Research on the Impact of Additional Research and Development Expenses Deduction on Technological Innovation of Manufacturing Enterprises

Yumin Yang

Nanjing University of Science and Technology, Nanjing, China

Abstract. At the present stage, the international situation is becoming more and more tense, and the R&D and innovation ability is an important standard to measure the comprehensive strength of a country. For this reason, China has introduced many fiscal and tax policies to incentivize enterprises to carry out technological innovation activities, among which one of the preferential policies with the widest scope of action and the greatest strength is the policy of additional R&D expenses deduction. Taking A-share enterprises in China's manufacturing industry from 2013-2020 as a sample, this paper finds that China's manufacturing enterprises are incentivized to improve their technological innovation level after enjoying a higher proportion of tax incentives, and that the policy has a more significant incentive effect on non-state-owned manufacturing enterprises and manufacturing enterprises in the eastern region.

Keywords: Additional R&D expenses deduction, Technological Innovation, Incentive effect.

1. Introduction

Since the reform and opening up, with the development of China's scientific and technological undertakings and achievements of the production scale is growing, in all fields have continued to make brilliant achievements. However, at the present stage, the situation at home and abroad is grim, international competition has intensified, trade protectionism has risen in recent years, international competition within the developed countries and small and medium-sized enterprises is increasing, technical barriers are increasingly strengthened, and it is imperative to enhance the scientific and technological innovation capacity of China's manufacturing enterprises.

The essence of science and technology is innovation, and scientific and technological innovation is also the experience and inevitable choice of historical development. The manufacturing industry is not only the main body of China's national production, but also an important manifestation of China's creativity, competitiveness and comprehensive national strength, while the manufacturing industry as a whole has the highest R&D investment. For a long time, the manufacturing industry, mining industry and electricity, heat, gas and water production and supply industry has been the highest proportion of R&D investment in industrial enterprises industry in the three industries. But the manufacturing industry R&D investment is much higher than the mining industry and electricity, heat, gas and water production and supply industry and the sum of up to 30 times more, ranking first in China's industries, which shows that the manufacturing industry in China's scientific and technological development, technological innovation on the pivotal position. However, China's manufacturing industry, whether compared with manufacturing powerhouses or from the point of view of their own development, have the problem of poor quality of development [1]. Especially in terms of technological innovation, China's manufacturing enterprises still have many problems, has not been fully realized to the transformation of manufacturing power. At present, China is in urgent need of breakthrough innovations to support the critical period of the transformation to a manufacturing power, so the study of technological innovation development of China's manufacturing enterprises is particularly important [2], and the research will be centered on China's manufacturing enterprises.

In the real environment, due to the enterprise's technological innovation activities have a greater risk, completely by the enterprise spontaneous technological innovation R&D activities enthusiasm is low or can only carry out limited innovation research, which is why the government has introduced a number of tax incentives to encourage the company in technological innovation to make more investment. And relatively speaking one of the policies with the widest coverage is the policy of additional R&D expenses deduction, from the implementation of the policy to date, the subject and industry enjoying the policy has been expanding, and it has a far-reaching impact on China's manufacturing enterprises. Therefore, this paper uses the data of listed manufacturing companies to empirically analyze the impact of the increase in the proportion of R&D expenses plus deduction on the technological innovation of manufacturing enterprises.

In the theoretical significance, this study selects the data of A-share manufacturing listed companies during the period of 2013-2020 from the perspectives of R&D inputs and innovation outputs to study and analyze the impact of the increase of the proportion of R&D expenses plus deduction on the technological innovation of China's manufacturing enterprises in a more comprehensive way, rather than considering a single input or output. In terms of practical significance, at this stage, international competition is becoming increasingly fierce, and all countries are utilizing fiscal and tax policies and other means to improve their own scientific and technological innovation capabilities. Based on this, through the research of this paper, we can deeply understand the implementation and effect of the policy in China, as well as the problems that exist, and put forward corresponding countermeasures, in order to improve the policy and play a greater role in the policy.

2. Theoretical foundation and Hypothesis formulation

2.1. Theoretical foundation

2.1.1 Endogenous growth theory

Endogenous growth theory, which originated in the 1980s, is a branch of Western macroeconomic theory that emphasizes the important role of human capital specialization, research and development and investment in knowledge in achieving sustainable economic improvement, with the key idea being that sustainable growth can be achieved without relying on external factors, and that endogenous technological progress is a central factor in ensuring sustainable economic growth. An opposite view to the endogenous growth theory is the exogenous growth theory, this view examines economic growth using technological progress as an external factor. In Romer Model, since technological progress is fully endogenized, an important factor in maintaining sustainable economic growth is R&D investment. Meanwhile, the endogenous variable is very sensitive to government policies, and government preferential policies can well stimulate economic growth and mitigate the impact of knowledge spillovers that enterprises may face.

From the above theory, we can see that technological innovation and progress is the key to achieve economic growth, and enterprises are the main body of economic growth, the government should adopt some subsidies and preferential policies such as R&D expenses plus deduction policy, to stimulate enterprises to increase their investment in technological innovation, to achieve the purpose of social and economic growth.

2.1.2 Market failure theory

Classical economics holds that the best way to allocate resources is a perfectly competitive market structure, but in reality, the conditions required for a perfectly competitive market structure are too harsh, and it is an idealized situation that is difficult to meet the standards. R&D innovation activities due to its risk, externality and information asymmetry, resulting in the market can not be a reasonable allocation of resources, which requires the government's "visible hand" to carry out macro-control, through the government's intervention in the form of tax incentives, can be a certain amount of "compensation" for enterprises. "Through government intervention in the form of tax incentives, enterprises can be compensated to a certain extent, so as to achieve the purpose of promoting technological innovation through policy.

2.1.3 Tax incentive theory

Tax incentives, also known as tax preferences, are a theory that suggests that governments need to sacrifice a certain amount of revenue to give tax benefits for specific economic behaviors and activities. Tax incentives do not directly affect the innovation intensity of firms, but rather incentivize firms to invest in innovation by directly reducing their tax burden and lowering costs. Tax incentives can internalize the externality of innovation activities, reduce the uncertainty of innovation activities, and give enterprises a certain compensation for R&D costs in order to increase private benefits to converge with social benefits. At the same time, tax incentives have a certain degree of orientation, the enterprise's technological innovation activities have a guiding role and maintain market flexibility, to create a virtuous circle, improve the level of technological innovation and bring social benefits.

2.2. Hypothesis formulation

From the existing literature, scholars have studied the relationship between R&D expense deduction policy and R&D investment, and the conclusions are mainly categorized into "promotion theory" and "inhibition theory". Scholars holding the "promotion theory" believe that the R&D expense deduction policy is a policy tool that can not only enhance the enterprise's willingness to technological innovation, but also enhance the enterprise's income. Chang et.al. (2018) found that tax incentives increase the speed of technological innovation research and development of enterprises [3]. Scholars in favor of the "disincentive theory" argue that policies have little impact on incentivizing firms to increase R&D investment. This is because tax incentives such as the policy of additional R&D expenses deduction will increase the fiscal pressure on the government to a certain extent, and will not be a good solution to the problem of market failure caused by innovation externalities [4]. Li et al. (2011) took a questionnaire survey as a sample in Shanghai, and found that most of the enterprises believed that the policy had an incentive effect in general, but a small number of them reduced their R&D investment instead [5]. At present, the debate on the impact of tax incentives on R&D investment, such as additional deduction for R&D expenses, is still ongoing, but on the whole, most scholars are more in favor of the incentive effect of the policy.

The main reasons for the emergence of market failure can be seen from the fact that the technological innovation activities of enterprises have the characteristics of quasi-public goods, with strong externality, high risk and information asymmetry, so the policy support of the government's "visible hand" is very necessary for the innovation of enterprises. Difficulty in guaranteeing the rate of R&D results, rapidly changing market winds, knowledge spillovers and other factors are important constraints on enterprises to carry out R&D and innovation resistance, for the results of R&D can be transformed into products on the ground or the development of the long term are not sure. Policies do not act directly on the results of technological innovation, but by reducing the tax burden pressure on enterprises, easing the pressure on capital flow, and then investing funds in R&D. Therefore, one of the most important problems faced by enterprises in R&D activities is the problem of funding. Luo and Liu (2020) [6], Li and Xu (2021) [7] believe that tax incentives can reduce the problem of information asymmetry of enterprises and alleviate the pressure of cash flow in order to enhance the ability of enterprise financing. Therefore, the implementation of the addition and deduction policy can be very effective in reducing the risk of enterprise failure, especially the new policy implemented since 2016, the enterprise income tax concessions are unprecedentedly large, and it also pushes more manufacturing enterprises to increase their R&D investment. Caishui [2018] No. 99 Policy increases the proportion of additional deduction for R&D expenses of enterprises in China to 75% across the board, which also means that the taxable income of enterprises will be less when they pay the same R&D expenses and do not incur additional costs, which indirectly improves the net profit of enterprises, and thus increases the willingness of enterprises to expand their R&D activities in response to the state's policy.

Thus, the hypothesis is formulated as follows:

H1: The increase in the proportion of deductions for R&D expenses has a positive effect on the technological innovation of manufacturing enterprises.

The nature of property rights can directly affect the enterprise's management mechanism, and the management mechanism will affect the enterprise's innovative behavior, so the increase in the proportion of R & D expenses plus deductions for state-owned manufacturing enterprises and non-state-owned manufacturing enterprises may have different incentive effects. State-owned enterprises because of their own particularity, by the government's management more, and the goal of state-owned enterprises is not to maximize profits, it also need to bear more social responsibility. In addition, SOEs have a serious agency problem, which can also lead to a lower willingness to innovate in SOEs. Chen (2021) showed that managers of state-owned enterprises have some negative attitudes towards carrying out innovation, which need to be rationally channeled [8]. Li et al. (2019) selected the data of listed companies on the main board from 2013 to 2016, and found that the expansion of the scope of the deduction in 2015 had a significant effect on the R&D investment of enterprises, and private enterprises and regions with a high degree of marketization had a faster growth of R&D investment under the effect of the policy [9]. At the same time, state-owned enterprises will have more resources in comparison, because it is not so sensitive to the adverse effects caused by positive externalities, in a number of preferential policies have applicability, and therefore reduces the impact of the addition and deduction policy for state-owned manufacturing enterprises [10]. Unlike state-owned enterprises, non-state-owned enterprises face more intense market competition, and their business objective is to realize higher profits, occupy a larger share of the market and be in a competitive position. As a result, non-state enterprises will pay more attention to the risks and benefits of innovation, and tax incentives can precisely reduce the riskiness of innovation, so non-state enterprises will be more sensitive to the policy and will spontaneously invest more resources in R&D activities. Thus, the hypothesis is formulated as follows:

H2: The increase in the proportion of R&D expenses plus deduction has a more significant effect on the incentive effect of technological innovation of non-state-owned manufacturing enterprises than that of state-owned manufacturing enterprises.

China is a vast country, and the eastern region, compared with the central and western regions, has a better enterprise base of its own, and the coasts are more open to the outside world, making it relatively easier to meet national standards on tax incentives and stimulating enterprises to engage in technological innovation. Uneven economic development exists among enterprises in different regions, with different geographical locations leading to differences in transportation and other conditions, which lead to differences in access to factors of production such as technology, information and raw materials, as well as differences in company culture and perceptions of competitiveness. Differences in the performance of relevant local government departments can also have an impact on the effectiveness of policy implementation.

Harris et al. (2008) studied the manufacturing industry in Northern Ireland, UK, and showed that tax incentives have an overall boost to manufacturing output in relatively less developed regions in the long run, but the short-run effect is not very prominent [11]. By analyzing the results of the questionnaire, Bai (2015) found that the policy of additional R&D expenses deduction has played an obvious role in promoting and improving the rapid development of Tianjin's private economy, the R&D investment of enterprises and the industrial layout of Tianjin [12]. Wang et al. (2016) took the relevant data of GEM listed companies as a sample and concluded through empirical research that the incentive effect of the add-and-deduct policy has achieved the expected effect [13]. However, Peng et al. (2016), through questionnaires and focused interviews with tax authorities and enterprises in Ganzhou, Jiangxi Province, found that the implementation of the policy of additional R&D expenses deduction in Ganzhou was not satisfactory [14]. Li et al. (2017) took the data of China's GEM listed companies in 2010-2014 as a sample, and found that the policy is significant in the overall implementation effect of China's GEM listed companies, but the practical effect varies due to regional factors, and the regional fiscal policy plays a key role in the middle [15]. Therefore, inter-regional differences have a significant impact on the effectiveness of the implementation of the policy of additional R&D expenses deduction. Thus, the hypothesis is formulated as follows:

H3: The increase in the proportion of additional deduction for R&D expenses has a more significant effect on the incentives for technological innovation of manufacturing enterprises in the eastern region than those in the central and western regions.

3. Research Design

3.1. Sample selection and Data sources

This paper studies the implementation effect of Caishui [2018] No. 99 Policy to explore the impact of the increase in the proportion of deductions on the technological innovation of China's manufacturing enterprises. However, since Caishui [2017] No. 34 Policy has increased the deduction tax rate for science and technology-based small and medium-sized enterprises (SMEs) before the deduction ratio is raised for all eligible subjects, science and technology-based SMEs are not considered in the sample to avoid the disturbance caused by Caishui [2017] No. 34 Policy. Since 2013, the development of China's R&D expense deduction policy has entered the fourth stage, the scope of application is expanding, and the declaration is gradually simplified, so the sample is the A-share manufacturing enterprises in Shanghai and Shenzhen from 2013 to 2020, and at the same time, the data are processed as follows to make the data analysis more stable and accurate:

1) Delete companies on ST and *ST for the period 2013-2020;
2) Delete companies with zero R&D investment between 2013-2020 and missing important data;
3) Winsorize 1 percent of all continuous variables to ensure accuracy of results.

A total of 2252 observations from 936 enterprises were obtained after the above screening. In this paper, we obtain the required information data through the Cathay Pacific database and use Stata 16.0 software to organize and analyze the data.

3.2. Variable design

3.2.1 Selection of explained variables

The explanatory variables selected in this paper for the study are R&D inputs and innovation outputs of the firms. For an enterprise to have more innovative results it must invest a lot and keep trying and improving in order to lead to good results. For the measurement index of R&D input, a single value of R&D investment is more one-sided, so this paper adopts the R&D investment intensity, which is currently more recognized, to measure, i.e., R&D expenditure/total operating income. And R&D output is currently mainly measured by the number of patent applications, new product output value and other indicators, the number of patent applications is more intuitive compared to other indicators, while the lag is weaker, so this paper draws on the research of scholars such as Zhong et al. (2018), the enterprise R&D expenditures are measured by the number of patent applications, and they are processed by adding 1 to take the logarithm [16].

3.2.2 Selection of explanatory variables

This paper studies Caishui [2018] No. 99 Policy, in which the state's proportion of additional deduction for R&D expenses was raised from 50% to 75%, and the main body of enjoying the policy was also expanded from scientific and technological small and medium-sized enterprises to all eligible enterprises, so this paper sets the policy of additional R&D expenses deduction as a dummy variable, which is stipulated to be taken as the value of 0 before 2018, and as the value of 1 in 2018 and the following years [17].

3.2.3 Selection of control variables

For the control variables, reference was made to existing studies, and they were selected and defined as shown in Table 1.

Table 1. Variables and definitions

	Variables	Definition
explained variables	R&D investment intensity (Rd)	R&D expenses/total operating income
	number of patent applications (Pat)	Ln (number of patent applications) + 1
explanatory variables	plus deduction of R&D expenses (EPD)	years prior to 2018 take the value of 0 and years 2018 and after take the value of 1
control variables	enterprise size (Size)	Ln (Total assets at the end of the period) + 1
	asset-liability ratio (Lev)	total liabilities/total assets
	return on equity (Roe)	net profit/average shareholders' equity
	cash flows (Cash)	Net cash flow/total assets
	nature of shareholding (Type)	State-owned enterprises take the value of 1, otherwise 0
	intangible asset (IA)	Ln (intangible asset) + 1
	enterprise area (Area)	1 in the East and 0 in the West and Central regions
	Operating margin (Om)	operating profit/operating income
	fixed asset intensity (Fa)	Fixed assets/total assets

3.3. Multivariate model

Based on the assumptions and variable definitions above, a multiple linear regression model was used in testing Hypothesis 1.

To study the impact of the R&D expense deduction policy on R&D investment:

$$Rd=\beta_0+\beta_1 EPD+controls+\gamma \tag{1}$$

To study the impact of the R&D expense deduction policy on R&D output:

$$Pat=\beta_0+\beta_1 EPD+controls+\gamma \tag{2}$$

Subsequently, group regression analyses were conducted to test Hypothesis 2 based on the nature of equity and Hypothesis 3 based on the region of the firm.

4. Empirical results

4.1. Descriptive analysis

Based on the selection and definition of variables above, the data of the screened companies from 2013-2020 were subjected to descriptive statistics, and the results are shown in Table 2.

Table 2. Results of descriptive statistics for the main variables

Variables	Sample size	Mean	Standard deviation	Minimum	Maximum
Rd	2,252	0.0226	0.0362	0.0010	0.183
Pat	2,252	3.007	1.836	0	6.653
EPD	2,252	0.437	0.496	0	1
Size	2,252	22.08	1.132	20.07	25.36
Lev	2,252	0.378	0.191	0.0466	0.839
Roe	2,252	0.0773	0.0990	-0.384	0.396
Cash	2,252	0.0565	0.0631	-0.120	0.248
Type	2,252	0.329	0.470	0	1
IA	2,252	4.258	7.438	0	20.43
Area	2,252	0.717	0.450	0	1
Om	2,252	0.0918	0.128	-0.501	0.459
Fa	2,252	0.234	0.133	0.0165	0.608

Observing the results of descriptive statistics, it can be seen that the mean value of R&D investment intensity (Rd) is 2.26%, and the standard deviation is 0.0362, which indicates that China's manufacturing enterprises have made outstanding contributions to the technological innovation of the whole industry as a whole. Among the selected A-share listed companies in the manufacturing industry, the maximum R&D investment intensity is 18.3%, and the minimum value is 0.1%, especially the minimum value is seriously low, indicating that the incentive effect of the policy of additional R&D expenses deduction in manufacturing enterprises to some enterprises is low, and the policy landing is still to be supervised. The number of patent applications (Pat) mean value of 3.007, the standard deviation of 1.836 is obviously large, the maximum value of 6.653 and the minimum value of 0 also corroborates the manufacturing enterprises in the R & D output of the huge differences, but also shows that there are invested in R & D funds but no R & D output of the year the enterprise, but also measure the face of the R & D activities to confirm that the high-risk nature is a major feature of R & D activities.

The mean value of the explanatory variable extraordinary deduction for R&D expenses (EPD) is 0.437, indicating that there is not much difference in the sample size before and after the implementation of the policy in the sample.

4.2. Regression results

In this paper, when the constructed panel data are regressed, the regression results are shown in Table 3.

Table 3. The Impact of Increased Deduction Policy Ratios on Technological Innovation in Manufacturing Firms

Variables	Rd	Pat
EPD	0.050*** (47.79)	0.156** (2.14)
Size	-0.002*** (-3.92)	0.544*** (13.43)
Lev	-0.016*** (-4.32)	0.496* (1.92)
Roe	-0.053*** (-6.33)	0.450 (0.78)
Cash	0.022** (2.28)	0.998 (1.51)
Type	-0.003*** (-2.74)	0.207** (2.47)
IA	0.000*** (4.41)	0.016*** (3.09)
Area	0.001 (0.46)	0.040 (0.50)
Om	0.017** (2.53)	-0.311 (-0.65)
Fa	-0.035*** (-8.49)	-1.995*** (-6.97)
Constant	0.067*** (5.57)	-9.027*** (-10.84)
Observations	2,252	2,252
R-squared	0.561	0.181
r2_a	0.559	0.178

Note: ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

As can be seen from Table 3, the increase in the proportion of additional deduction for R&D expenses (EPD) leads to a significant increase in the intensity of R&D investment (Rd) and the number of patent applications (Pat), and there is a strong positive incentive relationship, indicating that when the deduction proportion of the policy is increased, it indirectly reduces the cost of manufacturing enterprises, stimulates enterprises to expand R&D investment, and ultimately leads to an increase in R&D output as well, and the incentive effect of the policy is significantly, verifying the H1.

Regarding the impact of control variables on the R&D funding of enterprises, the coefficients of enterprise size (Size), gearing ratio (Lev), return on net assets (Roe), nature of equity (Type), and fixed asset intensity (Fa) are all significantly negative at the 1% level, which is basically in line with the relevant statements above. Generally speaking, firms' R&D funding comes largely from external investment, coupled with the high risk nature of R&D activities, so when firms are engaged in important R&D activities, the gearing ratio will be higher. At the same time, some of the enterprise's creditors tend to prefer that their funds can be recovered on schedule, so when the enterprise's gearing ratio increases, the creditors will reduce the scale of investment in order to reduce the risk of investment. R&D expenditures are negatively correlated with return on net assets, on the one hand, it may be due to the fact that firms with higher profitability levels have higher operating income, thus the R&D investment intensity indicator will be low. On the other hand, a high return on net assets indicates that the enterprise has strong market competitiveness, the market share will be higher than the yield of the enterprise, the enterprise will choose to maintain the status quo to continue to operate, for the R & D activities will reduce the funds invested; on the contrary, even in the case of low yield of enterprises in order to improve their own competitiveness, but also carry out research and development activities, the performance of the R & D investment intensity will be higher. The intensity of R&D investment will be higher.

Regarding the effect of control variables on R&D output, firm size is significantly and positively related to the number of patent applications; a patent has to go through a complicated procedure and a not-so-small cost from R&D to filing, and large-scale firms are able to support the birth of a patent. In this model, gearing ratio is significantly positively correlated with firm output at the 10% level, which is opposite to model 1. From the above, it is known that the gearing ratio negatively affects the R&D investment of the enterprise, when the gearing ratio is higher the creditors will put great pressure on the enterprise to protect their own rights and interests, and they are very concerned about the use of the funds, which plays a certain role in monitoring the enterprise, so as to improve the R&D efficiency.

4.3. Heterogeneous effects analysis

4.3.1 Nature of shareholding

According to H2, models (1) and (2) are analyzed based on the nature of equity and the results are shown in Table 4.

As can be seen from Table 4, in terms of R&D investment, the regression coefficient of non-SOEs is 0.0558, and the regression coefficient of SOEs is 0.0384, and both SOEs and non-SOEs significantly and positively affect R&D investment at the 1% level, indicating that the explanatory variables have a more pronounced promotional effect on the R&D investment of non-SOEs than that of SOEs, and at the same time the intensity of the R&D investment of non-SOEs is higher than that of the full sample, which also suggests that the increase in the deduction ratio has a stronger incentive effect on the R&D investment of non-SOEs than SOEs. In order to enhance their market competitiveness and not to be eliminated quickly by the market, non-SOEs increase their R&D investment to maximize their benefits. In terms of R&D output, the change in policy has a significant effect on non-state-owned enterprises at the 5% level, but not on state-owned enterprises, which can be intuitively seen that the policy has a greater impact on the R&D output of non-state-owned enterprises, and that state-owned enterprises are not efficient in transforming their R&D results. Hypothesis H2 is verified. The most important goal of non-state-owned enterprises is profit maximization, so they are more willing to seize all the tax incentives such as additional deduction for R&D expenses to innovate and produce better quality patents for the profitability of enterprises [18].

Table 4. Heterogeneity analysis based on nature of shareholding

Variables	Rd		Pat	
	non-state enterprise	state-owned enterprise	non-state enterprise	state-owned enterprise
EPD	0.0558***	0.0384***	0.183**	0.0566
	(40.46)	(27.25)	(1.99)	(0.47)
Size	-0.00110	-0.00380***	0.499***	0.630***
	(-1.33)	(-5.49)	(9.08)	(10.76)
Lev	-0.0242***	-0.00274	1.073***	-0.476
	(-4.83)	(-0.57)	(3.22)	(-1.16)
Roe	-0.0614***	-0.0296***	0.599	-0.205
	(-5.12)	(-2.87)	(0.75)	(-0.23)
Cash	0.0186	0.0103	1.946**	-0.260
	(1.49)	(0.80)	(2.35)	(-0.24)
IA	0.000386***	0.000279***	0.00268	0.0290***
	(3.80)	(3.20)	(0.40)	(3.93)
Area	-0.000541	-0.00134	0.00897	-0.0128
	(-0.33)	(-0.95)	(0.08)	(-0.11)
Om	0.0136	0.0298***	-0.401	0.217
	(1.52)	(2.78)	(-0.67)	(0.24)
Fa	-0.0466***	-0.0145***	-1.682***	-2.433***
	(-8.21)	(-2.83)	(-4.45)	(-5.60)
Constant	0.0448***	0.0901***	-8.304***	-10.13***
	(2.62)	(6.30)	(-7.29)	(-8.37)
Observations	1,511	741	1,511	741
R-squared	0.581	0.543	0.124	0.246
r2_a	0.579	0.538	0.119	0.236

Note: ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

4.3.2 Enterprise Area

According to H3, models (1) and (2) are analyzed based on the area of enterprises and the results are shown in Table 5.

According to the data in Table 5, the regression coefficients of the eastern region and the central and western regions are positive and passed the significance test at the 1% level, indicating that the increase in the proportion of R&D expense deduction has a significant positive incentive effect on the R&D investment of enterprises in both the eastern region and the central and western regions. Compared with the two, the coefficient of the eastern region is larger than that of the central and western regions, indicating that with the increase in the proportion of deduction and the expansion of the scope of use of the policy, the incentive for R&D investment of manufacturing enterprises in the eastern region is more effective. In terms of R&D output, the effect of explanatory variables is not significant for the central and western regions, while the promotion effect for the eastern region is significant at the 5% level. Hypothesis H3 is verified. On the one hand, the transformation from R&D inputs to R&D outputs takes a certain amount of time, which often exceeds one accounting period, so when R&D funding is significantly incentivized to expand inputs, outputs such as patents may not change immediately, and thus the promotion of R&D outputs is not as pronounced as that of R&D inputs. On the other hand, manufacturing enterprises in the eastern region have more convenient geographic location and abundant human and material resources compared with those in the central and western regions, and they are more sensitive to policies and respond to national policies more actively, which makes the incentive effect more obvious.

Table 5. Heterogeneity analysis based on nature of enterprise Area

Variables	Rd		Pat	
	central and western regions	eastern region	central and western regions	eastern region
EPD	0.0481*** (24.25)	0.0508*** (40.81)	0.0586 (0.45)	0.178** (2.03)
Size	-0.00438*** (-4.03)	-0.00141** (-2.01)	0.597*** (8.33)	0.541*** (10.91)
Lev	-0.0104 (-1.44)	-0.0176*** (-4.01)	-0.474 (-0.99)	0.872*** (2.82)
Roe	-0.0539*** (-3.60)	-0.0536*** (-5.27)	1.638* (1.66)	-0.179 (-0.25)
Cash	0.0102 (0.55)	0.0260** (2.33)	0.309 (0.26)	1.284 (1.63)
Type	-0.000988 (-0.47)	-0.00462*** (-3.09)	0.292** (2.10)	0.185* (1.75)
IA	0.000176 (1.37)	0.000373*** (4.21)	0.0168** (1.99)	0.0149** (2.37)
Om	0.0279** (2.19)	0.0137* (1.67)	-0.795 (-0.95)	-0.00702 (-0.01)
Fa	-0.0361*** (-4.97)	-0.0352*** (-6.98)	-1.667*** (-3.48)	-2.186*** (-6.14)
Constant	0.111*** (5.03)	0.0475*** (3.28)	-9.887*** (-6.78)	-9.006*** (-8.80)
Observations	637	1,615	637	1,615
R-squared	0.550	0.568	0.199	0.179
r2_a	0.544	0.565	0.187	0.175

Note: ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

4.4. Robustness checks

In order to ensure the robustness of the results of this paper, this paper will conduct regression analysis again after replacing the indicators of the explanatory variables. The R&D investment is assessed by replacing the R&D investment intensity with the R&D expenses of the enterprise and taking the logarithm, which is expressed by LnRd. As for the R&D output, although the number of patent applications can more accurately reflect the R&D level of the enterprise, there is the case of uneven patent quality [19], and the authorization of the patents will be subjected to a screening test [20], so the number of patents authorized plus one is taken as the logarithm of the number of patents authorized is used to measure the number of patents authorized and taken as the logarithm of the number of patents authorized, which is expressed by Pat1 denoted. The obtained robustness test results are shown in Table 6.

By observing the data in Table 6, it is found that the significance of the results of the two explanatory variables after replacing the measurement indexes is the same as the original conclusion, and the rest of the variables' regression coefficients take the value of positive and negative, and the significance is basically the same as the results of the regression of the original model. Similarly, it can be concluded that after Caishui [2018] No. 99 Policy increased the proportion of additional deduction for R&D expenses, the number of R&D expenditures and innovation outputs of manufacturing enterprises expanded, i.e., the level of technological innovation was significantly promoted. The model passed the robustness test, further verifying its validity.

Table 6. Analysis of robustness test results

Variables	LnRd	Pat1
EPD	18.188*** (461.09)	0.232*** (3.01)
Size	0.349*** (15.92)	0.532*** (12.38)
Lev	-0.636*** (-4.54)	0.425 (1.55)
Roe	1.340*** (4.27)	0.602 (0.98)
Cash	0.811** (2.27)	0.417 (0.60)
Type	0.010 (0.21)	0.363*** (4.09)
IA	0.011*** (4.04)	0.012** (2.18)
Area	0.082* (1.89)	0.141* (1.66)
Om	-1.219*** (-4.71)	-0.531 (-1.05)
Fa	-0.085 (-0.55)	-1.602*** (-5.28)
Constant	-7.556*** (-16.76)	-9.285*** (-10.52)
Observations	2,252	2,252
R-squared	0.990	0.166
r2_a	0.990	0.162

Note:***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

5. Conclusions and policy recommendations

At the present stage, international competition is fierce and trade protectionism is on the rise, and the technological innovation capability of manufacturing enterprises, which is the main productive force of a country, has become a key element in assessing the country's scientific and technological level. Incentivizing enterprises to carry out R&D activities is a work that the government continues to promote now and in the future, and the policy of adding deduction for R&D expenses among the many tax incentives is an important measure of the government, so it is of great significance to analyze the implementation effect of the policy and optimize it. Thus, this paper, in order to analyze the impact of the increase in the additive deduction ratio of Caishui [2018] No. 99 Policy on the technological innovation of manufacturing enterprises, selects the panel data of the Shanghai and Shenzhen A-share listed companies of China's manufacturing enterprises in the eight years from 2013 to 2020 for the study and conducts a heterogeneity analysis based on the nature of equity and the classification of the enterprise's region, and the resulting empirical results are as follows:

First of all, at present, manufacturing enterprises are generally able to enjoy the policy to bring preferential treatment, the new policy for the manufacturing enterprises of R & D investment and innovation output has a significant role in promoting, and the continuous improvement of the proportion of deduction to make the incentive effect more obvious, but there is a large gap between the manufacturing enterprises. Secondly, the increase in the proportion of deduction for non-state-owned enterprises by the incentive effect is more significant. Finally, the incentive effect of the policy on innovation is stronger for manufacturing enterprises in the eastern region than in the central and western regions.

To summarize, this paper puts forward the following suggestions: First, continue to expand the policy preference, due to the long-term nature of R&D activities, in order to ensure the continuity and stability of an R&D activity from the beginning to the final innovation output, it is important to cancel the time limit of the policy. Second, play the role of government supervision to improve the efficiency of R&D. When revising the policy, the government can provide tax incentives for innovative outputs, give more consideration to R&D results-oriented, play the role of supervision and urging by the corresponding government departments, and take the R&D inputs in the early stage and R&D results in the later stage as the tracking and evaluating indexes, so as to practically improve the R&D efficiency. Third, the heterogeneity of enterprises to develop differentiated policies, the number of enterprises in China, enterprises due to geographic location, local policies and other factors and the situation is very different, such as the nature of equity, enterprise size of different enterprises, the development of preferential policies in line with their characteristics, to achieve policy "universality" and "preferential" and "preferential". "Preferential" coordination [21].

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