Tax Rate-based Incentives, Tax Base-based Incentives, and the Combined Policy Effects on Corporate Innovation

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Abstract: Tax incentive policies are an important means for governments to encourage corporate innovation. The issue of policy composite fallacy exists under certain conditions, which has been overlooked by existing studies. Based on China's tax survey data from 2008 to 2016 and employing the method of constructing the marginal effective tax rate for enterprises, this paper empirically tests the effects of tax rate-based incentives, tax base-based incentives, and their combined policy effects. The following findings are obtained: tax base-based incentives consistently promote corporate innovation through the innovation risk-sharing mechanism. Whether tax rate-based incentives promote innovation depends on the extent to which the expectation of compensating for innovation risk loss through tax rate incentives is met. The combined policy effect of tax base- and tax rate-based incentives also depends on the level of government risk-sharing and the expectation of compensation for corporate innovation risk loss, with empirical results showing that the combination of the two policies impedes corporate innovation; compared with tax rate-based incentives and their combination, tax base-based incentives have a greater and more lasting impact in terms of lagged effects. Finally, the paper conducts a heterogeneity analysis on enterprises with different levels of innovation and different property rights. The conclusions of the article provide theoretical and practical bases for optimizing the combination of tax incentive policies and improving the quality of innovation.

Keywords: Tax incentives, Risk sharing, Innovation

JEL Classification: H20, O10, O31

1. Introduction

Innovation is a key driver of economic development and a critical factor in enhancing competitiveness for countries around the world (Aerts and Schmidt 2008). As the most important carrier of innovation, how to motivate corporate innovation has naturally become a focal point for academia and policymakers. Unlike conventional production and general investments, corporate innovation is characterized by significant positive externalities, high risks, and uncertain returns (Holmstrom, 1989). To mitigate the market failure of private R&D costs not fully aligning with returns, governments have implemented various public policies to foster corporate innovation. Among these policies, tax reduction policies are currently the most widespread and scrutinized incentives for innovation (Montmartin and Massard, 2015). At present, governments have not only implemented singular policies to encourage corporate innovation but also combinations of tax reduction policies, collectively affecting corporate innovation (Howoldt, 2024). Due to the different mechanisms and directions of the impact of various incentives, the interaction between these policies may result in either offsetting or reinforcing effects. The impact of these policy combinations on innovation is therefore more complex (Flanagan et al., 2011).

Most literature affirms the positive effects of single tax reduction policies on corporate innovation (Hemphill, 2006; Brown et al., 2009; Nussim and Sorek, 2017), while a few studies have analyzed the impact of different combinations of tax incentive policies on corporate innovation, with varying results and lack of in-depth mechanism analysis (Dumont, 2017; Howoldt, 2024). Domar and Musgrave (1944) suggests that tax incentives are closely related to the degree to which the government shares corporate risks. On this basis, this paper establishes a theoretical model of risk-sharing and analyzes the mechanisms through which tax rate-based incentives, tax base-based incentives, and their combinations affect corporate innovation. Compared with developed economies such as the United States, the United Kingdom, and Sweden, which have long maintained a leading innovation position, China, as an emerging developing country, has seen its innovation index ranking rise from 37th in 2008 to 11th globally in 2022, showing a steady upward trend. Behind this innovation capability lies a large number of innovation policies issued by the Chinese government over the past two decades. Diversified tax reduction policies are not only the main means of innovation policies but also provide a foundation for studying the impact of various tax reduction policy combinations on corporate innovation. In addition, as the world's second-largest economy, China is striving to transition from a manufacturing economy to an innovation-driven economy. Analyzing these policies can help predict future trends in global innovation and provide information for policy decisions in other countries to maintain competitiveness in the constantly changing economic landscape. Therefore, using China’s national tax survey data from 2008 to 2016, this study empirically tests the impact of the combination of tax rate- and tax base-based incentive policies on corporate innovation. In the empirical analysis, the paper focuses on two common tax reduction policies in China: the additional deduction of R&D expenses and the identification policy for high-tech enterprises, where the former represents tax base-based incentives, and the latter includes tax base- and tax rate-based incentives. To clarify the individual impacts of different tax incentive policies on corporate innovation, the paper calculates the marginal effective tax rates under different tax incentive policies and regresses them against corporate innovation variables. Ultimately, the study concludes the following: first, the impacts of tax rate- and tax base-based incentives on corporate innovation are inconsistent. Tax base-based incentives, through the innovation risk-sharing mechanism, can always promote corporate innovation regardless of the level of innovation.

Whether tax rate-based incentives can promote innovation depends on whether the expected compensation for innovation risk loss can be met through tax rate incentives, which may either promote innovation, have no effect, or even hinder innovation. Second, the combined policy effect of tax base- and tax rate-based incentives also depends on the level of government risk-sharing and the expectation of compensation for corporate innovation risk loss. However, the regression results from the existing sample data show that in most cases, the combined effect of the two policies either impedes corporate innovation or has no impact. Third, compared with tax rate-based incentives and their combined policy effect, tax base-based incentives have a more significant and lasting impact in terms of lagged effects. In the long term, the impact of tax base-based incentives is the most significant, followed by tax rate-based incentives, with the combined policy effect of both incentives being the least effective. Fourth, heterogeneity is present in the effects of tax base-based incentives, tax rate-based incentives, and their combined policy effect on enterprises with different levels of innovation and different property rights.

The marginal contributions of this paper are primarily reflected in two aspects: first, the literature is largely consistent regarding the impact of single tax reduction policies on corporate innovation, but the results vary for the combined effects of different tax incentive policies. Additionally, the tools used to measure the innovative incentive effects of tax policy combinations have been inconsistent, such as using dummy variables for different policy combinations (Dumont, 2017; Neicu, 2019), a certain policy's tax exemption amount divided by a company's relevant variable (Zhang 2021), conducting laboratory experiments (Ackermann et al., 2013), or using the 2K factorial design method (Ghazinoory and Hashemi 2021). Although these methods have scientifically quantified different tax policy combinations and minimized the impact of different corporate characteristics on the policy combinations, they have rarely considered the heterogeneity of corporate tax burdens. As different companies face unequal tax burdens, tax policies will have varying effects across companies due to corporate characteristics. Therefore, an indicator that can uniformly measure the effect of tax incentives must be chosen. This paper consequently constructs an indicator to measure the marginal effective tax rate of companies, which can directly separate the marginal effective tax rates under each tax policy or policy combination, thereby more accurately identifying the independent and combined impacts of tax base- and tax rate-based incentive policies on corporate innovation.

Second, regarding how tax policies stimulate innovation, although the literature has provided multiple explanations from the perspective of compensating for market failures, few researchers have focused on the fact that tax reduction is a government's act of sharing corporate innovation risks. Most research that compares the effects of different tax policies on corporate innovation does not deeply analyze the mechanisms involved. Domar and Musgrave (1944) were among the first to theoretically analyze the relationship between taxation and risk-sharing, arguing that the impact of corporate income tax on risk investment depends on the extent to which investment losses are compensated. The tax reduction policies provided by the government are precisely the value compensation for corporate innovative risk investment. Therefore, based on Domar and Musgrave (1944), this paper finds that tax incentive policies are a government risk-bearing mechanism, where different tax incentives have varying degrees of risk-bearing, thus affecting corporate innovation differently. More specifically, through theoretical and empirical evidence, the paper demonstrates that the impacts of tax rate-and tax base-based incentives on corporate innovation are not consistent. Tax base-based incentives can always promote corporate innovation through the innovation risk-sharing mechanism, while the encouragement of corporate innovation by tax rate-based incentives has certain constraints. This finding differs from the literature that only proved the individual promotion effects of tax rate-based or tax base-based incentives on corporate innovation.

The rest of the paper is organized as follows: Section 2 reviews the literature and institutional background. Section 3 analyzes the theoretical framework and research hypotheses, establishing a risk investment model of corporate innovation and government risk-sharing heterogeneity, revealing the relationship between tax base-based incentives, tax rate-based incentives, and corporate innovation. Section 4 describes the research design, calculates the marginal effective tax rates of enterprises, and provides descriptive statistics of the data. Section 5 presents empirical tests, analyzes the short- and long-term effects of different tax incentive policies on corporate innovation using national tax survey data from China, and performs endogeneity tests. Section 6 offers further heterogeneity analysis. Finally, the paper concludes with the main findings and policy implications.

2. Literature Review and Institutional Background

2.1 Literature Review

The question of whether government tax incentive policies invariably yield the intended outcomes is debated. Most studies suggest that tax reductions can compensate for market failures in the innovation process, ultimately spurring innovation investments by microeconomic entities (Nelson and Phelps, 1966; Hall, 1993), or enhancing corporate innovation by increasing cash flow and the availability of external financing (Hemphill, 2006; Brown et al., 2009; Nussim and Sorek, 2017). However, some research indicates that tax policies may lead to mismatches in input–output or imbalances in subsidy structures (Mansfield, 1986; Lach, 2002), and in extreme cases, poorly designed incentive policies may even encourage R&D manipulation, resulting in a negative impact on innovation (Brown et al., 2017; Chen et al., 2021). Additionally, the existence of a threshold effect in tax incentives suggests an optimal incentive range due to corporate heterogeneity, meaning not all firms are equally motivated to innovate (Guellec et al., 2003; Lokshin and Mohnen, 2012).

In practice, firms often benefit from multiple policies simultaneously (Howoldt, 2024). When multiple tax policies overlap for the same enterprise, synthetic effects between policies may cause biases in estimating the motivational effects of tax reductions (Busom et al., 2017). Research on the relationship between combinations of tax policies and innovation is relatively scarce, and findings are inconsistent. Some studies suggest that policy combinations have complementary effects. Bérubé and Mohnen (2009), using Canadian innovation survey data, found that firms receiving R&D tax credits and R&D grants had better innovation outcomes than those receiving only R&D tax credits. Neicu (2019) found that individual tax credits increased R&D expenditure, but fiscal subsidies only had an effect when used alongside tax credits. Guerzoni and Raiteri (2015), analyzing the policy mix in 27 EU countries, found inconsistent results, but overall, combined policies outperformed single effects.

Some research suggests that policy combinations have crowding-out effects. Ackermann et al. (2013) found through experiments that people dislike complex policies, making the combined incentives less effective than single ones. Marino et al. (2016) analyzed the effects of French fiscal subsidies and tax benefits on innovation, finding that the policy combination was detrimental to corporate R&D activities. Montmartin (2018), using a spatial Durbin model, verified this conclusion. Dumont (2017), using Belgian enterprise panel data from 2003 to 2011, also found that combining fiscal subsidies with tax benefits reduced policy effectiveness. Guellec and Van Pottelsberghe De La Potterie (2003) observed that individual government grants or tax incentives had a significant positive effect on corporate R&D, but the simultaneous implementation of both resulted in substitution effects, where increasing one would reduce the other's impact on corporate R&D.

Other studies have found that crowding-out and complementary effects exist in policy combinations. Rogge and Reichardt (2014), identifying tax policy combinations in Germany and OECD countries, noted a negative restraining effect due to the inconsistency and dispersion of policy combinations, with higher internal balance enhancing the promotion of technological dynamics.

These analyses show that existing literature offers conflicting conclusions on the impact of tax incentive policies, especially policy combinations, on corporate innovation, with most studies not delving deeply into the mechanisms of these effects. Therefore, accurately assessing the impact of tax policy combinations on corporate innovation and analyzing the mechanisms of their effects requires further research.

2.2 Institutional Background

In China, tax rate- and tax base-based incentive policies are the most common forms of tax incentives, aimed at reducing corporate tax burdens to enhance profitability and simultaneously secure and stabilize tax revenues. Tax rate-based incentives, which have been utilized earlier, can be traced back to policies implemented in 1991, such as the “Conditions and Methods for the Recognition of High-tech Enterprises in National High-tech Industrial Development Zones” (State Issue [1991] No. 12) and the “Income Tax Law for Foreign Investment Enterprises and Foreign Enterprises.” The former applied a 15% reduced income tax rate for qualified high-tech enterprises, while the latter provided “two exemptions and three reductions” income tax incentives for productive foreign-invested enterprises, with reduced tax rates of 15% and 24% in special economic zones and economic and technological development zones[①], respectively. The “two exemptions and three reductions” policy allowed enterprises to enjoy a two-year income tax exemption from the profit-earning year, followed by a 50% reduction in income tax for the next three years. After 2000, China implemented a 10% low tax rate policy for certain industries, including software and integrated circuits, to develop key sectors. In

① Special Economic Zones are pilot zones set up by the Chinese government to implement reform and opening-up policies; Economic and Technological Development Zones are specific zones for the development of knowledge-intensive and technology-intensive industries, and enterprises entering the zones enjoy certain preferential policies, such as preferential provision of industrial land and tax exemptions. Enterprises in the zones enjoy certain preferential policies, such as preferential provision of industrial land and tax exemptions.

2008, China redefined the criteria for identifying high-tech enterprises, maintaining the tax rate at 15%. In the same year, China applied a 20% tax rate to qualified small and micro enterprises. In 2010, China implemented a preferential income tax rate of 15% for high-end technology service industries until the implementation of new standards in 2017, which expanded the scope of tax incentives.

Tax base incentives started later and primarily revolve around the super deduction policy for R&D expenditures. In 1996, China issued the "Notice of the Ministry of Finance and State Administration of Taxation on Financial and Taxation Issues Related to Promoting Technological Progress of Enterprises" (Cai Gong Zi [1996] No. 41), which allowed a 50% additional deduction for qualifying enterprise R&D expenses, initially implemented only in state-owned and collective enterprises. From 2003 to 2007, the scope of policy beneficiaries gradually expanded, and in 2008, China enacted the "Interim Measures for the Pre-tax Deduction of Enterprise Research and Development Expenses (Trial)" (Guo Shui Fa [2008] No. 116), formally extending the super deduction policy for R&D inputs to recognized high-tech enterprises. In November 2015, with the approval of the State Council, the Ministry of Finance, State Administration of Taxation, and Ministry of Science and Technology jointly issued the "Notice on Improving the Policy of Pre-tax Deduction of Research and Development Expenses" (Cai Shui [2015] No. 119), in which the Chinese government relaxed the scope of enterprises eligible for tax incentives related to R&D activities and expenses, significantly reducing the differences between the scope of R&D expenses eligible for deduction and the scope collected for high-tech enterprise recognition. Since then, most industries have been able to enjoy tax benefits from the policy of additional deductions for R&D inputs. After 2017, China has continuously increased the additional deduction rate from 50% to 75%, to 100%, and then to 120%.

3. Theoretical Analysis and Research Hypotheses

3.1 Theoretical Model Inference

Innovation is a high-risk activity for enterprises (Ackermann et al., 2013). The purpose of corporate innovation activities is to enhance production efficiency and product competitiveness, so companies need to mitigate the investment risks of innovation failures and consider the risks of spillover leading to backlash. Lewis (1955) also noted that innovation implies risk, equating corporate innovation activities with risk investments. According to the theory of Domar and Musgrave (1944), investors have a preference between risky assets and safe assets; the preference for risk depends on the extent to which income tax can compensate for expected losses. When the government's risk-bearing through income tax sufficiently supplements expected losses, companies will lean towards innovation; otherwise, they will forego it. Feng and Liu (2017) showed that corporate income tax has an inherent mechanism for sharing government risks—first, current innovation inputs can be deducted before corporate income tax, and second, the corporate income tax system also includes a mechanism for risk-bearing in innovation through the additional deduction policy for R&D expenses, offering companies another option for compensating expected risk losses.

This paper, drawing on the studies of Domar and Musgrave (1944) and Feng and Liu (2017), equates innovation activities with risk investments. It investigates the effects of preferential income tax rates and additional deduction policies for R&D expenses on economic agents' risk choices and analyzes how these affect innovation activities differently. The model's conditions are set as follows:

First, the enterprise is assumed to hold initial assets W_0, composed of risk-free and risky assets. The proportion of risky assets in the initial assets W_0 is a, and the proportion of risk-free assets is $1-a$, with $1> a>0$, meaning the enterprise does not hold only risky or only risk-free assets. Let t be the corporate income tax rate, k be the deduction rate for taxable income from risk investments, r be the return rate on risk-free investments, and x be the return rate on risky investments, with θ representing the cost multiplier for risk investments, independent of the total capital investment. Thus, the final assets of the enterprise are:

$$W = W_0\{1 + [ax + (1-a)r](1-t) + a(k-\theta)t\} \tag{1}$$

Feng and Liu (2017) proved that if corporate risk investment losses are completely non-deductible (implying $k = 0$), investors would tend towards risk aversion when taxed by the government, reducing the proportion of risky assets in total assets, which means companies would not further increase innovation inputs and might even reduce them. Therefore, this paper only considers scenarios where corporate risk investment losses can be deducted.

We assume E is the expectation operator, and U is a strictly concave utility function, meaning U'>0 and U''<0, indicating that the enterprise is risk-averse. The expected utility of the final assets W can then be expressed as

$$E[U(W)] = \int U\left\{W\{1 + [ax + (1-a)r](1-t) + a(k-\theta)t\}\right\}f(x)dx \tag{2}$$

To maximize the expected utility $E[U(W)]$ of the enterprise, the optimal proportion a must be calculated. Taking the partial derivative of $E[U(W)]$ with respect to a, the first-order condition is

$$\frac{\partial E}{\partial a} = E\{U'[(x-r)(1-t) + (k-\theta)t]\} = 0 \tag{3}$$

First, we consider the relationship between the deduction rate kkk and aaa. Taking the derivative of equation (3) with respect to k yields

$$\frac{\partial^2 E}{\partial a \partial k} = E\left\{U''\left[\frac{\partial a}{\partial k}\big((x-r)(1-t) + (k-\theta)t\big) + at\right]\begin{bmatrix}(x-r)(1-t) \\ +(k-\theta)t\end{bmatrix}\right\} + E\{U't\} = 0 \tag{4}$$

We obtain:

$$\frac{\partial a}{\partial k} = \frac{tE\{U'\} + atE\{U''[(x-r)(1-t) + (k-\theta)t]\}}{-E\{U''[(x-r)(1-t) + (k-\theta)t]^2\}} \tag{5}$$

Equation (5) shows that the tax rate t has a multiplier effect on $\frac{\partial a}{\partial k}$. If equation (5) is positive, the higher the tax rate t, the greater the incentive effect of the deduction rate k on the proportion of risky assets a. If Equation (5) is negative, the higher the tax rate t, the greater the inhibitory effect of the deduction rate k on the proportion of risky assets a.

To determine the positivity or negativity of Equation (5), let $Z = aW_0$ be the initial wealth amount of risky assets. Then the end-of-period assets W can be expressed as

$$W = W_0 + W_0 r(1-t) + Z(x-r)(1-t) + Z(k-\theta)t \tag{6}$$

From Equation (6), Equation (2) can be rewritten as

$$E\{U[W_0 + W_0 r(1-t) + Z(x-r)(1-t) + Z(k-\theta)t]\} \tag{7}$$

Taking the derivative of Equation (7) with respect to a yields

$$\frac{\partial E}{\partial a} = E\{U'[W_0 + W_0 r(1-t) + Z(x-r)(1-t) + Z(k-\theta)t]\begin{bmatrix}(x-r)(1-t)\\+(k-\theta)t\end{bmatrix} = 0 \tag{8}$$

Taking the derivative of Equation (8) with respect to W_0 yields

$$\frac{\partial^2 E}{\partial a \partial W0} = E\{U''\left[1 + r(1-t) + \frac{\partial Z}{\partial W_0}(x-r)(1-t) + \frac{\partial Z}{\partial W_0}(k-\theta)t\right]\begin{bmatrix}(x-r)(1-t)\\+(k-\theta)t\end{bmatrix}\} \tag{9}$$

We obtain

$$\frac{\partial Z}{\partial W0} = \frac{E\{U''[1+r(1-t)][(x-r)(1-t)+(k-\theta)t]\}}{-E\{\{U''[(x-r)(1-t)+(k-\theta)t]^2\}}$$

$$= \frac{E\{U''[(x-r)(1-t)+(k-\theta)t]\}}{-E\{\{U''[(x-r)(1-t)+(k-\theta)t]^2\}}[1+r(1-t)] \tag{10}$$

Substituting Equation (10) into Equation (5), we get

$$\frac{\partial a}{\partial k} = \frac{tE\{U'\}}{-E\{U''[(x-r)(1-t)+(k-\theta)t]^2\}} + \frac{at}{1+r(1-t)}\frac{\partial Z}{\partial W_0} \tag{11}$$

Given $U'' < 0$, $[(x-r)(1-t)+(k-\theta)t]^2 > 0$, $-E\{U''[(x-r)(1-t)+(k-\theta)t]^2\} > 0$. Given that $U' > 0$, $t > 0$, so $tE\{U'\} > 0$, the left part of Equation (11) ($\frac{tE\{U'\}}{-E\{U''[(x-r)(1-t)+(k-\theta)t]^2\}}$) is always greater than 0. If the firm exhibits non-increasing absolute risk aversion, the amount of risky assets will not decrease with an increase in total wealth (Arrow, 1965; Salanie, 2011), which is also supported by most of the literature. Therefore, Z will not decrease with an increase in $\frac{\partial Z}{\partial W0} \geq 0$, and the right part of Equation (11) ($\frac{at}{1+r(1-t)}\frac{\partial Z}{\partial W_0}$) is also greater than or equal to 0. The above derivation shows that $\frac{\partial a}{\partial k}$ is greater than 0, indicating that the deduction rate k is positively correlated with the proportion of risky assets a.

Simultaneously, the analysis of Equation (5) shows that the tax rate t has a multiplier effect. The higher the tax rate t, the greater the impact of the deduction rate k on the proportion of risky investment a; the lower the tax rate t, the smaller the impact of the deduction rate k on the proportion of risky investment a. This means that the level of the tax rate t does not affect the positive correlation between the deduction rate k and the proportion of risky investment a but only amplifies or reduces the incentive effect of the deduction rate k. Therefore, regardless of whether the firm first enjoys a tax rate-based preference before enjoying a tax base-based preference, the tax base-based preference can always incentivize the firm's risky investment.

Next, we consider the effect of the tax rate t on a. Taking the derivative of Equation (3) with respect to t yields

$$\frac{\partial^2 E}{\partial a \partial t} = E\left\{U''\begin{bmatrix}\frac{\partial a}{\partial t}\left((x-r)(1-t)+(k-\theta)t\right)\\ -a(x-r)-r+a(k-\theta)\end{bmatrix}\begin{bmatrix}(x-r)(1-t)\\ +(k-\theta)t\end{bmatrix}\right\}$$

$$+E\{U'(-x+r+k)\}=0 \tag{12}$$

We obtain

$$\frac{\partial a}{\partial t}=\frac{E\{U''[-a(x-r)-r+a(k-\theta)][(x-r)(1-t)+(k-\theta)t]+E\{U'(r+k-\theta-x)\}}{-E\{U''[(x-r)(1-t)+(k-\theta)t]^2\}} \tag{13}$$

Given $U''<0$, $[(x-r)(1-t)+(k-\theta)t]^2>0$, $-E\{U''[(x-r)(1-t)+(k-\theta)t]^2\}>0$。 To judge the positivity or negativity of $\frac{\partial a}{\partial t}$, we consider the positivity or negativity of the numerator. The positivity or negativity of the numerator is related to $[-a(x-r)-r+a(k-\theta)][(x-r)(1-t)+(k-\theta)t]$、$(r+k-\theta-x)$. There are three different situations at this time:

First, $[-a(x-r)-r+a(k-\theta)][(x-r)(1-t)+(k-\theta)t]>0$, and $(r+k-\theta-x)<0$. At this time, there are two situations:

· If $[-a(x-r)-r+a(k-\theta)]>0$ and $[(x-r)(1-t)+(k-\theta)t]>0$, then $a(k+r-\theta-x)>r$ and $t(r+k-\theta-x)>r-x$. However, the preconditions need to be satisfied $(r+k-\theta-x)<0$. In practice, market interest rates $r>0$, so this situation does not hold.

·If $[-a(x-r)-r+a(k-\theta)]<0$ and $[(x-r)(1-t)+(k-\theta)t]<0$, then $a(k+r-\theta-x)<r$ and $t(r+k-\theta-x)<r-x$, and the preconditions need to be satisfied $(r+k-\theta-x)<0$. Given $t>0$, the equation does not hold. If the deduction rate of taxable income for venture capital is $k\to 0$, Equation (13) will be less than 0. Lowering the tax rate at this time is beneficial for enterprises to increase the proportion of risk assets, which means increasing their willingness to innovate.

Second, $[-a(x-r)-r+a(k-\theta)][(x-r)(1-t)+(k-\theta)t]<0$, and $(r+k-\theta-x)>0$. In this case, the right part of Equation (13) is always positive, and the left part is always negative. Therefore, the tax rate *t* positively affects the proportion of risky assets *a*.

Third, if $[-a(x-r)-r+a(k-\theta)][(x-r)(1-t)+(k-\theta)t]<0$, and $(r+k-\theta-x)<0$, or $[-a(x-r)-r+a(k-\theta)][(x-r)(1-t)+(k-\theta)t]>0$, and $(r+k-\theta-x)>0$, the positivity and negativity of molecules cannot be distinguished, and it depends on the size of various influencing factors. That is, whether reducing tax rates can increase the proportion of enterprise risk assets is related to the return on safety assets *r*, return on risk assets *x*, the proportion of enterprise risk assets *a*, and the multiplier of risk investment cost *θ*, given the predetermined deduction rate *k* of taxable income from venture capital.

3.2 Research Hypotheses

The theoretical derivation shows that tax base- and tax rate-based incentives have differing impacts on corporate innovation activities. Tax base-based incentives, by effectively shouldering a part of the enterprise's innovative inputs that does not exist, and by shouldering more than the enterprise's expected threshold for government risk loss, always encourage corporate innovation. Tax rate-based incentives can have multiple outcomes. By reducing the corporate income tax rate, they also reduce the government's share of risk-taking in corporate innovation. If the profits obtained by enterprises through a low tax rate are sufficient to compensate for the reduced government risk-sharing, then it remains conducive to innovation; otherwise, it may hinder innovation. Additionally, whether tax rate-based incentives can promote innovation also depends on several factors: the deduction rate for taxable income from risk investments, the return rate on safe assets, the return rate on risky assets, the initial proportion of risky assets in the enterprise, and the cost multiplier for risky investments. In some scenarios, the higher the deduction rate for taxable income from risk investments, the less likely tax rate-based incentives are to promote innovation, only becoming effective when the deduction rate approaches zero.

From the implementation of policies, although tax rate- and tax base-based incentives can achieve the goal of reducing immediate corporate tax burdens, their mechanisms of action differ significantly. Tax rate-based incentives reduce corporate income tax rates directly after the taxable income is calculated, which has nearly no connection to the process of corporate innovation. By contrast, tax base-based incentives are applied during the calculation of taxable income, effectively lowering the tax rate indirectly, and thereby directly affecting the process of innovation investments. From the perspective of the entire tax chain for corporations, tax base-based incentives also play a stronger role in preventing firms from manipulating R&D activities and exploiting tax benefits. Many studies have demonstrated that some firms adjust their structures to meet national recognition rules to enjoy tax rate-based incentives, but after recognition, their actual innovative capabilities are often mediocre (Chen et al., 2021).

Therefore, the impact of the combination of tax base- and tax rate-based incentives on innovation crucially depends on the size of the tax base that is exempt from taxation. If the exempt portion of the innovative costs in the tax base is substantial, reaching or exceeding the expectations of the taxed enterprises, then the tax rate incentives imply a reduction in the government's share of risk-sharing in corporate innovation, and the enterprise will bear a greater share of the innovation risks. This consequence is that the combination of tax base- and tax rate-based incentives may suppress corporate innovative activities.

Based on these discussions, the paper proposes the following hypotheses:

Hypothesis 1: Tax base-based incentive policies are beneficial to corporate innovation.

Hypothesis 2: The impact of tax rate-based incentive policies on corporate innovation is uncertain.

Hypothesis 3: The combination of tax base- and tax rate-based incentives may be detrimental to corporate innovation.

4. Research Design and Descriptive Statistics

4.1 Econometric Model Design

Changes in tax policy can affect corporate tax burdens and investment levels, and the impact varies among different companies, thus making each firm's marginal effective tax rate unique. Based on the theoretical analysis and research hypotheses outlined earlier, the following econometric regression equation is constructed:

$$Innovation_{i,t} = \alpha + \beta_1 \cdot \Delta Tax\_mar_{i,t} + \gamma \bar{X}_{i,t} + \mu_i + \rho_t + \lambda + \theta + \varepsilon_{i,t} \quad (14)$$

Here, i represents the firm, t represents the year, $Innovation_{i,t}$ refers to the investment or quality of innovation activities of firm i in year t, $\Delta Tax\_mar_{i,t}$ represents the change in the marginal effective tax rate due to tax policies, $\bar{X}_{i,t}$ is a vector of other control variables, and μ_i is the individual fixed effect, ρ_t is the year fixed effect, λ is the region fixed effect, θ is the industry fixed effect, and $\varepsilon_{i,t}$ is the residual term.

4.2 Methodology for Measuring Marginal Effective Tax Rates

The marginal effective tax rate ($\Delta Tax\_mar_{i,t}$) is used to gauge the tax incentives enjoyed by firms. The reasons for choosing this measure are threefold. First, Hall and Jorgenson (1967) demonstrated through neoclassical investment theory that tax policy (including tax rates, depreciation, and investment credits) is closely related to corporate investment. Tax rate-based incentives and tax base-based incentives correspond to the factors affecting tax rates and investment credits, respectively, and innovation investment is a crucial part of corporate investment. Second, the marginal effective tax rate represents the tax level borne by an additional unit of investment, essentially acting as a tax wedge, which can measure the distortion of tax on the capital return (Graham, 1996). Third, the tax effects of tax rate-based incentives, tax base-based incentives, and their combination can be reflected through changes in the marginal effective tax rate, making it an ideal tool for assessing multidimensional tax policies.

In the institutional background section, this paper reviewed key elements affecting corporate tax burdens, focusing on the preferential income tax rate policy for high-tech enterprises and the additional deduction policy for R&D expenses, which are currently the most influential tax incentive policies affecting corporate tax burdens. The data used covers a broad spectrum of general and high-tech enterprises in China from 2008 to 2016. The year 2008 marks the publication of the new catalog of high-tech enterprises, and the year 2016 saw the implementation of a 50% additional deduction for R&D inputs, applicable to general and high-tech enterprises.

Within the dataset for this period, four types of firms are identified based on their eligibility for tax incentives and their tax rates:

Type 1: Firms with a 25% [①]corporate income tax rate that enjoy the R&D expenditure additional deduction policy.

Type 2: Firms with a 15% corporate income tax rate that also enjoy the R&D expenditure additional deduction policy.

Type 3: Firms with a 15% corporate income tax rate that do not engage in R&D.

Type 4: Firms with a 25% corporate income tax rate that do not engage in R&D.

Based on these assumptions, this paper proposes constructing several comparable indicators to assess the impact of tax rate-based incentives, tax base incentives, and their combined effects on corporate innovation. The use of marginal effective tax rates provides a solution to the problem of accurately measuring the effects of tax incentive policies. The construction method is as follows: first, we calculate the marginal effective tax rates for four types of enterprises—those with a tax rate of 25% and a super deduction rate of 0%, those with a

[①] In China, the corporate income tax rate for enterprises that do not enjoy tax incentives is usually 25%. The corporate income tax rate for enterprises that enjoy the high-tech enterprise certification policy is 15%.

tax rate of 25% and a super deduction rate of 50%, those with a tax rate of 15% and a super deduction rate of 0%, and those with a tax rate of 15% and a super deduction rate of 50%. Then, by differentiating the marginal effective tax rates of these four types of enterprises, one can derive (1) the effect of the R&D super deduction policy on innovation when the tax rate is uniformly 25%; (2) the effect of the R&D super deduction policy on innovation when the tax rate is uniformly 15%; (3) the policy effects when the super deduction rate is uniformly 50% under different tax rates; and (4) the dual policy effect when the tax rate shifts from 15% to 25% and the super deduction rate from 50% to 0%. The specific construction method is as follows:

The formula for calculating the marginal effective tax rate is as follows:

$$METR = \frac{Tax_{before} - Tax_{after}}{Tax_{before}} \tag{15}$$

Referring to the research ideas of Devereux and Griffith (1998) and McKenzie et al. (1998)[①], the pre-tax capital return rates Tax_{before} and Tax_{after} are set as follows

$$Tax_{after} = (1-m)\alpha i + (1-n)(1-\alpha)\omega - \pi - W_p \tag{16}$$

$$Tax_{before} = (1 - tz - k)\frac{(1-t)\alpha i + (1-\alpha)\omega - \pi + \delta}{1-t} - \delta \tag{17}$$

where α is the debt financing ratio, i is the rate of return on debt, m is the individual income tax levied on interest income, n is the individual income tax levied on dividends, π is the inflation rate, W_p is the property tax rate levied on individuals, ω is the rate of return on equity, t is the corporate income tax rate, δ is the economic depreciation rate, k is the credit rate of fixed assets investment, and z is the depreciation present value of unit fixed assets. This article only considers the issue of income and taxation during the corporate income tax stage. Personal income has not been allocated yet, so m, n and W_p are all 0. Therefore, the post-tax capital gains are

$$Tax_{after} = \alpha i + (1-\alpha)\omega - \pi \tag{18}$$

Equations (15), (17), and (18) are:

$$METR = 1 - \frac{(1-t)[\alpha i + (1-\alpha)\omega - \pi]}{(1-tz-k)[(1-t)\alpha i + (1-\alpha)\omega - \pi] + t\delta(1-z)} \tag{19}$$

For the parameters in Equation (19), the settings are as follows: the corporate income tax rate t is set at 25% or 15%, without consideration for other lower tax rates. The investment offset k is calculated as the enterprise R&D expenditure * (1 + 50%) / net value of enterprise assets, considering only the super deduction policy for R&D inputs. The debt financing ratio α is represented by the debt-to-asset ratio, as is common practice. The creditor's yield i is denoted by the nominal market interest rate. Under conditions of perfect competition, investments are made only if bond yields exceed the nominal market rate. Thus, the interest rates for 1–3 year fixed asset loans published by the People's Bank of China are used prior to 2014, and 1–5 year medium to long-term fixed asset loan rates thereafter. The equity yield ω is approximated using the average

[①] This section of this article only provides a brief description, and the detailed model setting logic can be found in Devereux and Griffith (1998) and McKenzie, Mansour and Brûlé (1998).

yield of 10-year government bonds, following Xu and Chen (2012). The inflation rate π is represented by the annual consumer price index; the economic depreciation rate δδ is represented by an overall economic depreciation rate of 9.6% according to Zhang et al. (2004). The present value of fixed asset depreciation zz assumes that enterprises use straight-line depreciation, following the approach of Zwick and Mahon (2017), with a 5% residual value and a 7% discount rate used to calculate the unit depreciation present value for machinery, buildings, and other assets, which are then aggregated using the weighted ownership ratios of the three asset types (Manual, 2005).

Subsequently, based on Equation (19), by adjusting the tax rate and the R&D expense super deduction ratio, the following four types of marginal effective tax rates (METR) for the R&D expense super deduction policy and corporate income tax rate incentive policy can be calculated:

$METR_0$: The marginal effective tax rate when the corporate tax rate is 25% and the R&D expense super deduction rate is 0%.

$METR_1$: The marginal effective tax rate when the corporate tax rate is 15% and the R&D expense super deduction rate is 50%.

$METR_2$: The marginal effective tax rate when the corporate tax rate is 15% and the R&D expense super deduction rate is 0%.

$METR_3$: The marginal effective tax rate when the corporate tax rate is 25% and the R&D expense super deduction rate is 50%.

Subsequently, by assuming that certain conditions remain constant, the marginal effective tax rates for different tax incentive policies are calculated as follows:

For non-high-tech enterprises under a 25% corporate income tax rate, the actual marginal effective tax rate due to the 50% super deduction policy for R&D expenses is $\Delta Tax\_mar_1 = METR_0 - METR_3$;

For high-tech enterprises under a 15% corporate income tax rate, the actual marginal effective tax rate due to the income tax rate incentive policy is $\Delta Tax\_mar_2 = METR_1 - METR_3$;

For high-tech enterprises under a 15% corporate income tax rate, the actual marginal effective tax rate resulting from the 50% super deduction policy for R&D expenses is $\Delta Tax\_mar_3 = METR_2 - METR_1$;

When considering the cross effects of policies, the actual marginal effective tax rate from the interaction of tax rate incentives and tax base incentives is $\Delta Tax\_mar_4 = METR_0 - METR_1$.

Based on these settings, the final regression equation for this paper is as follows:

$$Innovation_{i,t} = \alpha + \beta_1 \cdot \Delta Tax\_\grave{m}ar_{\imath,t} + \gamma \bar{X}_{i,t} + \mu_i + \rho_t + \lambda + \theta + \varepsilon_{i,t} \quad (20)$$

where $\Delta Tax\_\grave{m}ar_{\imath,t}$ includes the four types of marginal effective tax rates, representing the marginal effective tax rate for non-high-tech enterprises under the R&D expense super deduction policy, i.e., the tax base incentive enjoyed by enterprises without the benefit of tax rate incentives (ΔTax_mar_1); the tax rate incentive policy for high-tech enterprises, i.e., the marginal effective tax rate enjoyed by enterprises under tax rate incentives (ΔTax_mar_2)); the R&D super deduction policy for high-tech enterprises, i.e., the marginal effective tax rate for tax base incentives enjoyed by enterprises under tax rate incentives (ΔTax_mar_3); and the actual marginal effective tax rate from the interaction of tax rate and tax base incentives (ΔTax_mar_4). $\bar{X}_{i,t}$is the control variable, μ_i is the individual fixed effect, ρ_t is the year fixed effect, λ is the region fixed effect, θ is the industry fixed effect, and $\varepsilon_{i,t}$ is the residual term.

4.3 Selection of Other Variables

Dependent Variable, $Innovation_{i,t}$: Previous research typically measures innovation from three perspectives: using R&D expenditure as a proxy for innovation input, patent applications as a proxy for innovation output, and patent citations as a proxy for innovation quality (Wang and Tsai, 2009; Akcigit et al., 2016; Higham et al., 2021). Due to the availability of data, the Chinese tax survey data only include statistics on corporate R&D expenditure. Therefore, this study uses the proportion of R&D expenditure (*Innov*) as the proxy variable for innovation input.

For innovation quality, this study opts to use total factor productivity (*TFP*) as the measure. Theoretically, innovation is a driver of improvements in *TFP*; Solow (1957) highlighted that growth stems not only from labor and capital inputs but also from increases in other factors, known as *TFP*, which reflect technological progress. Only substantive, high-quality innovations can enhance *TFP*, while superficial or low-quality innovations cannot. Therefore, measuring innovation quality using *TFP* aligns with theoretical expectations and is practical because enterprises undertake innovation activities either to improve production efficiency or to launch competitive new products, and enhancing technological progress through high-quality innovation is fundamental to achieving these goals. The calculation of *TFP* follows the OP method developed by Olley and Pakes (1996).

Control Variables, $\bar{X}_{i,t}$: Based on previous empirical studies (Spooner, 1986), the control variables at the company level that influence innovation include Enterprise Asset Size (*Lcapital*): Represented by the natural logarithm of total assets at year's end. Financial Leverage (*Lev*): Measured by the ratio of total liabilities to total assets at year-end. Inventory Intensity (*Hasset*): The net value of inventory to total assets ratio at year-end. Tangible Asset Intensity (*PPE*): The net value of fixed assets to total assets ratio at year-end. Investment Returns (*Eqinc*): Investment income as a percentage of total assets at year-end. Return on assets (ROA): Net profit as a percentage of total assets at year-end. Enterprise Revenue Size (*Loperation*): Represented by the natural logarithm of total revenue. Product Market Competition (*Sfin*): The ratio of sales expenses to total revenue for the year.

4.4 Data

The data for this study come from the Chinese National Tax Survey covering 2008–2016. Several cleaning tasks were performed to ensure data quality. Tax Identification Numbers: Spaces and other invalid characters were removed from the tax identification numbers to prevent the misidentification of the same enterprise as different entities during processing. Industry Classification of Enterprises: Due to changes in the national economic industry codes in 2011, standardizing and updating to the new standards was needed; this study adjusted them to the 2011 codes. Administrative Region Codes of Enterprises: Adjustments were made to account for mergers of districts, conversion of counties to districts, and splits over some years, standardized to the six-digit administrative division codes of 2014. Removal of Abnormal Entries: Data entries that clearly violated accounting principles were removed, including entries with negative operating income, total assets less than or equal to zero, negative actual tax amounts, and negative R&D inputs. After cleaning, a 1% trimming was applied to related variables. Descriptive statistics of the data are presented in Tables 1 and 2.

Tables 1 Variable Definitions

Variable	Definition
Innov	Innovation : enterprise R&D investment /total revenue
TFP	Total factor productivity
ΔTax_mar	Marginal effective tax rates
Lcaptial	Firm size: natural logarithm of total assets
Lev	Financial leverage: total liabilities /total assets
Hasset	Inventory density: net inventory /total assets
PPE	Tangible asset intensity: net fixed assets /total assets
Eqinc	Investment returns :investment income /total assets
ROA	Return on assets : net profit / total assets
Loperation	Enterprise revenue size :the natural logarithm of total revenue
Sfin	Product market competition :sales expenses / total revenue

Table 2 Summary statistics

Variable	N	Mean	SD	Min	Max
Innov	116699	7.204	2.279	0.547	16.213
TFP	56557	3.569	4.1256	0.0419	8.4637
ΔTax_mar_1	116699	0.233	0.284	0.082	0.654
ΔTax_mar_2	116699	0.185	0.203	0.017	0.644
ΔTax_mar_3	116699	0.104	0.144	0.007	0.589
ΔTax_mar_4	116699	0.053	0.087	0.003	0.299
Lcaptial	116699	11.639	1.732	4.700	14.938
Loperation	116699	3.138	4.331	1.355	13.816
Lev	116699	0.515	0.254	0.136	2.361
Hasset	116699	0.022	0.093	0.000	0.553
PPE	116699	0.194	0.162	0.000	0.911
Eqinc	116699	0.002	0.009	-0.002	0.059
ROA	116699	0.068	0.166	-0.182	2.499
Sfin	116699	0.094	0.104	0.000	0.572

5. Empirical Analysis

5.1 Baseline Regression

In all equations, the analysis controlled for time-, region-, and industry-fixed effects. The study employed cluster-robust standard errors at the company level to minimize errors. The regressions were conducted using a two-way fixed-effects model, and the results are summarized in Table 3. Columns (1)–(4) consider innovation input as the dependent variable. The results indicate that:

Firms not benefiting from tax rate-based incentives but benefiting from tax base-based incentives (ΔTax_mar_1), those enjoying tax rate-based incentives (ΔTax_mar_2), and those benefiting from tax rate- and tax base-based incentives under the tax rate-based premise (ΔTax_mar_3) show marginal effective tax rates significantly positive at the 1% level. This indicates that these types of marginal effective tax rates have a positive impact on corporate innovation input. The empirical p-values of the marginal effective tax rates across different groups indicate significant inter-group differences, suggesting that the combination of tax rate- and tax base-based incentives (ΔTax_mar_3) has a stronger stimulative effect on innovation compared with tax base-based incentives alone (ΔTax_mar_1), with values (2.7232 > 1.8911). The impact of tax rate-based incentives on corporate innovation (ΔTax_mar_2) is measured at 1.6189, which is less than the impact under tax base-based conditions. Hypothesis 1 is supported.

Additionally, the different effects of the same policy (ΔTax_mar_1 not equal to ΔTax_mar_3) might be because firms benefiting from tax rate-based incentives are high-tech enterprises, which inherently have stronger innovation drivers. First, these enterprises must meet the high threshold set by national standards to qualify as high-tech enterprises, which includes criteria such as innovation personnel structure, innovation level, and the proportion of new product sales. This alignment with government objectives of enhancing innovation through external tax incentives and internal corporate motivation is intended to create a virtuous cycle of innovation enhancement. Second, high-tech enterprise status must be re-validated every three years, compelling enterprises to continuously innovate to maintain their tax benefits, naturally instilling a greater motivation compared with general enterprises.

Column (4) addresses the interactive effect of tax rate- and tax base-based policies, where the marginal effective tax rate (ΔTax_mar_4) coefficient is −1.6233, significant at the 1% confidence level, corroborating Hypothesis 3. This finding illustrates that the intersection of the two policies may exert a crowding-out effect on corporate innovation. Why might policies that individually stimulate innovation through positive incentives collectively lead to negative effects when combined?

Empirically, tax base- and tax rate-based incentives meet or exceed most enterprises' compensation expectations for losses, so they are beneficial for innovation. In this study, the tax base-based incentive refers to the R&D expense super deduction policy. Under a fixed tax rate, more R&D investment results in greater tax base relief, effectively increasing the government's share of tax loss. Tax rate-based incentives directly reduce corporate income tax liability, similarly transferring some tax loss to the government. The more tax loss the government assumes, the greater the share of innovation risk it bears, and the lower the innovation risk for enterprises, and vice versa. According to previous theoretical analysis, when firms benefit from the R&D expense super deduction policy, which fully compensates innovation costs in the tax base, then further enjoying tax rate-based incentives reduces the government's share of innovation risk, increasing the firm's own innovation risks. Thus, the combination of tax base- and tax rate-based incentives weakens the firm's engagement in innovation activities. From practical observations, compared with enterprises that do not receive these tax benefits, those that only enjoy a 15% tax incentive without implementing the R&D expense super deduction have a 10% increase in government risk-sharing; those only benefiting from a 50% R&D expense super deduction without the low tax rate have a 12.5% increase; and those benefiting from both have a 5% increase.[①] Numerical comparisons reveal that when firms only benefit from the R&D expense super deduction policy, the government suffers the greatest tax revenue loss, assumes the highest increase in sharing corporate innovation risk, and thus provides the strongest incentive for innovation, with the ΔTax_mar_3 coefficient significantly higher than other core policy variable coefficients. When firms only benefit from the low tax rate, the government's share in innovation risk increases less than in the previous case, and the incentive strength for innovation is weaker than in the previous case, with ΔTax_mar_2 coefficient being 1.6189, less than the ΔTax_mar_3 coefficient of 2.7232. Under the condition of implementing both policies simultaneously, the increase in the government's sharing of corporate innovation risks is minimal, naturally resulting in the weakest incentive for corporate innovation. The coefficient of ΔTax_mar_4 is −1.6233, indicating that the increase in the government's sharing of corporate innovation risks has not reached the threshold for businesses to increase innovation activities. Instead, the combination of the two policies has a significant inhibitory effect on corporate innovation.

Columns (5)–(8) use TFP as a proxy variable for the quality of corporate innovation. The coefficients in these columns do not differ in sign from the first four columns, but the marginal effective tax rate coefficient ΔTax_mar_2, which represents the corporate income tax rate incentive, is no longer significant. This indicates that under the measurement of innovation quality, the reduction in government risk-sharing caused by the decrease in the corporate income tax rate suppresses innovation more than the positive incentive of increased corporate profits after the tax rate reduction. Therefore, tax rate-based incentives do not necessarily promote corporate innovation, confirming Hypothesis 2. Regarding the magnitude of the coefficients, the absolute value of the combined policy effect (ΔTax_mar_4) is larger than that of the marginal effective tax rates of the first three types, which is the opposite of the model measured by R&D input. This suggests that the interaction effect of tax base- and tax rate-based incentives differs between innovation quality and innovation input. Innovation input may manipulate R&D inputs due to the super deduction policy for R&D expenditures, allowing some companies to use R&D as a tax shield, achieving tax avoidance effects (Laplante et al. 2019). However, corporate innovation measured by TFP must be high-quality innovation resulting from inputs, and high-quality innovation requires greater intensity and risk level, thus companies expect higher compensation for losses, so

[①] During the sample period, the enterprise income tax rate without preferential tax rate is 25%, and the enterprise income tax rate with preferential tax rate is 15%. The deduction rate of R&D input is 50%, and the deduction rate of R&D input is 0, and the unit value of R&D input is 1. According to the above conditions, the following calculation can be made: the added value of innovation risk shared by the government under the preferential tax rate and without the policy of deducting R&D expenses plus =(1+0)*(25%-15%)=10%; The added value of innovation risk shared by the government under the policy of additional deduction of R&D expenses and without preferential tax rate =(1+50%-1)*25%=12.5%; At the same time, the added value of innovation risk shared by the government under the policy conditions of preferential tax rates and additional deduction of R&D costs =(1+50%-1)*(25%-15%)=5%.

the absolute value of the combined policy effect is larger than other individual policies.

Table 3 The Impact of Different Tax Reduction Incentives and Combined Effects on Innovation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Innov	*Innov*	*Innov*	*Innov*	*TFP*	*TFP*	*TFP*	*TFP*
ΔTax_mar_1	1.8911^{***}				0.0822^{***}			
	(0.0520)				(0.0233)			
ΔTax_mar_2		1.6189^{***}				0.0386		
		(0.0446)				(0.0243)		
ΔTax_mar_3			2.7232^{***}				0.1184^{***}	
			(0.0748)				(0.0335)	
ΔTax_mar_4				-1.6233^{***}				-0.3118^{**}
				(0.1617)				(0.1265)
p-value		0.0267^{**}	0.0139^{**}	0.0241^{**}		0.0137^{**}	0.0794^{*}	0.0577^{*}
p-value			0.0417^{**}	0.0394^{**}			0.0856^{*}	0.0819^{*}
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	85423	31276	31276	116699	45268	11289	11289	56557
R^2	0.482	0.466	0.482	0.469	0.396	0.371	0.364	0.441

Note: Brackets contain robust standard errors. "*", "", and "*" indicate significance at the 10%, 5%, and 1% levels, respectively. Empirical p-values (1), (2) indicate the difference in coefficients between Column (1) and other columns, and between Column (2) and other columns, respectively. The same applies below.

5.2 Lag Effects of Tax Incentives on Corporate Innovation

After analyzing the immediate effects, this paper examines the lag effects of the four types of marginal effective tax rates. Figures 1 and 2 respectively illustrate the tax incentive effects on innovation R&D input and innovation quality, with the base year being 2008 (the base year for the super deduction policy is 2013). Overall, the lag effect of tax incentives on innovation, whether at the input end or the quality end, shows a decline, with the innovation input end almost disappearing after the fourth year and the innovation quality end declining faster, virtually zeroing out by the third year. This indicates that innovation incentive policies need to be consistent to avoid a rapid expiration of their effects, failing to sustainably promote corporate innovation. Additionally, the combined effect of policies compared with individual policies declines more rapidly in both measures of innovation.

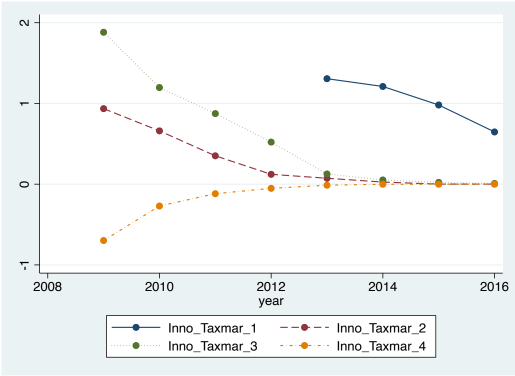


Figure 1: Lag Effects of Marginal Effective Tax Rates on Innovation R&D Input

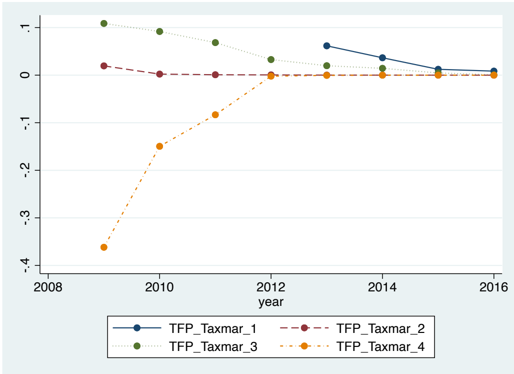


Figure 2: Lag Effects of Marginal Effective Tax Rates on Innovation Quality

5.3 Long-Term Effects of Tax Incentives on Corporate Innovation

Further, this paper examines the long-term differences of tax incentive policies, using existing data for comparative analysis. Since the tax system reform, China's corporate income tax has undergone several major reforms: one is the unification of domestic and foreign corporate income tax rates beginning in 2008, reducing the tax rate from 33% to 25%; another is allowing high-tech enterprises to deduct 50% of R&D inputs (amortizing intangible assets at 150%) starting in 2008, expanded to most enterprises in China in 2016.[①] This paper selects the year 2000 as the base year for calculations, because at the time the corporate income tax rate was still 33% and no super deduction policy was available for R&D inputs, with few changes to corporate income tax policy between 1994 and 2000, while post-2000 included policies such as the "two exemptions and three reductions" for integrated circuit enterprises and software enterprises, and the "two exemptions" policy for national key software enterprises and integrated circuit design enterprises within the state's key planning layout. Therefore, to ensure data stability, the year 2000 was chosen as the base year. Following Akcigit et al. (2022), the research model is set as follows:

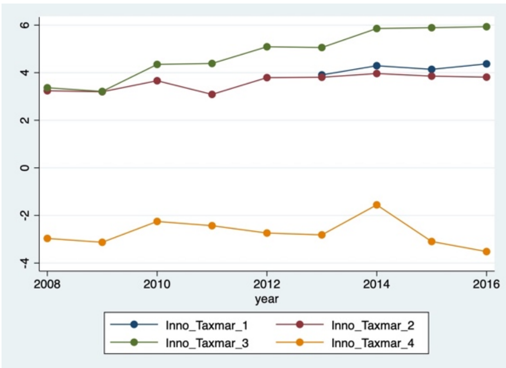
$$\Delta Innovation_{i,t} = \beta_1 \cdot \Delta Tax\_mar_{1,i,t} + \gamma \Delta \bar{X}_{i,t} + \rho_t + \varepsilon_{i,t}$$

The proxy variable for innovation $\Delta Innovation_{i,t}$, represents the difference in each year's innovation

① The R & D investment deduction policy has been revised several times, but it is beyond the sample range of this paper and beyond the discussion.

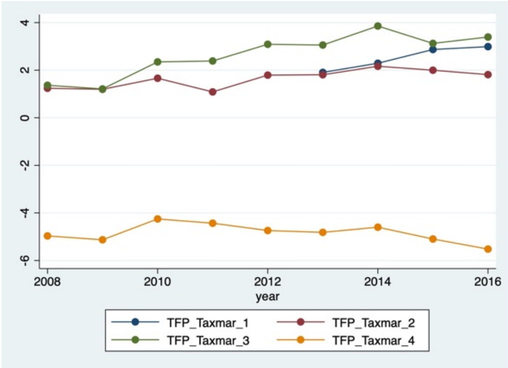
input and innovation quality from 2008 to 2016 compared with macroeconomic variables in 2000. The innovation input for 2000 was obtained by taking the logarithm of the research and development expenditures divided by the number of scientific institutions from the China Statistical Bureau, and TFP was calculated using that year's macroeconomic data. The marginal effective tax rate $\Delta Tax\_mar_{1,i,t}$ is the difference between the marginal effective tax rate at the macro level for enterprises in 2000 and the marginal effective tax rates for each year from 2008 to 2016 under tax incentive policies.[①] Control variables $\Delta\bar{X}_{i,t}$ are based on the availability of data, using the average values from the 2000 China Industrial Enterprise Database as baseline indicators, and then calculating differences to obtain subsequent values.

Figures 3 and 4 illustrate the long-term tax incentive effects on innovation input and innovation quality, respectively. Trends show that since 2008, the impact of tax incentives (ΔTax_mar_1, ΔTax_mar_2, ΔTax_mar_3) on innovation has been gradually increasing annually. Since 2008, the country has progressively implemented various innovation policies, including some policy refinements and improvements, which could be one reason for the gradually increasing impact. However, the combined effect of tax base and tax rate incentives (ΔTax_mar_4) generally fluctuates between −0.4 and −0.2, indicating a significant mutual erosion effect, with a long-term trend of expansion. Additionally, since 2013, the impact of ΔTax_mar_1 and ΔTax_mar_3 on innovation has been higher than ΔTax_mar_2, indicating that the long-term effect of tax base incentives is superior to that of tax rate incentives. In light of recent policy developments, the state increased the super deduction rate for R&D inputs from 50% to 75% in 2018, further raised it to 100% in 2021, and plans to increase the deduction rate to 120% for some enterprises by 2024. This highlights the positive impact of the super deduction policy for R&D inputs as a tax base incentive on corporate innovation.



Figures 3 and 4: Long-term Effects of Marginal Effective Tax Rates on Innovation R&D Input

① In the marginal effective tax rate calculation formula, the income tax rate is 33% and the additional deduction is 0.



Figures 4: Long-term Effects of Marginal Effective Tax Rates on Innovation Quality

5.4 Robustness Tests

5.4.1 Endogeneity Test

In this study, endogeneity issues primarily arise from three sources. First, the factors affecting the corporate macro tax burden are diverse, but this study can only control for regional and industry-level factors and cannot control other macro variables affecting innovation, leading to omitted variable problems. Second, tax survey data, aside from their own tax and accounting data, lack micro factors that might affect corporate innovation drive, such as entrepreneurial risk-taking, also leading to omitted variable issues. Third, firms with high levels of innovation activity, by improving production efficiency through new technologies and processes, are more likely to achieve economies of scale and reduce their marginal tax rates, so a bidirectional causality might occur between the two. To mitigate the estimation biases that endogeneity might cause, this paper employs two-stage least squares regression and uses the tax avoidance motives (Avoidance) of other sample firms in the same city and industry as an instrumental variable to resolve endogeneity issues. The basic condition for choosing an instrumental variable is that it is related to the selected independent variable but not related to the dependent variable. The feasibility of using other firms' tax avoidance motives as an instrumental variable lies in that the tax avoidance motives of other firms in the industry may affect the marginal tax rate of the firm in question but do not influence the firm's innovation, thus fitting the selection principle for instrumental variables. The final results, as shown in Table 4, indicate that the regression results using the instrumental variable are still significant and do not differ much from the baseline regression (Table 3), suggesting that the conclusions are robust.

Table 4 Regression results with introduction of instrumental variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Innov	*Innov*	*Innov*	*Innov*	*TFP*	*TFP*	*TFP*	*TFP*
Tax_mar_1	2.1181***				0.1292***			
	(0.0921)				(0.0534)			
Tax_mar_2		1.8549***				0.0566		
		(0.0646)				(0.0393)		
Tax_mar_3			2.8911***				0.2645***	

			(0.0977)				(0.0556)	
Tax_mar$_4$				-1.8637***				-0.4193**
				(0.2573)				(0.2254)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	85423	31276	31276	116699	8268	11289	11289	56557
R^2	0.532	0.444	0.468	0.379	0.412	0.514	0.551	0.425

5.4.2 Other Robustness Tests

Additional robustness tests (Table 5) conducted in this study include: (1) excluding the impact of the VAT reform policy. China gradually implemented the VAT reform pilot in multiple regions and industries from 2012 to 2016. To avoid the impact of the VAT reform policy, this paper excludes samples from pilot industries in pilot regions, and the results remain robust. (2) Excluding the impact of the financial crisis. This study excludes samples from 2008 to exclude the impact of the financial crisis, and the results remain robust. (3) Replacing the dependent variable. In the robustness tests, the study replaces the dependent variables of the baseline regression, which are the proportion of R&D inputs and TFP calculated using the OP method, with the logarithm of R&D inputs and TFP calculated using the LP method, and the results remain robust.

Table 5 Additional robustness tests

Exclude VAT samples								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	innov	*innov*	*innov*	*innov*	*tfp*	*tfp*	*tfp*	*tfp*
Tax_mar$_1$	2.2692***				0.0419***			
	(0.1040)				(0.0144)			
Tax_mar$_2$		2.009***				0.0651		
		(0.3642)				(0.3211)		
Tax_mar$_3$			2.2984***				0.2873**	
			(0.3368)				(0.1436)	
Tax_mar$_4$				-1.7904***				-0.2543**
				(0.6046)				(0.1226)
N	75695	30562	30562	106257	37416	9651	9651	47067
R^2	0.308	0.467	0.411	0.497	0.374	0.338	0.317	0.370
Exclude samples from 2008								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	innov	*innov*	*innov*	*innov*	*tfp*	*tfp*	*tfp*	*tfp*

Tax_mar$_1$	1.8061***				0.0875***			
	(0.0437)				(0.0211)			
Tax_mar$_2$		1.4620***				0.0423		
		(0.0309)				(0.1164)		
Tax_mar$_3$			2.3919***				0.1272***	
			(0.0805)				(0.0415)	
Tax_mar$_4$				-1.8522***				-0.3548**
				(0.2388)				(0.1874)
N	75931	37405	37405	113336	40458	10952	10952	51410
R^2	0.408	0.410	0.421	0.477	0.329	0.317	0.322	0.445

Replace the dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	linnov	*linnov*	*linnov*	*linnov*	*tfp_lp*	*tfp_lp*	*tfp_lp*	*tfp_lp*
Tax_mar$_1$	1.5492***				0.0812***			
	(0.0262)				(0.0135)			
Tax_mar$_2$		1.2735***				0.0337		
		(0.0157)				(0.0416)		
Tax_mar$_3$			2.4168***				0.1214***	
			(0.0246)				(0.0275)	
Tax_mar$_4$				-1.5537**				-0.3077**
				(0.7708)				(0.1233)
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES	YES	YES
N	85423	31276	31276	116699	45268	11289	11289	56557
R^2	0.364	0.358	0.447	0.460	0.387	0.388	0.341	0.434

6. Extended Research

6.1 Impact of Tax Incentives on Innovation Across Different Levels of Enterprise Innovation

Enterprises at different stages of their lifecycle exhibit significant differences in innovation strategies and performance (Shahzad et al. 2022). During the development stage, firms commonly refer to their peers for innovation strategies, where innovation imitation is not only cost-effective but also carries less risk of failure due to predecessors' failures. Conversely, mature enterprises tend to engage in proprietary innovation, where imitation is insufficient to compete. However, inevitably, this comes with high innovation risk and the potential for failure. Some research has studied the impact of different tax incentive policies on enterprises with different innovation strategies, such as government subsidies that are only effective for exploratory innovation performance in the short term but provide the greatest incentives for mature enterprises, and tax incentives that are more suitable for exploratory innovation activities (Yu, 2013). These studies do not distinguish between tax base incentives and tax rate incentives. This section considers a classified analysis of different innovation stages of enterprises' responses to tax incentives: first, the average R&D input of enterprises over three years is calculated, then enterprises within an industry are selected from the top and bottom fifth percentiles to consider the innovation effects brought by two types of tax incentives.

The results, as shown in Table 6, indicate that for enterprises in the bottom fifth percentile of industry R&D input, the results for tax base incentives and tax rate incentives (ΔTax_mar_1、ΔTax_mar_2、ΔTax_mar_3) do not differ much from the overall sample, being positive and significant at the 1% level. However, the combined policy effect (ΔTax_mar_4) is positive but not significant, differing from the baseline regression (where it was −1.6233), indicating that enterprises with low levels of innovation have risk loss expectations after tax rate reductions that are basically consistent with the government's risk-sharing, thus not hindering innovation but also not promoting it. By contrast, for enterprises in the top fifth percentile of industry R&D input, all tax incentives were found to promote corporate innovation input, including the combined effects of tax base and tax rate incentives.

Columns (5)–(8) in Table 6 show the regression results for innovation quality measured by *TFP*. For enterprises in the bottom fifth percentile of industry R&D input, the conclusions are broadly consistent with the baseline regression, but tax rate incentives and combined policy incentives are not significant. This suggests that the decrease in the tax rate is insufficient to compensate for the expected loss in innovation risks after the tax reduction. For enterprises in the top fifth percentile, the regression results showed that none of the policies could enhance the quality of corporate innovation. A possible reason, as found in studies like Yu (2013), is that mature, leading enterprises do not significantly benefit from tax incentives aimed at innovation, as policies such as super deductions for R&D inputs might serve more as a means to reduce tax burdens rather than directly incentivize improvements in innovation quality.

Table 6 Heterogeneity analysis of firms with different innovation inputs

	Enterprises in the bottom 5% of industry R&D investment							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Innov	*Innov*	*Innov*	*Innov*	*TFP*	*TFP*	*TFP*	*TFP*
Tax_mar_1	1.5259***				0.1935**			
	(0.1796)				(0.0773)			
Tax_mar_2		1.2426***				0.1112		
		(0.1782)				(0.0799)		
Tax_mar_3			2.1972***				0.2786**	
			(0.2586)				(0.1112)	
Tax_mar_4				1.5322				-0.3111

				(0.9556)				(0.3766)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4271	1563	1563	5835	2070	758	758	2828
R^2	0.517	0.444	0.468	0.379	0.458	0.314	0.331	0.427

Enterprises in the top 5% of industry R&D investment								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Innov	*Innov*	*Innov*	*Innov*	*TFP*	*TFP*	*TFP*	*TFP*
Tax_mar_1	0.3459***				-0.0942			
	(0.0643)				(0.1255)			
Tax_mar_2		0.3680***				-0.1412		
		(0.0639)				(0.1253)		
Tax_mar_3			0.4981***				-0.1356	
			(0.0925)				(0.1807)	
Tax_mar_4				0.5205*				-1.0391
				(0.2692)				(0.6888)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4271	1563	1563	5835	2070	758	758	2828
R^2	0.418	0.339	0.405	0.486	0.337	0.308	0.315	0.423

6.2 Differences in Innovation Heterogeneity Between Private and State-Owned Enterprises

Different types of ownership in enterprises lead to variations in innovation activities (Jefferson et al. 2003). State-owned enterprises (SOEs) naturally have institutional advantages in risk-taking because the government provides them with more resources and implicit political support (Kornai, 1992), so they have a stronger capacity to bear the risks of innovation failure. Tax incentives are less effective in sharing risks for SOEs compared with private enterprises, which do not receive such favorable treatment and are thus more sensitive to innovation risks. This section divides the sample into SOEs and private enterprises to analyze the impact of tax base incentives and tax rate incentives on innovation across different ownership types.

As shown in Table 7, the results for the upper half indicate that SOEs and private enterprises, when measured by innovation input, show that tax base incentives and tax rate incentives (ΔTax_mar_1、ΔTax_mar_2、 Δ*Tax_mar*$_3$), as well as the combined policy effect (Δ*Tax_mar*$_4$), are consistent with the baseline regression results, being significant at the 1% level, but the coefficients are slightly higher for the private enterprise group. However, the policy combination effect shows a difference in terms of innovation quality measured by *TFP*, where the coefficient for the SOE group is not significant, while it is significantly negative for the private enterprise group. The results representing innovation input and innovation quality illustrate two issues. First, although SOEs hand over their taxes and profits to the government, the government's risk-sharing mechanism is still in effect, albeit slightly less effective than for private enterprises. Second, in terms of the quality of innovation, SOEs, leveraging their own characteristics, easily obtain more resources and thus produce higher-quality innovations. Third, SOEs, carrying national tasks and social responsibilities for innovation, often do not consider profit and tax issues, so they are less sensitive to policy combinations compared with private enterprises.

Table 7 Heterogeneity analysis between SOEs and private enterprises

	Innovation							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SOEs	Private	SOEs	Private	SOEs	Private	SOEs	Private
Δ*Tax_mar*$_1$	1.8584***	2.0316***						
	(0.0555)	(0.0821)						
Δ*Tax_mar*$_2$			1.5866***	1.7608***				
			(0.0472)	(0.0839)				
Δ*Tax_mar*$_3$					2.6760***	2.9256***		
					(0.0800)	(0.1182)		
Δ*Tax_mar*$_4$							-1.4825***	-2.5477***
							(0.1609)	(0.3751)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	32993	52430	12104	19172	12104	19172	45073	71626
R^2	0.576	0.487	0.462	0.447	0.439	0.507	0.455	0.462
	TFP							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	SOEs	Private	SOEs	Private	SOEs	Private	SOEs	Private
Δ*Tax_mar*$_1$	0.0682**	0.0976**						
	(0.0264)	(0.0390)						
Δ*Tax_mar*$_2$			0.0386	0.0376				

			(0.0271)	(0.0405)				
ΔTax_mar_3					0.0982^{**}	0.1405^{**}		
					(0.0381)	(0.0562)		
ΔTax_mar_4							-0.1885	-0.4532^{*}
							(0.1318)	(0.2355)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	17519	27749	4369	6920	4369	6920	21888	34669
R^2	0.557	0.556	0.578	0.588	0.449	0.470	0.587	0.556

7. Conclusion

Tax incentives and corporate innovation have long been subjects of keen interest but also of divergent opinions. Different scholars, using various data and methods, often arrive at differing conclusions. This paper uses data from a national tax survey in China and builds on the theory of innovation risk-sharing, employing the concept of the marginal effective tax rate as a more direct measure of policy impact. It seeks to provide a fresh perspective on the effects of tax base incentives and tax rate incentives on corporate innovation. The key findings of the study are as follows:

Tax Base Incentives: Regardless of the level of innovation or whether the firm is state-owned or privately owned, tax base incentives consistently promote corporate innovation through the innovation risk-sharing mechanism.

Tax Rate Incentives: Whether tax rate incentives can promote innovation depends on whether the expected compensation for innovation risk loss through tax rate reductions is met. If not, they might either promote innovation, have no effect, or even hinder innovation.

Combined Policy Effects: The effectiveness of the combination of tax base and tax rate incentives also depends on the levels of government risk-sharing and corporate expectations for compensation of innovation risk loss. However, regression results from the available sample data indicate that in most cases, the combined effects of these policies either hinder innovation or have no impact.

Long-Term and Lag Effects: Tax base incentives have a more prolonged and sustained impact compared to tax rate incentives and their combinations in terms of lag effects. In the long term, the policy of super deductions for R&D inputs has the most significant impact, followed by tax rate incentives.

Based on these conclusions, the study offers several policy insights:

Super Deduction for R&D Inputs: This deduction is a crucial policy tool for encouraging firms to engage in innovative activities. Originating in the USA in 1954 and quickly adopted by Western European countries, the effectiveness of this policy in guiding corporate innovation is evident. China has adjusted this policy several times since its introduction in 1996, increasing the super deduction rate from 50% to up to 100% for some enterprises. Future reforms should ensure that only genuine R&D inputs that lead to innovation progress are encouraged, and enhanced monitoring could prevent the misuse of this policy for tax evasion.

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