Environmental Science and Pollution Research (2023) 30:101546–101564
https://doi.org/10.1007/s11356-023-29268-0

RESEARCH ARTICLE

Macro tax incentives and corporate sustainable innovation: Evidence from Chinese Enterprises

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Received: 15 May 2023 / Accepted: 7 August 2023 / Published online: 31 August 2023

Abstract

Innovation has become the driving force behind China's economy's sustainable growth. Due to the efficient transmission of taxation leverage, preferential tax policies are frequently used to stimulate innovation. Therefore, the incentive effect of preferential tax policies on sustainable innovation has gradually become the focus of attention. This paper takes the 2016–2019 China A-share listed high-tech enterprises as a sample, calculates tax incentive intensity with the aid of B-index, and studies the incentive effect of preferential tax policies on the sustainability of corporate innovation. This study shows that: (1) Tax incentive intensity has a positive incentive effect on corporate sustainable innovation. (2) The R&D expenses plus deduction policy and the preferential tax rate policy can significantly enhance corporate sustainable innovation, but there is a substitution effect between them. (3) Based on the heterogeneity of institutional environment and enterprise characteristics, the incentive effect of tax preferential policies is more obvious in enterprises which are non-state-owned and in areas with low government intervention and sound legal system. However, the incentive effect of different types of preferential policies differs in the size of the enterprise. This study will provide reference for the improvement of preferential tax policy system and the optimization of innovation policy environment.

Keywords Preferential tax policies · Tax incentive intensity · The R&D expenses plus deduction policy · The preferential tax rate policy · Corporate sustainable innovation

Introduction

Strong innovation contributes to a nation's prosperity, whereas weak innovation makes a nation nearly powerless. China's economic development has entered a new phase, the change of China's economic growth mode from high-speed to high-quality will be driven in large part by technological innovation (Dang and Motohashi 2015). The government's "tangible hand" can effectively compensate for market mechanism failure-related difficulties. Among them, policy support has an important impact on corporate innovation, especially in newly industrialized countries and developing countries (Ernst and Kim 2001). The promulgation of the "National Innovation-Driven Development Strategy Outline" clearly defines the strategic goals of China's innovation and development. By 2020, China will enter the ranks of innovative countries, the independent innovation capability will be greatly improved, and the innovation environment will be more optimized (Bloom et al. 2002).

Enterprises are the carriers attached to the innovation activities at the micro level, and the improvement of their independent innovation capabilities play an important role in enhancing China's core competitiveness. However, technological innovation activities of enterprises are expensive, risky, and time-consuming, which drives up the cost of their R&D activities. Once the innovation activities are suspended, businesses will face huge losses or opportunity costs (Hall 2002). Corporate sustainable innovation is oriented to the sustainable development of the company and can bring

Responsible Editor: Arshian Sharif

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continuous improvement of financial and social performance. Therefore, ensuring corporate sustainable innovation is critical to building dynamic competitive advantage of a company (Latham 2006).

The government relies heavily on the incentive effect of taxation to design preferential tax policies and foster enterprise innovation (Yi et al. 2023; Yu et al. 2023; Cheng et al. 2023). It refers to the government's adjustment of taxation to encourage taxpayers to be more inclined to carry out certain activities, thus achieving an incentive effect on the economic behavior of taxpayers. According to the relevant theories of public economics, the preferential tax policy tool can correct the externality and risk of enterprise innovation activities, and increase the internal income of enterprise innovation investment (Hsu et al. 2015). Thereby, the innovation power and enthusiasm of taxpayers can be mobilized. China has steadily emphasized preferential tax policies for scientific and technical innovation since the 1980s (Hong et al. 2016). It has formulated and promulgated a large number of tax incentives, covering corporate income tax, personal income tax, customs duties, value-added tax, stamp duty and other taxes, and effectively reducing the burden on enterprises (Zhang et al. 2018). In particular, for a large number of high-tech enterprises, they have been given preferential tax policies such as the R&D expenses plus deduction policy and the preferential tax rate policy, and are encouraged to place a greater emphasis on and increase their investment in innovation activities in order to become a leader in the innovation army. After years of hard work, China's preferential tax policies have been continuously enriched, the scope has been continuously expanded, and its strength has been continuously enhanced. With the advancement of innovation-driven development strategies, a preferential tax policy system guiding enterprise innovation has been initially established. This is the reason why we choose Chinese enterprises as our study subject.

In light of this, it is crucial to investigate in depth the incentive effect of China's current preferential tax policies on the sustainability of corporate innovation. As shown in Fig. 1, the main issues to be discussed in this paper are as follows: (1) How effective are China's preferential tax policies at incentivizing enterprise innovation? (2) How does the tax incentives intensity affect sustainable innovation of high-tech enterprises? (3) How do the R&D expenses plus deduction policy and preferential tax rate policy affect corporate sustainable innovation of high-tech enterprises? When the two policies are implemented simultaneously, do they contribute to promoting or suppressing innovation performance? (4) Will the incentive effect of preferential tax policies be influenced by the heterogeneity of institutional environment and the heterogeneity of corporate characteristics?

This paper examines the innovation incentive effect of preferential tax policies and the implementation effect of preferential tax policies from the perspective of heterogeneity. The contributions of this paper are mainly reflected in three aspects. First of all, at the research perspective level, this paper discusses the interactions between various preferential tax policies at the macro level and sustainability of enterprise innovation at the micro level in China, the largest developing country. Thus, this paper broadens the research perspective of preferential tax policies and the sustainability of corporate innovation, filling the gap of research in related fields. Secondly, at the policy implication level, this paper investigates the different impacts of different policies and the heterogeneity of institutional environment on the actual implementation of tax preferential policies. Hence, this paper presents policy enlightenment for further optimizing the innovation incentive effect of China's preferential tax policy system. Thirdly, at the application level, this paper also discusses the impact of the heterogeneity of enterprise characteristics on the incentive effects of tax preferential policies, providing directions and empirical basis for promoting the sustainable innovation performance of Chinese businesses and the development of innovative nations.

This article proceeds as follows. "Literature review" section reviews the literature on preferential tax policies and corporate sustainable innovation. The calculation of tax incentive intensity "The calculation of tax incentive

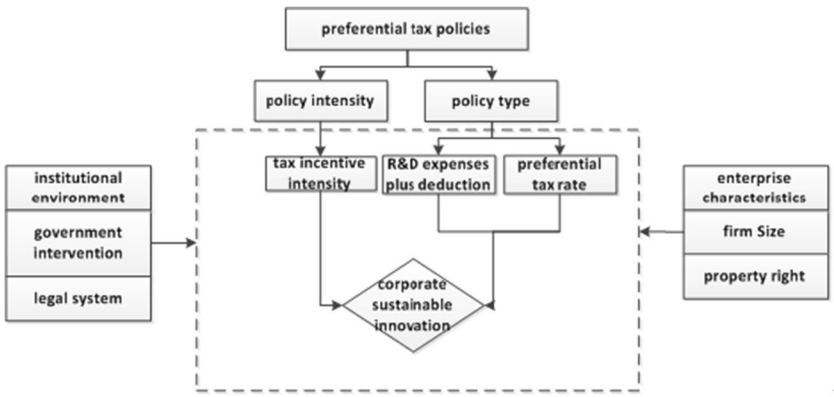

Fig. 1 Research framework

intensity" section measures the tax incentive intensity. "Theoretical analysis and research hypothesis" section presents the theoretical analysis and develops research hypotheses. "Methods" section introduces the sample selection, data sources, variable definitions, and model construction. "Empirical results" section presents the empirical results, and "Conclusions and discussion" section offers the conclusion, suggestion, and prospect.

Literature review

Research on preferential tax policies and enterprise innovation

Numerous academic studies on preferential tax policies for business innovation have surfaced, but none have come to a consensus (Hall 1993; Li et al. 2021; Wang et al. 2021; Wang and Tang 2020). Bronzini and Piselli (2016) observes the relationship between 19 years of taxation in 9 OECD countries and corporate R&D investment. Research shows that preferential tax policies effectively increase R&D intensity, R&D costs decrease by 10%, and short-term R&D investment levels increase by 1%; while about 10% in the long run. In the article "The Impact of Government Subsidies and Enterprise Innovation ", Hodžić (2012) points out that the government can reduce the tax burden of enterprises and alleviate the problem of enterprise R&D funds by providing preferential tax policies, thereby indirectly reducing the R&D risks of enterprises and encouraging enterprises to increase innovation R&D investment, and achieving better innovation performance. Therefore, preferential tax policies incentives for R&D are important factors for innovation. Countries should use their fiscal policies to stimulate R&D investment through various forms of tax incentives. Hall and Reenen (2000) contend that taxation has a significant impact on R&D by calculating R&D user costs and building econometric models. As the tax policy for R&D is becoming more lenient, A tax mechanism rather than a direct financial transfer will be preferred by nations. Therefore, tax incentives relatively effectively stimulate the company's innovative behavior, can help companies achieve great success and produce top-notch goods (Berube and Mohnen 2009). It can be seen that some scholars have recognized that preferential tax policies can effectively stimulate enterprise innovation (Xie et al. 2023; Li and Sun 2020; Huang et al. 2021), but some scholars believe that preferential tax policies cannot effectively stimulate enterprise innovation. Griffith (Griffith et al. 1995) finds that R&D's tax treatment seems to be rarely associated with the number of R&D completed. For example, Canada's R&D tax treatment is very generous, but the R&D intensity is very low. Most scholars who support suppression theory are based on the crowding out effect of policy support. This is because when companies are expected to receive substantial benefits from government support, more resources and energy will be devoted to the "seeking support" behavior. Thomson (Thomson 2010) selects unbalanced financial data from about 500 large companies in Australia to analyze the determinants of corporate investment in R&D. The study finds that there is no evidence that tax incentives are an effective policy tool, and sales growth is a major determinant of R&D investment. Howell (Howell 2016) finds that the reduction of corporate tax burden only encourages new goods and new processes in sales, does not have an impact on the decision of its R&D and innovative investment, pointing out the ubiquity of other innovation barriers such as talents and laws. The reduction of corporate financial constraints brought about by preferential tax policies cannot effectively compensate for the lack of innovation investment caused by market failures.

A study on the heterogeneity of the impact of tax preferential policies on enterprise innovation

Some scholars have comprehensively considered various factors in the impact of preferential tax policies on corporate innovation, and believe that the relationship between preferential tax policies and corporate innovation cannot be described simply by promotion or inhibition (Gao et al. 2020; He et al. 2022; Zhao et al. 2023). The incentives for preferential tax policies will be affected by other external factors. Klasse et al. (2004) finds that there is an interaction between tax incentives and fiscal constraints, and in the case of a positive tax credit, all companies will increase R&D investment regardless of whether they are affected or not. Companies with greater financial constraints are more responsive to tax rates than companies with less financial constraints. Lokshin and Mohnen (2012) use Dutch companies from 1996 to 2004 as a sample to study the impact of fiscal concessions on corporate R&D Short-term R&D investment can be successfully stimulated for small businesses by fiscal preferential policy, but financial concessions for large businesses don't seem to work as well because the social unnecessary loss covers up the increase in R&D. Huang (2014)maintains that firm size and corporate profitability have significant positive correlation with tax credit treatment. Large enterprises, especially high-tech enterprises, are more likely to use tax incentives; but there are significant differences in tax incentives between electronic and non-electronic companies. Based on the industry heterogeneity of R&D intensity and market concentration, Freitas et al. (2017) explore the impact of R&D tax deduction on corporate innovation input and output. they find that in high R&D-oriented industry, the incentive

effect of R&D tax deduction on innovation input and output is obvious; conversely, the higher the market concentration, the greater the incentive effect of tax incentives on innovation investment.

All the above studies show that preferential tax policies have a certain impact on enterprise innovation, which serves as an important benchmark for further study, although there are still some drawbacks.

Enterprise innovation activities are a long-term and continuous process. Higher uncertainty and internal–external constraints make them vulnerable to external shocks. Therefore, whether preferential tax policies can effectively stimulate enterprise innovation, the increase, decrease or even break of innovation investment will inevitably lead to certain effect on the sustainability of the innovation activity. However, from the above literature, the ideas and horizons of the existing literature still have limitations, and they rarely mention the impact of preferential tax policies on the sustainability of corporate innovation, and lack of a three-dimensional evaluation of the incentive mechanism and process of preferential tax policies (Qiu et al. 2023; Hu et al. 2021). We introduce corporate sustainable innovation and study the impact of preferential tax policies on corporate sustainable innovation and its influence mechanism. On this basis, we will analyze whether there are differences in the influence of different traits and enterprises in different institutional environments, and enrich the research in related fields.

The calculation of tax incentive intensity

In order to quantify the incentive intensity of tax incentives to stimulate independent innovation of high-tech businesses, this research chooses the B-index created by Freitas et al. (2017). The index measures the minimum present value of the marginal pre-tax income that the enterprise needs to generate in order to pay for the R&D investment cost and pay the corporate income tax, that is, the actual cost per unit of the enterprise's innovative investment, and also the company's principal-guaranteed income. The calculation formula is:

$$B-index=\frac{A}{1-t} \tag{1}$$

where A represents the present value of the post-tax net cost of the enterprise unit's R&D investment minus tax incentives, and t is the corporate income tax rate. Under China's current preferential tax policies, assuming that r is the pre-tax comprehensive deduction rate, then A = 1—rt. And the calculation formula can be written as:

$$B-index=\frac{1-rt}{1-t} \tag{2}$$

The lower the index is, the stronger the motivation for corporate R&D investment is. For convenience, we use 1-B to measure tax incentive intensity (when B < 1, this indicator measures the tax burden of R&D investment). The larger the 1-B, the more R&D costs the company saves due to tax incentives, which means the greater tax incentive intensity.

$$Tax incentives=1-B \tag{3}$$

The following fundamental presumptions are made when calculating the B-index: (1) Assume that the company's R&D expenses can be divided into recurring expenditures and capital expenditures, accounting for 90% and 10% respectively. Among them, wages and other expenditures account for 2:1 of recurrent expenditure and machinery and construction account for 5% of capital expenditures. (2) The calculation is based on income tax incentives without including other taxes. (3) Assume that the company has enough profits to fully use the opportunity to enjoy R&D preferential tax policies, despite carry-over difficulties. (4) Financial costs are not considered. (5) Assuming that only tax deductible exists. This research incorporates the following factors in the calculation together with China's actual national conditions: (1) Earlier documents filed a new recognition standard in R&D expenses plus deduction of 150%. This paper uses the promulgation of new enterprise income tax law (2007) as the starting point for the implementation of this policy. In order to further encourage enterprises to increase investment in R&D, the fiscal and taxation No. 99 issued on September 20, 2018 stipulates that the R&D expenses plus deduction rate will be increased to 75% from January 1, 2018 to December 31, 2020. Since this paper's research spans the years 2010 to 2015, we continue to employ a 50% deduction rate. (2) Capital expenditure refers to the expenditure incurred in the year for new buildings, machinery, and equipment. It excluded the depreciation of existing machinery and equipment and buildings (depreciation has been amortized to recurring expenditures). (3) In the provisions of the Enterprise Income Tax Law, there are several provisions for the pre-tax deduction limit for machinery and equipment purchased by enterprises for R&D. For the convenience of calculation, this article assumes that the expenditure can be deducted once before tax. (4) The prior enterprise income tax law stipulates that only enterprises in high-tech parks apply 15% preferential income tax rate, which is not universal. Therefore, this paper uses the tax rate of 33% for both ordinary enterprises and high-tech enterprises for the calculation of old enterprise income tax law.

The tax incentive intensity before the implementation of the new tax law is negative, as shown in Tables 1 and 2. This is because the pre-tax deduction rate is below 1,

Table 1 Calculation of pre-tax comprehensive deduction rate

	recurring expenditures		capital expenditures		Weighted pre-tax deduction rate
	wage	others	machinery and equipment	buildings	
weight	60%	30%	5%	5%	-
r(old tax law)	100%	100%	100%	0%	95%
r(new tax law)	150%	150%	100%	0%	140%

Table 2 Calculation of tax incentive intensity

type of enterprises	the old tax law[1]		the new tax law	
	high-tech enterprises	ordinary enterprises	high-tech enterprises	ordinary enterprises
Weighted pre-tax deduction rate	95%	95%	140%	140%
tax rate	33%	33%	15%	25%
B-index	1.02	1.02	0.93	0.87
1-B	-0.02	-0.02	0.07	0.13

[1]The old tax law refers to the enterprise income tax law that was implemented before 2008. The new tax law refers to the corporate income tax law that was officially implemented after January 1, 2008

the enterprise needs to pay additional tax from the income generated from R&D investment, and the preferential tax policies do not bring substantial subsidies to the enterprise. The intensity of tax incentives has greatly increased since the new tax law's introduction, showing that the Chinese government is continuing to boost the level of innovation support for tax policies as the status of business innovation becomes more and more essential. It is worth noting that high-tech enterprises have additional tax incentives compared to ordinary companies, while tax incentive intensity is much lower. That is to say, under the same pre-tax deduction rate, the higher the tax rate applicable to enterprises, the greater the incentive intensity of tax incentives is. This means that there seems to be an inhibitory effect between R&D expenses plus deduction policy and the preferential tax rate policy. We further explore the relationship between the two by deriving the tax rate.

$$K = \frac{\partial B}{\partial t} = \frac{1 - r}{(1 - \mathrm{t})^2} \tag{4}$$

when r > 1, K < 0, the B-index will increase as the tax rate decreases; when r < 1, K > 0, the B-index will decrease as the tax rate decreases; when r = 1, K = 0, then B = 1, and has nothing to do with the change in tax rate. Only when there are inadequate incentives for pre-tax deductions can the impact of tax rate concessions be observed. After the implementation of the new tax law, the pre-tax comprehensive deduction rate of Chinese enterprises is greater than 1. At this time, the tax incentive intensity will become weaker as the tax rate decreases, so the tax incentive intensity of ordinary enterprises will be higher than that of high-tech enterprises. Preliminary findings indicate that after the implementation of the new tax law, the intensity of tax incentives for enterprises R&D innovation increased a lot. Moreover, due to the offsetting effect between R&D expenses plus deduction policy and the preferential tax rate policy, the incentive intensity tax advantages for high-tech businesses is even smaller than that of ordinary enterprises. Later, we will further verify the incentive effect of tax incentives and the relationship between the two specific tax incentives through empirical analysis of high-tech sample companies, in order to provide a valuable reference for optimizing China's tax incentive system.

Theoretical analysis and research hypothesis

Theoretical analysis of preferential tax policies affecting corporate sustainable innovation

Based on the important role of tax incentive intensity in balancing risks, reducing costs, and increasing revenue expectations, companies have incentives to favor innovative projects in strategic decision-making and resource allocation, and benefit from the increase in core intellectual property, such as new processes and new technologies, which enhances their long-term competitiveness (Warda 2006). The government also achieved the goal of macroeconomic regulation and policy guidance by intervening in the direction, speed and scale of technological progress. High-tech enterprises enjoy a lot of tax incentives, and have strong R&D and technological achievements transformation capabilities. The tax incentive intensity on corporate sustainable innovation should be obvious. Therefore, this paper proposes hypothesis H1:

H1: Tax incentive intensity has a positive incentive effect on corporate sustainable innovation of high-tech enterprises.

The R&D expenses plus deduction policy is a policy with fewer restrictions and more preferential benefits in the preferential tax policies. It allows companies to deduct 50% (or 75%) of R&D expenses before tax, and effectively reduces the income tax burden of enterprises in the form of "non-debt tax shield", thus helping companies reduce funding constraints for innovative R&D activities. In terms of the level of innovation, it can correct the problem of

insufficient R&D investment caused by market failures and thus increase the enthusiasm of enterprise innovation activities. Therefore, this paper proposes hypothesis H2a:

H2a: The R&D expenses plus deduction policy can effectively improve corporate sustainable innovation of high-tech enterprises.

The level of tax burden directly affects the company's capital return rate, which in turn affects the company's innovative strategic decision-making. If the cost of innovation is too high, enterprise technology innovation will be discouraged. The reduction of the tax rate can guide enterprises to pursue innovative production and management activities in accordance with the government's regulatory objectives while maximizing their benefits. At the same time, the preferential tax rate policy will reduce the company's cash outflow, allowing it to fulfill the high investment requirements for innovation activities. The saved funds are invested in technical innovation activities such as R&D equipment renewal, scientific and technological personnel training, and new product inventions, thereby promoting corporate sustainable innovation. Therefore, this paper proposes hypothesis H2b:

H2b: The preferential tax rate policy has a positive incentive effect on corporate sustainable innovation of high-tech enterprises.

The preferential tax rate policy reduces the taxable amount of the enterprise, and more profits remain in the enterprise, thus ensuring the supply of innovative funds. The R&D expenses plus deduction policy reduces the cost of corporate innovation behavior by affecting the tax base. Both are powerful policies that encourage sustainable corporate innovation (Czarnitzki et al. 2011). The calculation of the B-index, however, revealed that when the pre-tax deduction rate is greater than 1, the reduction of the corporate income tax rate will lead to a weakening of the incentive intensity for tax incentives. Considering that the preferential tax rate policy and the R&D expenses plus deduction policy are all related to the level of R&D investment, the effect of innovation incentives may be somehow offset by the overlapping of policy areas. Therefore, this paper proposes hypothesis H2c:

H2c: There is a substitution effect between the preferential tax rate policy and the R&D expenses plus deduction policy on corporate sustainable innovation of high-tech enterprises.

Theoretical analysis of preferential tax policies affecting corporate sustainable innovation from the perspective of heterogeneity

In areas with high levels of economic development where the government has a low level of market intervention and the legal system is relatively complete, enterprises can obtain their own resources and achieve lasting competitive advantages through sound market mechanisms. In areas with high levels of government intervention and imperfect legal systems, the offside and misplacement of government functions disperse the energy and resources of enterprise, and i and it is difficult to effectively defend intellectual property rights. Therefore, the innovation motivation and innovation needs of enterprises in such areas are very low, and their sensitivity to preferential tax policies is weaker than that of businesses in sectors with robust markets. For example, US interstate banks increased their patent application activities through the expansion of credit supply brought about by deregulation (Busom et al. 2014). Therefore, this paper proposes hypothesis H3a:

H3a: The incentive effect of preferential tax policies in regions with low levels of government intervention and sound legal system is more obvious.

Table 3 Definition of control variables

Variable name	Variable symbol	Variable calculation
firm Size	Size	LN(assets)
property right	Soe	State-owned = 1, non-state-owned = 0
government subsidy	Sub	LN(government subsidy + 1)
asset-liability ratio	Lev	liability/asset
return on assets	Roa	net profit/asset
equity restriction	Shrc	the sum of the shareholding ratio of the top ten shareholders
firm cash	Cash	monetary Fund/total assets
year	Year	dumb variable

Table 4 Descriptive statistics

Variable	Average	Median	Standard Deviation	Minimum	Maximum
SInnov	3.835	3.781	1.494	0.000	10.202
TII	15.716	15.706	1.637	0.000	20.468
Taxrate	16.903	17.013	1.928	0.000	22.717
Deduction	15.784	15.775	1.640	0.000	20.537
Size	22.395	22.278	1.040	20.072	27.307
Soe	0.350	0.000	0.478	0.000	1.000
Cash	0.167	0.141	0.103	0.003	0.771
Roa	0.043	0.038	0.059	-0.860	0.340
Sub	16.701	16.786	2.162	0.000	22.106
Lev	0.421	0.411	0.180	0.017	1.256
Shrc	0.541	0.544	0.139	0.133	0.918

When small enterprises carry out innovative activities, they often face restrictions such as insufficient R&D funds, lack of scientific and technical personnel, and slow equipment renewal, resulting in a low degree of technological innovation. And because of its lack of understanding of tax incentives, there will be more bottlenecks in the implementation of preferential tax policies (Amore et al. 2013). The nature of property rights is another important feature that will affect the innovation incentive effect of preferential tax policies. state-owned enterprises often have the natural advantage of receiving more government subsidies than non-state-owned enterprises. Since they have already received more subsidies, the double overlap of tax incentives will enable enterprises to obtain excessive support gains, thus crowding out R&D investment from enterprises themselves. On the other hand, state-owned enterprises have high industry monopoly profits and undertake more political and social functions in addition to pursuing economic goals, as a result they are reluctant to engage in technological innovation activities with high risks and uncertainties. Therefore, this paper proposes hypothesis H3b:

Table 5 Empirical results

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-10.752***	-10.764***	-10.42 ***	-10.099***	-5.43***
	(-14.241)	(-14.258)	(-13.215)	(-12.94)	(-5.901)
TII	0.147***				
	(6.686)				
Taxrate			0.073***	0.073***	0.285***
			(3.195)	(3.239)	(8.872)
Deduction		0.146***		0.146***	0.391***
		(6.662)		(6.682)	(11.36)
Taxrate*Deduction					-0.961***
					(-9.077)
Size	0.459***	0.46***	0.488***	0.378***	0.09
	(10.986)	(11.007)	(10.528)	(7.756)	(1.58)
Soe	0.151**	0.151**	0.179***	0.172***	0.127**
	(2.288)	(2.289)	(2.671)	(2.592)	(1.958)
Cash	0.175	0.41	0.42	0.363	0.343
	(1.358)	(1.358)	(1.378)	(1.206)	(1.164)
Roa	2.217***	2.129***	1.556**	1.283**	-0.328
	(3.63)	(3.632)	(2.406)	(2.004)	(-0.504)
Sub	0.101***	0.101***	0.11***	0.101***	0.086***
	(6.662)	(6.666)	(7.165)	(6.674)	(5.756)
Lev	0.244	0.244	0.277	0.244	0.311
	(1.113)	(1.114)	(1.253)	(1.116)	(1.455)
Shrc	-0.073	-0.073	-0.162	-0.125	-0.169
	(-0.329)	(-0.33)	(-0.718)	(-0.561)	(-0.777)
Year	Control	Control	Control	Control	Control
N	1768	1768	1768	1768	1768
Adjusted-R2	0.288	0.288	0.274	0.291	0.323
F	65.905***	65.865***	61.585***	61.577***	65.815***

*** means significant at 1% level, ** means significant at 5%, and * means significant at 10% level, with T in parentheses

Table 6 High-level government intervention group

High Intervention	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-11.715***	-11.725***	-10.42 ***	-11.178***	-6***
	(-10.284)	(-10.293)	(-13.215)	(-9.392)	(-4.322)
TII	0.128***				
	(3.802)				
Taxrate			0.058	0.064	0.285***
			(1.396)	(1.566)	(5.527)
Deduction		0.127***		0.129***	0.425***
		(3.786)		(3.851)	(7.738)
Taxrate*Deduction					-1.151***
					(-6.676)
Size	0.504***	0.504***	0.54***	0.433***	0.131
	(7.776)	(7.788)	(7.219)	(5.484)	(1.472)
Soe	0.487***	0.487***	0.525***	0.492***	0.431***
	(4.608)	(4.61)	(4.936)	(4.662)	(4.197)
Cash	1.732***	1.732***	1.766***	1.708***	1.498***
	(3.323)	(3.324)	(3.356)	(3.28)	(2.969)
Roa	0.148	0.148	-0.615	-0.765	-2.231*
	(0.147)	(0.147)	(-0.524)	(-0.659)	(-1.949)
Sub	0.111***	0.111***	0.115***	0.11***	0.088***
	(4.941)	(4.943)	(5.09)	(4.911)	(4.018)
Lev	-0.66*	-0.661*	-0.691*	-0.648*	-0.448
	(-1.783)	(-1.784)	(-1.847)	(-1.75)	(-1.247)
Shrc	-0.108	-0.108	-0.135	-0.134	-0.113
	(-0.289)	(-0.289)	(-0.356)	(-0.358)	(-0.311)
Year	Control	Control	Control	Control	Control
N	648	648	648	648	648
Adjusted-R2	0.331	0.331	0.318	0.333	0.376
F	30.146***	30.13***	28.455***	27.887***	30.935***

H3b: In large-scale enterprises and non-state-owned enterprises, the innovation incentive effect of preferential tax policies is more obvious.

Methods

Sample selection and data source

This paper takes China A-share high-tech Enterprises from 2016 to 2019 as the research object, excluding ST, *ST and suspension of listing, delisting companies, new listed companies in the sample research area, and serious lack of R&D data and patent data companies. Considering the rationality of the preferential tax rate and corporate sustainable innovation index, this paper excludes enterprises with negative current income tax expenses and enterprises with zero patents lag for two years. Patents, R&D, and financial data are all from the CSMAR database. For the judgment of high-tech enterprises, we refer to the qualification information document of listed companies in the CSMAR database, and cross-check with the nominal tax rate of enterprises. The relationship between the government and the market and the legal environment data are from the "China Provincial Marketization Index Report (2016)" prepared by Walicka and Prystrom (2015). Part of the data missing is supplemented by the CCER database and manual collection, and finally 1,768 samples of 442 companies are sampled.

Variable definition

Corporate sustainable innovation

In current research, corporate sustainable innovation is measured by the increment of intangible assets, patents or R&D investment etc. However, based on the accumulation and dynamic characteristics of the innovation activities, this paper refers to the practice of Chen Y M, Triguero (Chen et al. 2013). We use the sum of the number of corporate invention patent applications in this year and last year to represent the innovation output of this period, and multiply the growth rate of the company's current innovation output by the current innovation output to measure corporate sustainable innovation, logarithmic

Table 7 Low-level government intervention group

Low Intervention	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-10.809***	-10.821***	-10.504***	-10.176***	-6.296***
	(-10.812)	(-10.826)	(-10.121)	(-9.882)	(-5.085)
TII	0.14***				
	(4.899)				
Taxrate			0.07***	0.067**	0.24***
			(2.591)	(2.515)	(5.85)
Deduction		0.139***		0.137***	0.325***
		(4.882)		(4.84)	(7.353)
Taxrate*Deduction					-0.737***
					(-5.489)
Size	0.476***	0.477***	0.502***	0.4***	0.157**
	(8.745)	(8.761)	(8.495)	(6.439)	(2.078)
Soe	0.046	0.046	0.061	0.07	0.024
	(0.529)	(0.529)	(0.7)	(0.802)	(0.279)
Cash	-0.273	-0.273	-0.267	-0.319	-0.255
	(-0.753)	(-0.752)	(-0.73)	(-0.88)	(-0.713)
Roa	2.988***	2.99***	2.641***	2.312***	1.013
	(4.227)	(4.23)	(3.477)	(3.062)	(1.295)
Sub	0.093***	0.093***	0.103***	0.093***	0.084***
	(4.573)	(4.576)	(5.101)	(4.627)	(4.218)
Lev	0.898***	0.898***	0.965***	0.886***	0.879***
	(3.342)	(3.344)	(3.571)	(3.304)	(3.322)
Shrc	-0.238	-0.238	-0.364	-0.294	-0.353
	(-0.873)	(-0.874)	(-1.32)	(-1.075)	(-1.308)
Year	Control	Control	Control	Control	Control
N	1120	1120	1120	1120	1120
Adjusted-R2	0.296	0.296	0.285	0.299	0.317
F	43.792***	43.771***	41.585***	40.844***	41.011***

processing of settlement results to eliminate the impact of quantitative scale. The calculation formula is as follows:

$$SInnov = LN(\frac{P_t + P_{t-1}}{P_{t-1} + P_{t-2}} \times (P_t + P_{t-1}) + 1) \quad (5)$$

Among them, SInnov represents corporate sustainable innovation, and *Pt* represents the number of invention patent applications in the t year of the enterprise.

Tax incentive intensity

This paper uses the calculation of the B-index to measure tax incentive intensity by multiplying the company's R&D expenses with 1-B.

$$TII = LN(R\&D \times (1 - B) + 1) \quad (6)$$

R&D represents the R&D expenses, and 1-B represents the cost savings of corporate unit R&D expenses due to tax incentives. Therefore, the product of the two can represent the total cost-saving of corporate innovation activities due to tax incentives. We also take logarithmic processing on the indicator to eliminate the influence of quantity scale.

The preferential tax rate policy

This paper uses the following indicator to measure the preferential tax rate policy of high-tech enterprises:

$$Taxrate = LN(\frac{c}{ntr} \times (gtr - ntr) + 1) \quad (7)$$

C represents current income tax expense, ntr represents nominal income tax rate,and gtr represents general income tax rate. Current income tax expense is the current expense recognized by the enterprise according to the principle of accrual basis. It is calculated as: current income tax expense = income tax expense—(deferred income tax liabilities endings—deferred income tax liabilities beginnings) + (deferred income tax assets endings—deferred income tax assets beginnings). The method first calculates the taxable income of the enterprise in the current period based on the ratio of the current income tax expense to the

Table 8 Sound legal system group

Sound legal system	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	13.881***	-13.896***	-13.868***	-13.264***	-8.059***
	(-12.43)	(-12.447)	(-12.027)	(-11.576)	(-5.293)
TII	0.17***				
	(4.394)				
Taxrate			0.093**	0.097**	0.262***
			(2.216)	(2.321)	(5.016)
Deduction		0.169***		0.171***	0.41***
		(4.379)		(4.432)	(6.783)
Taxrate*Deduction					-1.027***
					(-5.076)
Size	0.605***	0.606***	0.652***	0.507***	0.246***
	(9.389)	(9.406)	(9.222)	(6.591)	(2.69)
Soe	0.165	0.165	0.179	0.154	0.138
	(1.452)	(1.452)	(1.566)	(1.366)	(1.239)
Cash	0.583	0.583	0.579	0.57	0.643*
	(1.487)	(1.486)	(1.461)	(1.459)	(1.673)
Roa	2.171**	2.174**	1.242	0.825	-0.958
	(2.248)	(2.25)	(1.094)	(0.734)	(-0.826)
Sub	0.074***	0.074***	0.084***	0.076***	0.067***
	(3.328)	(3.33)	(3.757)	(3.425)	(3.081)
Lev	0.244	0.245	0.272	0.219	0.182
	(0.785)	(0.785)	(0.865)	(0.706)	(0.597)
Shrc	-0.344	-0.345	-0.529	-0.432	-0.41
	(-1.036)	(-1.037)	(-1.57)	(-1.294)	(-1.25)
Year	Control	Control	Control	Control	Control
N	700	700	700	700	700
Adjusted-R2	0.383	0.383	0.37	0.386	0.408
F	40.385***	40.366***	38.29***	37.687***	38.025***

nominal income tax rate, and then multiplies the tax rate difference between the general tax rate and the nominal tax rate to reflect the tax burden saved by the high-tech enterprise due to the preferential tax rate. Then we take logarithmic processing on the indicator to eliminate the influence of quantity scale.

The r&d expenses plus deduction policy

This paper uses the following method to calculate the company's R&D expenses plus deduction policy.

$$Deduction = LN(R\&D \times pdr \times itr + 1) \quad (8)$$

R&D represents the R&D expenses, pdr represents plus deduction rate, and itr represents income tax rate. This indicator can measure the reduced R&D cost of enterprise innovation investment due to pre-tax deduction and thus better measure the effect of R&D expenses plus deduction policy.

Control variable definitions are shown in the following Table 3:

Model building

To test hypothesis 1, this paper builds model 1:

$$SInnov = \alpha_0 + \alpha_1 TII + \alpha_2 Size + \alpha_3 Soe + \alpha_4 Cash + \alpha_5 Roa + \alpha_6 Sub + \alpha_7 Lev + \alpha_8 Shrc + \sum Year + \varepsilon$$

Among them, TII represents tax incentive intensity, α1 is the regression coefficient to be estimated, α0 is the constant term, and ε is the residual term. In the regression result, if α1 is significantly positive, it can be said that the intensity of tax incentives effectively stimulates the improvement of sustainability of enterprise innovation of high-tech enterprises.

To test hypothesis 2a, this paper builds model 2:

$$SInnov = \alpha_0 + \alpha_1 Deduction + \alpha_2 Size + \alpha_3 Soe + \alpha_4 Cash + \alpha_5 Roa + \alpha_6 Sub + \alpha_7 Lev + \alpha_8 Shrc + \sum Year + \varepsilon$$

Table 9 Insufficient legal system group

Insufficient legal system	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-8.742***	-8.753***	-8.192***	-8.003***	-3.546***
	(-8.564)	(-8.575)	(-7.658)	(-7.56)	(-2.933)
TII	0.135***				
	(4.973)				
Taxrate			0.071**	0.071***	0.297***
			(2.556)	(2.578)	(7.133)
Deduction		0.134***		0.134***	0.382***
		(4.954)		(4.964)	(8.743)
Taxrate*Deduction					-0.94***
					(-7.12)
Size	0.362***	0.362***	0.373***	0.278***	-0.016
	(6.512)	(6.525)	(6.016)	(4.329)	(-0.216)
Soe	0.119	0.119	0.151*	0.146*	0.094
	(1.382)	(1.383)	(1.723)	(1.691)	(1.106)
Cash	0.118	0.119	0.137	0.05	0.001
	(0.262)	(0.263)	(0.3)	(0.11)	(0.001)
Roa	2.309***	2.311***	1.804**	1.575**	0.174
	(3.078)	(3.08)	(2.231)	(1.967)	(0.215)
Sub	0.121***	0.121***	0.129***	0.12***	0.101***
	(5.915)	(5.918)	(6.252)	(5.888)	(5.001)
Lev	0.313	0.313	0.362	0.334	0.483
	(1.037)	(1.037)	(1.189)	(1.11)	(1.637)
Shrc	0.097	0.097	0.042	0.059	0.042
	(0.32)	(0.319)	(0.137)	(0.194)	(0.143)
Year	Control	Control	Control	Control	Control
N	1068	1068	1068	1068	1068
Adjusted-R2	0.238	0.238	0.225	0.242	0.276
F	31.273***	31.252***	29.131***	29.354***	32.273***

*** means significant at 1% level, ** means significant at 5%, and * means significant at 10% level, with T in parentheses

Deduction represents the R&D expenses plus deduction policy, and ifα1 is significantly positive, it can prove that the R&D expenses plus deduction policy can effectively improve corporate sustainable innovation of high-tech enterprises.

To test hypothesis 2b, this paper builds model 3:

$$SInnov = \alpha_0 + \alpha_1 Taxrate + \alpha_2 Size + \alpha_3 \mathrm{Soe} + \alpha_4 Cash + \alpha_5 Roa + \alpha_6 Sub + \alpha_7 Lev + \alpha_8 Shrc + \sum Year + \varepsilon$$

Taxrate represents the preferential tax rate policy, and if α1 is significantly positive, it can prove that the preferential tax rate policy has a positive incentive effect on corporate sustainable innovation of high-tech enterprises.

To test hypothesis 2c, this paper builds model 4 and model 5:

$$SInnov = \alpha_0 + \alpha_1 Taxrate + \alpha_2 Deduction + \alpha_3 Size + \alpha_4 \mathrm{Soe} + \alpha_5 Cash + \alpha_6 Roa + \alpha_7 Sub + \alpha_8 Lev + \alpha_9 Shrc + \sum Year + \varepsilon$$

$$SInnov = \alpha_0 + \alpha_1 Taxrate + \alpha_2 Deduction + \alpha_3 Taxrate \times Deduction + \alpha_4 Size + \alpha_5 \mathrm{Soe} + \alpha_6 Cash + \alpha_7 Roa + \alpha_8 Sub + \alpha_9 Lev + \alpha_{10} Shrc + \sum Year + \varepsilon$$

Model 4 incorporates the two policies into a regression model at the same time to observe the change of regression coefficient when compared with that of model 2 and model 3. Model 5 puts two policy interaction item on the basis of model 4. If the coefficient of the interaction term is significantly positive, it means that there is a complementary effect between the preferential tax rate policy and the R&D expenses plus deduction policy; if the coefficient of the interaction term is significantly negative, it can be proved that there is a substitution effect between the preferential tax rate policy and the R&D expenses plus deduction policy.

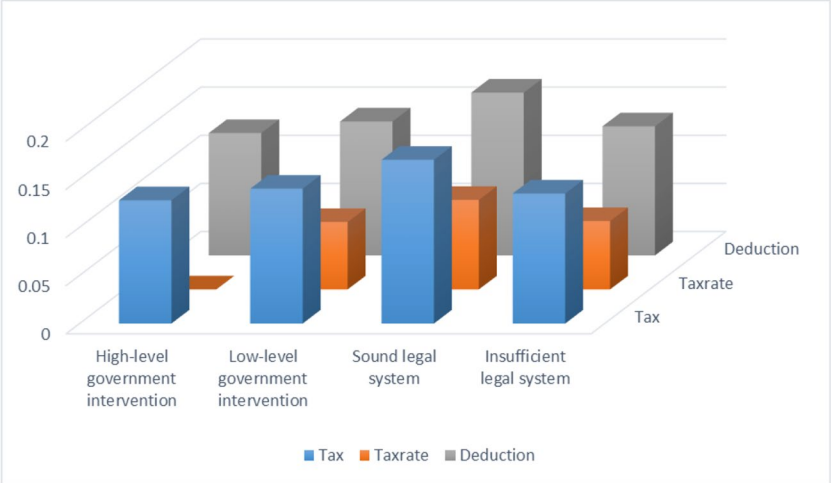

Fig. 2 Grouping regression based on institutional environment

Empirical results

Descriptive statistics

Through the descriptive statistics of each variable from Table 4, we can find that the average of corporate sustainable innovation is 3.835, the maximum is 10.202, and the minimum is 0, which indicates that the overall sustainability of enterprise innovation of Chinese high-tech enterprises is low and the gap is large. The zero persistence of innovation of some enterprises means that there are no substantial and high-quality innovation achievements. The average value of tax incentive intensity is slightly larger than the median, indicating that most sample enterprises enjoy no more than the

Table 10 Large scale group

Large scale	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-10.41***	-10.429***	-10.655***	-10.063***	-3.868**
	(-6.878)	(-6.89)	(-6.766)	(-6.554)	(-2.172)
TII	0.246***				
	(6.624)				
Taxrate			0.063	0.067	0.281***
			(1.272)	(1.392)	(4.9)
Deduction		0.245***		0.246***	0.503***
		(6.607)		(6.628)	(9.324)
Taxrate*Deduction					-1.376***
					(-6.424)
Size	0.386***	0.387***	0.521***	0.323***	0.054
	(5.063)	(5.074)	(6.045)	(3.631)	(0.564)
Soe	0.048	0.048	0.088	0.054	0.043
	(0.463)	(0.464)	(0.823)	(0.523)	(0.42)
Cash	0.535	0.535	0.601	0.522	0.636
	(1.125)	(1.125)	(1.23)	(1.097)	(1.371)
Roa	3.103***	3.105***	2.476*	2.172*	-0.011
	(2.808)	(2.809)	(1.866)	(1.681)	(-0.008)
Sub	0.082***	0.082***	0.095***	0.082***	0.071***
	(4.348)	(4.351)	(4.878)	(4.313)	(3.798)
Lev	0.082	0.082	0.026	0.084	0.214
	(0.232)	(0.231)	(0.072)	(0.238)	(0.621)
Shrc	0.119	0.118	-0.122	0.067	0.089
	(0.341)	(0.34)	(-0.341)	(0.193)	(0.26)
Year	Control	Control	Control	Control	Control
N	783	783	783	783	783
Adjusted-R2	0.198	0.198	0.155	0.199	0.239
F	18.603***	18.579***	14.004***	17.213***	19.894***

Table 11 Small scale group

Small scale	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-10.549***	-10.556***	-9.23***	-9.221***	-5.738***
	(-6.181)	(-6.185)	(-5.238)	(-5.255)	(-3.117)
TII	0.083***				
	(3.113)				
Taxrate			0.077***	0.076***	0.251***
			(3.074)	(3.057)	(6.258)
Deduction		0.083***		0.082***	0.297***
		(3.1)		(3.084)	(6.319)
Taxrate*Deduction					-0.721***
					(-5.508)
Size	0.47***	0.471***	0.407***	0.355***	0.113
	(5.554)	(5.56)	(4.454)	(3.842)	(1.12)
Soe	0.256***	0.256***	0.278***	0.282***	0.225***
	(2.951)	(2.951)	(3.185)	(3.241)	(2.604)
Cash	0.248	0.248	0.194	0.158	0.102
	(0.638)	(0.639)	(0.497)	(0.407)	(0.266)
Roa	1.653**	1.655**	1.097	0.908	-0.222
	(2.42)	(2.422)	(1.516)	(1.257)	(-0.3)
Sub	0.131***	0.131***	0.139***	0.133***	0.116***
	(4.647)	(4.649)	(4.929)	(4.743)	(4.171)
Lev	0.446	0.446	0.485**	0.439	0.428
	(1.591)	(1.592)	(1.734)	(1.574)	(1.556)
Shrc	-0.138	-0.138	-0.171	-0.189	-0.28
	(-0.479)	(-0.478)	(-0.592)	(-0.658)	(-0.987)
Year	Control	Control	Control		Control
N	985	985	985	985	985
Adjusted-R2	0.123	0.123	0.123	0.131	0.156
F	13.576***	13.568	13.551***	13.323***	15.003***

average level of preferential tax policies support. The reason why the minimum value of the preferential tax rate is zero is that the current business situation of the enterprise is not good, and there is no preferential tax treatment because there is no income tax to be paid. The difference between the maximum and minimum value of the additional deduction is large, which indicates that different enterprises enjoy different deduction of R&D expenses. The more a company's R&D expenditures, the greater proportion of those expenditures it may deduct.

Regression analysis

Analysis of innovative incentive effect of tax incentive intensity, the r&d expenses plus deduction policy and the preferential tax rate policy

From Table 5, we can see that the regression coefficient of tax incentive intensity in model 1 is 0.147, which is significant at 1% level. It shows that corporate sustainable innovation can be improved by 14.7% for every unit of tax incentive enjoyed by enterprises. That is to say, the tax incentive intensity has a significant positive incentive effect on the persistence of high-tech firm innovation, hypothesis H1 can be proved. Model 2 is used to validate the impact of R&D expenses plus deduction policy on corporate sustainable innovation. The regression coefficient of the R&D expenses plus deduction is 0.146, which is significant at the level of 1%. This shows that the tax shield effect of the R&D expense plus deduction policy has an effective incentive effect on the innovation persistence of high-tech enterprises, and H2a can be proved. Model 3 examines the impact of preferential tax rate on corporate sustainable innovation. The regression coefficient of preferential tax rate is 0.073, which is significant at the level of 1%, which means that corporate sustainable innovation will increase with the increase of preferential tax rate policy. The preferential tax rate of 15% is the key policy tool for the state to support high-tech enterprises in pursuit of innovation. The regression results show that the preferential tax rate reduction policy really embodies an important value in stimulating high-tech enterprises to

Table 12 State-owned enterprises group

State-owned	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-10.211***	-10.219***	-9.909***	-9.695***	-5.142***
	(-9.315)	(-9.323)	(-8.671)	(-8.509)	(-3.617)
TII	0.09***				
	(2.733)				
Taxrate			0.053	0.055*	0.304***
			(1.569)	(1.657)	(5.227)
Deduction		0.089***		0.091***	0.345***
		(2.718)		(2.769)	(5.875)
Taxrate*Deduction					-0.898***
					(-5.171)
Size	0.47***	0.471***	0.48***	0.409***	0.074
	(7.699)	(7.713)	(7.145)	(5.707)	(0.774)
Cash	0.51	0.511	0.601	0.495	0.41
	(0.952)	(0.953)	(1.12)	(0.926)	(0.781)
Roa	2.253**	2.254**	1.377	1.21	-1.048
	(1.961)	(1.961)	(1.047)	(0.924)	(-0.773)
Sub	0.113***	0.113***	0.114***	0.112***	0.099***
	(5.461)	(5.462)	(5.495)	(5.405)	(4.833)
Lev	-0.151	-0.151	-0.155	-0.196	-0.091
	(-0.412)	(-0.411)	(-0.42)	(-0.532)	(-0.252)
Shrc	0.449	0.449	0.496	0.465	0.478
	(1.023)	(1.023)	(1.124)	(1.06)	(1.112)
Year	Control	Control	Control	Control	Control
N	623	623	623	623	623
Adjusted-R2	0.286	0.286	0.28	0.288	0.317
F	25.939***	25.928***	25.235***	23.888***	25.048***

increase their innovation output. The hypothesis H3a in this paper is verified.

The fourth and fifth models are used to test whether there are complementary or substitution effects between the R&D expenses plus deduction policy and the preferential tax rate policy (Triguero et al. 2013). Model 4 first put the two policies into the regression model together. Under the same control variables, the regression coefficients of the deduction factor and preferential tax rate are the same as those of the two and three independent regression models. Model 5, on the basis of model 4, puts the multiplier of the two into the regression model.

The coefficient of the interaction term can reflect the relationship between the two variables. From the regression results of Table 5, the regression coefficient of Taxrate*Deduction is -0.961, which is significant at the level of 1%. This shows that there is a substitution relationship between the R&D expenses plus deduction policy and the preferential tax rate policy, and proves the validity of the hypothesis H2c. The R&D expenses plus deduction policy and the preferential tax rate policy are typical representatives of indirect preference and direct preference in China's current tax preferential policy system respectively, and they can play a positive role in promoting enterprise innovation. However, when adopted simultaneously, they increase the opportunity for enterprises to balance their interests. It is difficult to perform the role of 1 plus 1 equals 3 since the impacts of their respective policies somewhat negate each other out.

Further research based on heterogeneous grouping

(1) Grouping regression based on institutional environment.

Referring to the relationship index between government and market in China's Provincial Marketization Index Report (2016), this paper divides the samples into high-level government intervention group and low-level government intervention group. According to the development degree of market intermediary organizations and legal environment indicators in market-oriented indicators, the samples are divided into two groups: the group with sound legal system

Table 13 Non-state-owned enterprises group

Non-state-owned	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-11.408***	-11.425***	-10.96***	-10.542***	-5.542***
	(-10.459)	(-10.475)	(-9.573)	(-9.371)	(-4.276)
TII	0.207***				
	(6.846)				
Taxrate			0.108***	0.099***	0.267***
			(3.264)	(3.037)	(6.805)
Deduction		0.206***		0.202***	0.452***
		(6.828)		(6.717)	(10.007)
Taxrate*Deduction					-1.088***
					(-7.292)
Size	0.46***	0.461***	0.492***	0.352***	0.111
	(7.699)	(7.714)	(7.293)	(5.076)	(1.477)
Cash	0.348	0.347	0.266	0.279	0.321
	(0.952)	(0.952)	(0.715)	(0.765)	(0.901)
Roa	1.919***	1.921***	1.408*	1.08	-0.106
	(2.821)	(2.823)	(1.891)	(1.476)	(-0.144)
Sub	0.08***	0.08***	0.104***	0.083***	0.065***
	(3.396)	(3.401)	(4.367)	(3.502)	(2.808)
Lev	0.52**	0.52*	0.549*	0.542**	0.543**
	(1.88)	(1.88)	(1.952)	(1.965)	(2.011)
Shrc	-0.233	-0.234	-0.473*	-0.357	-0.385
	(-0.911)	(-0.912)	(-1.799)	(-1.382)	(-1.524)
Year	Control	Control	Control	Control	Control
N	1145	1145	1145	1145	1145
Adjusted-R2	0.269	0.269	0.246	0.274	0.306
F	43.024***	42.991***	38.227***	40.205***	42.984***

*** means significant at 1% level, ** means significant at 5%, and * means significant at 10% level, with T in parentheses

and the group with imperfect legal system. Tables 6, 7, 8, and 9 and Fig. 2 represent the regression results, showing that tax incentive intensity, the R&D expenses plus deduction policy and the preferential tax rate policy on corporate sustainable innovation is more significant in areas with low government intervention and sound legal system. Therefore, we can draw a conclusion that the incentive effect of preferential tax policies is more obvious in areas with low government intervention and a more robust legal system, hypothesis H3a can be proved.

(B) Group regression based on enterprise characteristics

This paper divides the sample enterprises into large-scale enterprises and small-scale enterprises on the basis of the average size of the sample enterprises, and divides the enterprises into state-owned enterprises and non-state-owned enterprises according to the property rights of the enterprises. Tables 10, 11, 12, and 13 and Fig. 3 represent the regression results, showing that the differences in tax incentive intensity, the R&D expenses plus deduction policy and the preferential tax rate policy of different sizes and ownerships. They demonstrate that the tax incentive intensity, deduction and preferential tax rate coefficients of non-state-owned enterprises are more significant, the results indicate that the incentive effect of preferential tax policies on corporate sustainable innovation is more obvious. The impact of tax preferential policies on corporate sustainability innovation is different when considering enterprises sizes. Tax incentive intensity and the R&D expenses plus deduction policy have a strong incentive effect on large-scale businesses. However, the incentive effect of the preferential tax rate policy on large-scale enterprises is not significant, which indicates that the innovation sustainability of large-scale enterprises is not very sensitive to preferential tax rate policies. H3b is not fully confirmed.

Robustness test

In order to ensure the reliability and accuracy of the research conclusions, this paper maintains other variables unchanged, and chooses the total number of patents applied

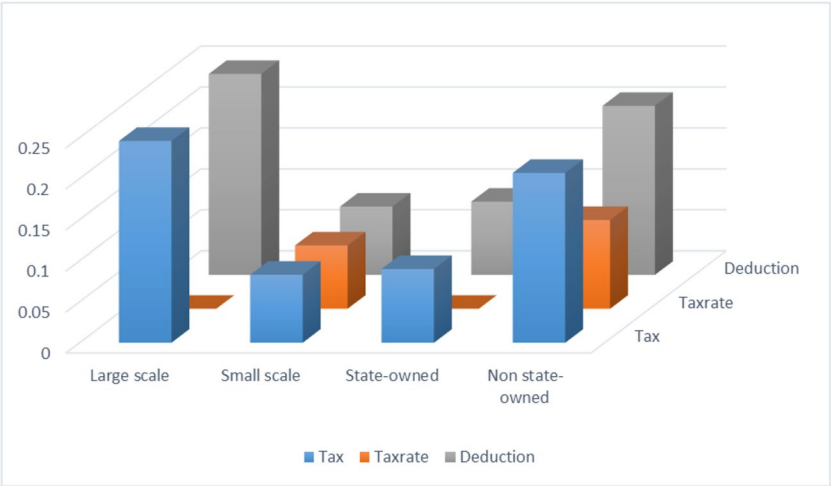

Fig. 3 Group regression based on enterprise characteristics

by enterprises in the same year instead of the number of patent applications for invention to calculate the corporate sustainable innovation for robustness test. The regression results represented from Table 14 are basically consistent with the previous ones, and the conclusion of empirical analysis is valid.

Table 14 Robustness test results

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
(constant)	-8.612***	-8.624***	-8.33***	-8.013***	-3.873***
	(-12.216)	(-12.234)	(-11.296)	(-10.995)	(-4.497)
TII	0.145***				
	(7.057)				
Taxrate			0.067***	0.067***	0.255***
			(3.138)	(3.186)	(8.482)
Deduction		0.144***		0.144***	0.362***
		(7.033)		(7.054)	(11.211)
Taxrate*Deduction					-0.853***
					(-8.6)
Size	0.404***	0.405***	0.439***	0.33***	0.075
	(10.364)	(10.385)	(10.115)	(7.25)	(1.4)
Soe	-0.029	-0.029	-0.003	-0.01	-0.05
	(-0.468)	(-0.466)	(-0.045)	(-0.163)	(-0.816)
Cash	0.163	0.164	0.177	0.121	0.103
	(0.58)	(0.581)	(0.62)	(0.43)	(0.372)
Roa	1.966***	1.968***	1.46**	1.191**	-0.237
	(3.593)	(3.596)	(2.414)	(1.993)	(-0.389)
Sub	0.089***	0.089***	0.097***	0.089***	0.075***
	(6.28)	(6.284)	(6.806)	(6.291)	(5.406)
Lev	0.766***	0.766***	0.799***	0.766***	0.826***
	(3.745)	(3.746)	(3.862)	(3.754)	(4.127)
Shrc	0.019	0.019	-0.065	-0.028	-0.068
	(0.092)	(0.091)	(-0.307)	(-0.136)	(-0.332)
Year	Control	Control	Control	Control	Control
N	1768	1768	1768	1768	1768
Adjusted-R2	0.289	0.289	0.273	0.292	0.321
F	66.265***	66.223***	61.266***	61.866***	65.17***

*** means significant at 1% level, ** means significant at 5%, and * means significant at 10% level, with T in parentheses

Conclusions and discussion

Conclusions

Sustainable innovation is very important for the long-term development of enterprises. It has been proven that tax incentives have a favorable impact on sustainable development from an inventive standpoint (Howell 2015)because preferential tax policies drive business sustainable innovation. While different policies also interact with each other, which restricts the effect of policy implementation (Pan et al. 2023). The paper finds that tax incentive intensity, the R&D expense plus deduction policy and the preferential tax rate policy can promote corporate sustainable innovation. This is in line with the concept of enterprise cost management, in which various tax advantages are beneficial to reducing enterprise costs and sharing risks, so allowing enterprises to anticipate long-term innovative initiatives.

As study objects, 442 A-share listed high-tech companies are selected in this paper. We empirically test the incentive effect of overall tax preferential intensity and specific tax preferential policies (including R&D expenses plus deduction and preferential tax rate) on corporate sustainable innovation, based on research on the current situation of preferential tax policies to encourage innovation among China's high-tech firms. Based on the heterogeneity of institutional environment and enterprise characteristics, further grouping regression analysis is carried out. In addition to the above conclusions, the paper also finds that: (1) because the incentives of the preferential tax rate policy and the R&D expenses plus deduction policy are related to the level of R&D investment. However, there is a phenomenon that the incentive effect of innovation is offset by the overlap of policy scope between these two policies. (2) from the perspective of heterogeneity of institutional environment, in regions with low degree of government intervention and sound legal system, a sound market mechanism enables enterprises to obtain the resources they need and maintain a sustainable competitive advantage, making the incentive effect of preferential tax policies more apparent. (3) based on the heterogeneity analysis of enterprise characteristics, because state-owned enterprises enjoy natural policy advantages in China, the tax preferential policies have better incentive effect on sustainable innovation of non-state-owned enterprises. The incentive effect of different types of preferential tax policies is different in the scale of enterprises, with tax incentive intensity and the R&D expenses plus deduction policy being more important to sustainable innovation of large technological firms. And the preferential tax rate policy is better in the implementation of small enterprises.

The main contribution of this paper focuses on the interactions between various preferential tax policies at macro level and sustainability of enterprise innovation at micro level in China, the largest developing country. It also discusses the different impacts of different policies, the heterogeneity of institutional environment and the heterogeneity of enterprise characteristics on the actual implementation of tax preferential policies. All this provides directions and empirical basis for further improvement and improvement of China's tax system.

Discussions

First, government should increase the way and the proportion of preferential transfer tax. The system structure of preferential tax policies should be adjusted and optimized (Nassani et al. 2023). The proportion of indirect preferential mode in tax preferential mode should be gradually increased. For instance, in order to solve the problem of lack of funds for innovative activities that high-tech enterprises often face, enterprises can be encouraged to draw technology development funds in proportion to the amount of investment in the form of tax incentives and deduct them before tax, so as to continuously stimulate the motive force of technological innovation.

Second, policymakers should strengthen the performance orientation of preferential tax policies. The government should link the beneficiaries, benefits and sustainable innovation performance, while formulating preferential tax policies (Yuan et al. 2023). China's current preferential tax policies have great room to improve the impact of innovation performance of enterprises. The preferential policies to encourage enterprise innovation are mostly process-oriented rather than result-oriented, and have no direct relationship with enterprise innovation performance. For example, the recognition criteria of high-tech enterprises only restrict R&D investment and R&D personnel proportion (Lahcene et al. 2023), and does not pay attention to the actual level of innovation output of enterprises. On one hand, it weakens the motivation of enterprises to actively promote innovation efficiency. On the other hand, it may even lead enterprises to actively cater to the accepted standards, which would undermine the purpose of tax favors as an incentive.

Third, the government should try to avoid the restrictive effect of different innovation support policies (Sun et al. 2021). The joint use of innovation policies provides all-round and multi-level to improve their independent innovation capability; however, the implementation effects of different policies in the policy mix may conflict with one another, reducing the effectiveness of policy implementation and making the expected policy effects difficult to achieve (Chien et al. 2021). In order to fully exploit the synergistic

effects between policies, the government should fully assess and calculate the characteristics, scope, and effects of each policy when planning and formulating innovative policies, include complementary effects policies in the policy basket, and use tax incentives and R&D subsidy policies to encourage business innovation. The policy offsetting each other should be selected after weighing the advantages and disadvantages. In order to ensure the best effect of innovation policies, R&D subsidies may be more appropriate than tax credits to encourage knowledge-intensive young enterprises.

Fourth, the government should pay more attention to the influence of institutional environment. Despite China's relative success in innovation, a number of problems, such as weak intellectual property law, insufficient talent reserve, a lack of market demand and financial constraints, will bring tremendous risks to China's innovation (Chien et al. 2022). Therefore, the government should formulate the most effective incentive scheme for enterprises in different regions according to the characteristics of regional institutional factors. Additionally, in order to better align the tax policy with the regional institutional context and achieve better support outcomes, the government should adjust the preferential tax policies dynamically according to the regional resource situation, talent structure and market-oriented level in different periods.

Limitations and future directions

The research of this paper has the following limitations: Firstly, China's preferential tax policies are referred to by a multitude of titles. The paper only considers the overall preferential tax intensity and the impact of the R&D expenses plus deduction policy The preferential tax rate policy on corporations' sustainable innovation, which is unable to test the precise impact of other policies on businesses. Second, the sample size is small. In order to facilitate the research, the paper selected the high-tech industries with the strongest innovation ability among Chinese listed companies, which can only represent a small part of Chinese listed companies. We suggest that future research should use manufacturing samples, which may have different influence on the results of the study. Moreover, other firm characteristics may also play different roles in corporate sustainable innovation persistence in emerging countries, and future research should focus on this issue.

Author contribution **Ning Li:** Conceptualization, Data curation, Methodology, **Junwen Feng:** Writing—original draft, Data curation, **Ce Zhang:** Visualization, supervision, editing, Writing—review & editing, and software.

Funding This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability The data can be available on request.

Declarations

Ethical approval and consent to participate The authors declare that they have no known competing financial interests or personal relationships that seem to affect the work reported in this article. We declare that we have no human participants, human data or human tissues.

Consent for publication N/A.

Competing interest The authors declare no conflict of interest.

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