0.01

2. Business life cycle

Based on the research framework, the life cycle of enterprise development can be systematically divided into three main stages: growth stage, maturity stage, and decline stage through the comprehensive assessment of four dimensions.

Based on the enterprise life cycle theory, this study divides the sample firms into mature and immature stages to examine in depth the heterogeneous characteristics of the policy effect of R&D expense deduction.

Table 11 Interaction term results2

	(1)
	Rd
Tax	7.894***
	(0.283)
Life*Tax	0.744***
	(0.164)
Lev	-0.027***
	(0.005)
Size	0.004***
	(0.001)
Indp	0.015
	(0.012)
Top1	-0.000***
	(0.000)
Roe	-0.059***
	(0.003)
Growth	0.001

	(0.002)
_cons	-0.020
	(0.026)
N	4199.000
r2	0.303
r2_a	0.159

Note: Standard errors in parentheses

*p<0.1,**p<0.05,***p<0.01

The coefficient of the interaction term (Life*Tax) in the results was 7.894, which passed the 1% significance test while at 1%. In the next Chow test, the results show that F (20,709) = 16.71, P value 0.005, the coefficient of the difference between the groups is obvious; empirical results show that for those life cycle is in the "maturity" of science and technology-based small and medium-sized enterprises, the effect of the policy is more prominent.

4.2 Mechanism analysis

Finally, a mechanism test was conducted to verify the mediating role of financing constraints in the R&D cost plus deduction policy on innovation investment of science and technology SMEs through a three-step method. The regression analysis results of model (2) show that the degree of financing constraints is significantly negatively correlated with the implementation strength of the R&D expense plus deduction policy. This empirical finding suggests that the increase in the strength of tax incentives can effectively alleviate the financing constraints faced by enterprises. In model (3), when the SA index is introduced as a proxy variable for financing constraints, the two sets of variables, namely, the intensity of R&D expense deduction and innovation input, and financing constraints and innovation input, all pass the test at the 1% level of statistical significance. In particular, it should be noted that the regression coefficient of financing constraints and innovation input shows a negative value, and this result verifies the theoretical expectation that an increase in the degree of financing constraints will significantly inhibit the level of enterprise R&D investment. At the same time, the coefficient of R&D expense plus deduction intensity and innovation input in the model (3) becomes smaller, indicating that financing constraints play a partly mediating role in the R&D expense plus deduction policy on the innovation input of science and technology-based SMEs. Thus hypothesis 2 is verified.

Table 12 Three-step regression results

	(1)	(2)	(3)
	Rd	SA	Rd
Tax	8.109 ***	-6.581 ***	7.837 ***
	(0.280)	(0.774)	(0.281)
Lev	-0.027 ***	-0.077 ***	-0.030***
	(0.005)	(0.013)	(0.005)
Size	0.004 ***	-0.144 ***	-0.002
	(0.001)	(0.003)	(0.001)
Indp	0.015	-0.091 ***	0.011
	(0.012)	(0.033)	(0.012)
Top1	-0.000 ***	0.006 ***	-0.000
	(0.000)	(0.000)	(0.000)
Roe	-0.060 ***	0.020**	-0.059 ***
	(0.003)	(0.009)	(0.003)
Growth	0.001	0.025 ***	0.002
	(0.002)	(0.005)	(0.002)
SA			-0.041 ***
			(0.006)
_cons	-0.023	-0.807***	-0.057**
	(0.026)	(0.071)	(0.026)
N	4199.000	4199.000	4199.000
r2	0.299	0.539	0.308
r2_a	0.155	0.444	0.166

Note: Standard errors in parentheses

*p<0.1,**p<0.05,***p<0.01

5 | Conclusion

5.1 Results of the study

This paper selects panel data from 2018 to 2023 as the research sample and applies the fixed effect model to analyze the impact of the R&D expense plus deduction policy on the R&D investment of science and technology-based SMEs as well as to verify whether the policy affects innovation investment by alleviating financing constraints through the signaling mechanism. The empirical study leads to the following main findings: in terms of policy effects, the implementation of the R&D expense deduction system significantly promotes the level of innovation investment of SMEs in science and technology. The results show that financing constraints play a signaling mechanism effect in the R&D expense deduction policy to alleviate the financing constraints and thus play a partly intermediary role in the innovation investment of SMEs in science and technology. The effect of the policy is more prominent for those SMEs that have the qualification of high-tech enterprises or are in the "mature stage" of their life cycle.

5.2 Policy recommendations

1. Implementing differentiated policy support based on enterprise heterogeneity

According to the results of heterogeneity analysis, the additional deduction policy has a more significant positive impact on high-tech enterprises and science and technology-based SMEs in the maturity period, and government departments should design a differentiated tax incentive policy system based on the characteristics of the growth stage of the enterprise and the industry attributes to implement precise incentives to regulate. For example, for start-up enterprises, the proportion of pre-tax deduction for employee education expenses can be increased to encourage them to increase employee training and cultivate independent research and development capabilities; the strength and precision of tax incentives can be increased to motivate enterprises in the growth period to increase research and development investment and enhance innovation capabilities.

2. Increase tax incentives for small and medium-sized enterprises to stimulate innovation and vitality

The proportion of research and development expenses plus deductions for science and technology-based small and medium-sized enterprises can be moderately continued to be increased, and the assessment criteria for science and technology-based small and medium-sized enterprises can be lowered. Specifically, the scope of beneficiaries of tax incentives can be expanded by optimizing the filing process and lowering the threshold of entry, thus enhancing the universality of the policy and enabling more market players to fully enjoy the policy dividends. Enterprises should take the initiative to disclose information on the policy preferences they enjoy

and enhance their social reputation and innovation capacity through cooperation with universities and research institutes.

3. Enhancing innovation efficiency

To promote the in-depth integration of industry, academia, and research, strategic collaboration between enterprises and institutions of higher learning and research institutes should be strengthened to promote the effective docking of basic research and market demand and to accelerate the industrialization of scientific and technological innovation achievements. For example, key laboratories and technology research centers can be jointly established to integrate high-quality resources to break through core technology bottlenecks. At the same time, the establishment of a sound system of technology transfer and transformation of results, optimizes the intellectual property protection mechanism, to ensure that the results of scientific research can be converted into real productivity promptly, to enhance the overall effectiveness of the innovation system.

4. Insufficient publicity of the policy, as well as the limited professional ability and biased understanding of the policy by the enterprise's finance and tax personnel, have weakened the actual effect of the policy. Enterprises should take into account the development trend of the industry and their business characteristics, carry out a comprehensive analysis of opportunities and risks, and formulate scientific and reasonable fiscal management strategies. In terms of talent recruitment, enterprises should improve the selection criteria to attract high-quality talents with professional tax knowledge and professionalism, to improve the overall level of the tax team. At the same time, it is also crucial to strengthen communication with tax authorities, which can help eliminate the problem of information asymmetry and ensure that enterprises can grasp the policy dynamics promptly and take corresponding measures.

To optimize the financial and tax management structure, technology-based SMEs should make a clear distinction between financial and tax work, set up an independent tax department, and clearly define the responsibilities of each position to ensure that each financial and tax personnel can efficiently perform their duties. Enterprises that lack independent planning ability, can seek support from professional tax service organizations. When selecting a partner, enterprises should consider its professional capability, market reputation, and credibility to ensure that the most appropriate service organization is selected. In the process of cooperation with third-party institutions, enterprises should actively participate in the implementation of tax planning, accumulate relevant experience, properly preserve invoices and vouchers, and adjust the tax management system according to the actual needs, to ensure the smooth implementation of tax planning solutions and the achievement of tax optimization goals.

5. Promote the transformation of informatization of financial accounting business

At the internal level, enterprises should be committed to improving operational efficiency, simplifying the financial accounting process, and carrying out scientific planning of financial work according to their actual situation, while continuously optimizing the relevant implementation programs. Through the introduction of modern information technology, enterprises can realize the digital management of financial accounting, reduce redundant links, and build a comprehensive integrated financial accounting system.

In the external environment, enterprises should establish a dynamic response mechanism, and actively use big data, cloud computing, and other modern information technology to reconfigure the financial management system and promote the digital transformation of finance. By deepening the integration and application of information technology, enterprises can not only realize the automation and precision of the financial accounting process but also build an intelligent decision support system based on data.

In summary, science and technology-based small and medium-sized enterprises should enhance their financial management capabilities by improving the level of fiscal management, optimizing the financial accounting process, and strengthening the construction of information technology, to lay a solid foundation for sustainable development.

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