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An empirical study on the impact of tax incentives on technological innovation in energy conservation and environmental protection industry

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Abstract: With the sustained and rapid development of China's economy, the extensive economic development mode has brought irreparable ecological and environmental problems, environmental pollution and resource scarcity have become increasingly prominent, and accelerating the construction of a green society and promoting sustainable and high-quality development are a major policy vision of China in recent years. The healthy development of the energy conservation and environmental protection industry can not only drive economic growth, but also promote the green transformation of the economic structure. Economic transformation and upgrading has put forward higher requirements for enterprises, and enterprises should accelerate technological upgrading and improve innovation capabilities. This paper selects the relevant data of 236 listed companies on energy conservation and environmental protection from 2011 to 2020, and uses multiple regression model to analyze the impact of tax incentives on the technological innovation of listed companies in energy conservation and environmental protection.

1. Introduction

With the sustained and rapid economic development and the acceleration of the industrialization process, China began to show environmental pollution and lack of resources and other environmental resource problems. The current total carbon emissions in China is still the world's first, China's industry has not yet gotten rid of the "high consumption, high emissions" development model dilemma, so China needs to find a new development model suitable for China's industrial economy.

2. Literature review

2.1. The development of energy conservation and environmental protection industry

Wang Penghui (2019)[1] believes that China's energy conservation and environmental protection industry has indeed developed rapidly in recent years, but at the same time, there are also some

problems, including strong policy dependence, weak scientific and technological support, and difficult financing. Mcewen T (2016)[2] argues that the development of the industry is largely due to government incentives, and proposes to focus on incentivizing small and medium-sized enterprises in the industry.

2.2. The impact of preferential tax policies on enterprise technological innovation

Dong Liming et al. (2020)[3] selected the communication industry as the research object, Alvarez-Ayuso, Kao, and Romero-Jordan (2018)[4] used panel data from Spanish manufacturing companies from 1990 to 2009 to build an empirical model, and found that tax credits are more effective in promoting long-term R&D investment.

3. Study design

3.1. Theoretical assumptions

Preferential tax policies can reduce the R&D costs of enterprises, increase the expected returns, correct the externalities of technological innovation, and reduce the R&D risks of enterprises, so they can increase their R&D and innovation investment.

H1: Preferential tax policies will have a positive incentive effect on the innovation investment of energy conservation and environmental protection enterprises.

H2: There is a difference in the impact of tax incentives on the investment of R&D funds and R&D personnel.

Many enterprises do not make substantive innovations when they enjoy the state's preferential tax policies, and may only adopt catering innovation in order to obtain national financial support, that is, they only increase R&D investment, but they may not be able to achieve the output of patent achievements, or produce utility model patents and designs that are not of high innovation quality.

H3a: Preferential tax policies will have a positive incentive effect on the innovation output of enterprises.

H3b: Preferential tax policies have no significant impact on firms' innovation output.

In order to study the impact of preferential tax policies on the core technological innovation of energy conservation and environmental protection enterprises, this paper refers to the practice of Chen Yuanyan et al. (2018)[5] and takes the number of invention patent applications as the measurement index of the core technological innovation of enterprises.

H4a: Preferential tax policies play an incentive role in the core technological innovation of energy conservation and environmental protection enterprises.

H4b: Preferential tax policies have no significant impact on the core technological innovation of energy conservation and environmental protection enterprises.

If an enterprise wants to carry out technological innovation, it first needs the input of innovation elements, and different innovation elements play different roles.

H5: Innovation input plays a mediating role in the impact of tax incentives on innovation output.

3.2. Data & Samples

The study interval was selected from 2011 to 2020. The panel data of 236 listed companies for 10 years were finally established, with a total of 2004 observations.

The original data used in this paper comes from CSMAR database and WIND database, and the missing values of individual data come from the environmental protection industry yearbook and environmental protection yearbook, and some indicators are calculated and sorted out.

3.3. Model settings

3.3.1. A model of the impact of tax incentives on firms' innovation investment

In order to study how tax incentives affect the investment of R&D funds and R&D personnel, a regression model was established with R&D expense investment and R&D personnel investment as the explanatory variables, and the tax return received by enterprises as the core explanatory variables1 and 2.

$$RD = \alpha_0 + \alpha_1 taxr_{it} + \alpha_2 size_{it} + \alpha_3 debt_{it} + \alpha_4 roe_{it} + \alpha_5 age_{it} + \alpha_6 profit_{it} + \varepsilon_{it} \quad (1)$$

$$Staff = \alpha_0 + \alpha_1 taxr_{it} + \alpha_2 size_{it} + \alpha_3 debt_{it} + \alpha_4 roe_{it} + \alpha_5 age_{it} + \alpha_6 profit_{it} + \varepsilon_{it} \quad (2)$$

Among them, i represents the individual energy conservation and environmental protection enterprise, i=1-267, t represents the year, and t=2012-2020.

3.3.2. A model of the impact of tax incentives on firms' innovation output

In order to study the direct impact of tax incentives on innovation output, model 3 was established, with tax incentives as the core explanatory variable and control variables added. Without examining the impact of tax incentives on the core technological innovation of enterprises, models 4 and 5 were established for comparative analysis, and the explanatory variable lnpatA is the number of invention patent applications, and lnpatB is the number of non-invention patent applications.

$$lnpatent = \alpha_0 + \alpha_1 taxr_{it} + \alpha_2 size_{it} + \alpha_3 debt_{it} + \alpha_4 roe_{it} + \alpha_5 age_{it} + \alpha_6 profit_{it} + \varepsilon_{it} \quad (3) \quad (3)$$

$$lnpatA = \alpha_0 + \alpha_1 taxr_{it} + \alpha_2 size_{it} + \alpha_3 debt_{it} + \alpha_4 roe_{it} + \alpha_5 age_{it} + \alpha_6 profit_{it} + \varepsilon_{it} \quad (4) \quad (4)$$

$$lnpatB = \alpha_0 + \alpha_1 taxr_{it} + \alpha_2 size_{it} + \alpha_3 debt_{it} + \alpha_4 roe_{it} + \alpha_5 age_{it} + \alpha_6 profit_{it} + \varepsilon_{it} \quad (5) \quad (5)$$

3.3.3. Mediation effect test model

In order to test whether R&D capital investment and R&D personnel investment play a mediating role in the impact of tax incentives on innovation output, a model was established by using both tax incentives (taxr) and R&D capital investment (RD) as explanatory variable6，(staff) as an explanatory variable7 to test the mediating effect of R&D capital investment and personnel investment, respectively.

$$lnpatent = \alpha_0 + \alpha_1 taxr_{it} + \alpha_2 lnrd_{it} + \alpha_2 size_{it} + \alpha_3 debt_{it} + \alpha_4 roe_{it} + \alpha_5 age_{it} + \alpha_6 profit_{it} + \varepsilon_{it} \quad (6) \quad (6)$$

$$lnpatent = \alpha_0 + \alpha_1 taxr_{it} + \alpha_2 lnstaff_{it} + \alpha_2 size_{it} + \alpha_3 debt_{it} + \alpha_4 roe_{it} + \alpha_5 age_{it} + \alpha_6 profit_{it} + \varepsilon_{it} \quad (7) \quad (7)$$

4. Empirical results and analysis

4.1. Descriptive statistics of variables

Table 1: Statistical characteristics

Variable	Number of samples	Mean	Standard deviation	Minimum	Maximum
R&D capital investment	2,004	2.020e+08	7.270e+08	83448	1.200e+10
lnR&D capital investment	2,004	17.78	1.475	11.33	23.24
R&D personnel input	2,004	334.4	990.6	0	18014
lnR&D personnel input	2,004	3.684	2.717	0	9.799
Total number of patent applications	2,004	77.40	304.5	0	5724
lnTotal number of patent applications	2,004	3.142	1.498	0	8.653
Number of invention patent applications	2,004	34.22	159.0	0	3312
lnNumber of invention patent applications	2,004	2.241	1.431	0	8.106
Tax rebates	2,004	5.300e+07	1.460e+08	0	2.000e+09
lnTax rebates	2,004	13.83	6.160	0	21.43
Debt-to-asset ratio	2,004	0.434	0.206	0	1.282
The size of the enterprise	2,004	22.21	1.246	19.01	26.95
Gross margin	2,004	0.270	0.127	-0.409	0.753
Return on equity	2,004	0.0534	0.154	-2.790	0.425
The age of the business	2,004	2.764	0.360	0.909	3.624

The descriptive statistics of related variables are shown in Table 1.

4.2. Correlation analysis

In order to test whether there are multicollinearity and correlation problems between variables, Pearson correlation analysis is performed on the variables, and the results are shown in Table 2. The absolute values of all the correlation coefficients are less than 0.5, so the control variables are more independent, there is no serious collinearity, and the mutual interference is small.

Table 2: Results of correlation analysis

	Lnrd	Lnstaff	Lnpatent	Taxr	Debt	Lnsize	Lnsize	Roe	Lnage
Lnrd	1								
Lnstaff	0.394***	1							
Lnpatent	0.651***	0.315***	1						
Taxr	0.334***	0.262***	0.313***	1					
Debt	0.190***	0.058***	0.160***	0.086***	1				
Profit	0.606***	0.331***	0.515***	0.349***	0.408***	1			
Lnsize	-0.214***	-0.060***	-0.093***	-0.043*	-0.265***	-0.265***	1		
Roe	0.087***	-0.068***	0.093***	0.047**	-0.047**	0.0370	0.306***	1	
Lnage	0.125***	0.429***	0.098***	0.190***	0.080***	0.254***	-0.075***	-0.057**	1

4.3. Regression results and analysis

4.3.1. Benchmark regression analysis

Table 3: Full-sample regression results

	Input model		Output model		
Variable	R&D funding input	R&D personnel input	Patent application total	Number of invention patent applications	Number of non-invention patent applications
Tax incentives	0.00874***	0.0173	0.0118**	0.00507	0.0162***
	(2.60)	(1.60)	(2.19)	(1.04)	(2.84)

Debt-to-asset ratio	0.0198	0.0680	-0.0796	-0.130	-0.0575
	(0.23)	(0.25)	(-0.59)	(-1.06)	(-0.40)
The size of the enterprise	0.739***	0.889***	0.607***	0.512***	0.561***
	(22.28)	(8.23)	(11.47)	(10.65)	(9.95)
Gross margin	0.449**	2.185***	0.103	0.168	0.0287
	(2.18)	(3.30)	(0.31)	(0.56)	(0.08)
Return on equity	0.315***	-0.415	0.395**	0.102	0.561***
	(3.24)	(-1.35)	(2.54)	(0.72)	(3.40)
The age of the business	0.571***	9.393***	0.231	0.402***	0.0744
	(6.05)	(28.39)	(1.53)	(2.94)	(0.46)
Constant	-0.474	-42.91***	-11.17***	-10.30***	-10.29***
	(-0.82)	(-22.85)	(-12.03)	(-12.23)	(-10.42)
Sample size	2004	1900	2004	2004	2004
r2	0.489	0.615	0.181	0.178	0.139

The regression results are shown in Table 3, from the perspective of the investment model, it can be seen that the tax return received by the enterprise can positively promote the investment of R&D funds, and it is significant at the 5% level, that is, the enterprise does not receive a unit of tax return. It will increase 0.00849 units of R&D expenditure, from the model 2, tax incentives for R&D personnel investment is also a positive effect, but not significant. From the perspective of the output-side model, the results of model 3 show that the tax refund received by enterprises can positively stimulate innovation output, with a coefficient of 0.0123 and a significance level of 5%, indicating that for every unit of tax refund received, the patent application will increase by 0.0123 units, and the incentive effect is obvious. The results of models 4 and 5 show that although tax incentives have a significant effect on the overall innovation output, they have no obvious effect on invention patents, while invention patents measure the core technological innovation capabilities of enterprises.

4.3.2. Mediator test

Firstly, the regression results of model 1, model 3 and model 6 are shown in Table 4. The results of model 3 show that tax incentives promote innovation output at the 5% significance level, indicating that there may be a mediating effect. Model 1 shows that tax incentives significantly promote R&D investment, and model 6 results show that R&D investment significantly promotes innovation output. Therefore, it can be considered that R&D investment plays a mediating effect. In model 6, when the number of patent applications is taken as the explanatory variable, and the tax incentives and R&D investment are included in the explanatory variables. But the direct effect of the value is smaller than that of model 2, indicating that the R&D investment plays a partial mediating role.

Table 4: Results of the intermediary role of R&D investment

	Model (1).	Model (3).	Model (6).
Variable	R&D capital investment	Number of patent applications	Number of patent applications
Tax incentives	0.00874***	0.0118**	0.0105*
	(2.60)	(2.19)	(1.95)
R&D capital investment			0.146***
			(3.85)
Debt-to-asset ratio	0.0198	-0.0796	-0.0825
	(0.23)	(-0.59)	(-0.61)
The size of the enterprise	0.739***	0.607***	0.500***
	(22.28)	(11.47)	(8.36)
Gross margin	0.449**	0.103	0.0374
	(2.18)	(0.31)	(0.11)
Return on equity	0.315***	0.395**	0.349**
	(3.24)	(2.54)	(2.25)
The age of the business	0.571***	0.231	0.148

	(6.05)	(1.53)	(0.97)
Constant terms	-0.474	-11.17***	-11.10***
	(-0.82)	(-12.03)	(-12.00)
Sample size	2004	2004	2004
r2	0.489	0.181	0.188

Secondly, the mediating effect of R&D personnel investment is examined, and the regression results of model 2, model 3 and model 7 are shown in Table 5, and the results of model 2 show that tax incentives are positive incentives for R&D personnel investment, but they are not significant, although model 7 shows that R&D personnel investment can significantly promote innovation output, but it cannot constitute a mediating effect.

Table 5: The mediating role of R&D personnel input

	Model (2).	Model (3).	Model (7).
Variable	R&D personnel input	Number of patent applications	Number of patent applications
Tax incentives	0.0173	0.0123**	0.0111**
	(1.60)	(2.22)	(2.01)
R&D personnel input			0.0715***
			(5.72)
Debt-to-asset ratio	0.0680	-0.0269	-0.0317
	(0.25)	(-0.19)	(-0.23)
The size of the enterprise	0.889***	0.603***	0.539***
	(8.23)	(10.86)	(9.62)
Gross margin	2.185***	0.149	-0.00721
	(3.30)	(0.44)	(-0.02)
Return on equity	-0.415	0.404**	0.434***
	(-1.35)	(2.55)	(2.76)
The age of the business	9.393***	0.115	-0.557***
	(28.39)	(0.68)	(-2.71)
Constant terms	-42.91***	-10.78***	-7.715***
	(-22.85)	(-11.18)	(-7.04)
Sample size	1900	1900	1900
r2	0.615	0.159	0.175

4.4. Robustness test

This subsection tests the robustness and reliability of the results by shortening the panel time length and setting the equilibrium panel. The results of the robustness test are shown in Table 6, and the test results are consistent with the regression results above, indicating that the main conclusions of this paper are robust.

Table 6: Results of the whole-sample robustness test

	Model 1	Model 2	Model 3	Model 4	Model 5
Variable	R&D capital investment	R&D personnel input	Total number of patent applications	Number of invention patent applications	Number of non-invention patent applications
Tax incentives	0.00906***	0.0340*	0.0128*	0.00307	0.0249***
	(2.69)	(2.38)	(1.84)	(0.47)	(3.23)
Debt-to-asset ratio	0.0987	-0.468	-0.0458	0.00311	-0.138
	(1.20)	(-1.34)	(-0.27)	(0.02)	(-0.73)
The size of the enterprise	0.660***	0.942***	0.598***	0.477***	0.531***
	(19.31)	(6.49)	(8.46)	(7.21)	(6.81)
Gross margin	-0.0993	1.443*	0.307	0.176	0.404
	(-0.49)	(1.68)	(0.73)	(0.45)	(0.87)
Return on equity	0.0274	-0.314	0.379*	0.127	0.581***
	(0.29)	(-0.79)	(1.95)	(0.70)	(2.72)

The age of the business	0.686***	7.671***	-0.525**	-0.0709	-0.723***
	(5.84)	(15.36)	(-2.16)	(-0.31)	(-2.69)
Constant terms	1.173*	-38.82***	-8.806***	-8.133***	-7.481***
	(1.94)	(-15.11)	(-7.04)	(-6.94)	(-5.42)
Sample size	1267	1267	1267	1267	1267
r2	0.517	0.436	0.104	0.0836	0.0848

4.5. Further analysis

4.5.1. Regression by regional grouping

The sample enterprises are grouped according to their regions, divided into eastern and non-eastern regions. According to the model constructed above, sub-sample regression was performed from the input side and the output side respectively. The results are shown in Table 7: (1) Whether it is the impact on innovation input or innovation output, the tax incentives have a more significant incentive effect in the non-eastern region, with a significance level of 10%, but no obvious effect on the eastern region. (2) For different energy-saving and environmental protection enterprises in different regions, the return on net assets, the age of the enterprise, the asset-liability ratio and the scale of the enterprise will have an impact on R&D investment and innovation output, but the impact is different.

Table 7: Regression results by regional grouping

	Input model				Output model	
Variable	R&D capital investment		R&D personnel input		Number of patent applications	
	Eastern	Non-Eastern	Eastern	Non-Eastern	Eastern	Non-Eastern
Tax incentives	0.00562	0.00984*	0.00750	0.0342*	0.00543	0.0172*
	(1.32)	(1.74)	(0.54)	(1.96)	(0.79)	(1.96)
Debt-to-asset ratio	-0.112	0.368**	0.0327	0.0861	-0.119	0.151
	(-1.16)	(2.14)	(0.10)	(0.17)	(-0.77)	(0.56)
The size of the enterprise	0.755***	0.747***	1.038***	0.261	0.545***	0.981***
	(20.92)	(9.15)	(8.59)	(1.05)	(9.39)	(7.74)
Gross margin	0.469*	0.226	3.221***	0.591	0.912**	-1.533***
	(1.85)	(0.63)	(3.87)	(0.54)	(2.23)	(-2.74)
Return on equity	0.0139	0.682***	-0.502	-0.244	-0.00794	1.033***
	(0.11)	(4.26)	(-1.24)	(-0.50)	(-0.04)	(4.16)
The age of the business	0.501***	0.682***	9.041***	11.09***	0.458***	-0.782**
	(4.83)	(3.06)	(24.23)	(15.30)	(2.74)	(-2.26)
Constant terms	-0.423	-1.364	-45.14***	-34.17***	-10.43***	-16.52***
	(-0.67)	(-0.97)	(-21.41)	(-8.09)	(-10.20)	(-7.60)
Sample size	1470	534	1470	534	1470	534
r2	0.510	0.454	0.623	0.606	0.185	0.220

4.5.2. Sub-equity nature grouping regression

According to the different property rights of energy conservation and environmental protection enterprises, the sample enterprises were divided into state-owned and non-state-owned enterprise groups, among which the non-state-owned enterprise group included foreign-funded, private and other enterprises, accounting for the majority. The results of the regression analysis of the input and output models are shown in Table 8: (1) From the perspective of innovation input, tax incentives have a significant positive correlation with the R&D investment of non-SOEs, with a significance level of 5%, but have no obvious effect on SOEs. The impact of tax incentives on R&D personnel investment has a significant 5% promotion effect in state-owned enterprises, but has no significant effect on non-

state-owned enterprises. (2) From the perspective of innovation output, whether state-owned enterprises or non-state-owned enterprises, the innovation output of energy-saving and environmental protection enterprises is positively correlated with tax incentives, but the tax incentive effect on non-state-owned enterprises is better and more significant.

Table 8: Regression results of grouping by equity nature

	Input model				Output model	
Variable	R&D capital investment		R&D personnel input		Number of patent applications	
	State-owned enterprises	Non-State Enterprises	State-owned enterprises	Non-State Enterprises	State-owned enterprises	Non-State Enterprises
Tax incentives	0.00927	0.00846**	0.0422**	0.0134	0.0148	0.0114*
	(1.36)	(2.25)	(1.98)	(1.18)	(1.62)	(1.71)
Debt-to-asset ratio	0.237	-0.100	0.179	-0.0872	0.165	-0.211
	(1.54)	(-1.02)	(0.36)	(-0.28)	(0.80)	(-1.21)
The size of the enterprise	0.869***	0.724***	0.888***	1.014***	0.741***	0.582***
	(11.72)	(20.21)	(3.64)	(8.74)	(7.44)	(9.16)
Return on equity	1.645***	-0.0789	3.500**	1.862***	-0.437	0.259
	(3.47)	(-0.36)	(2.22)	(2.67)	(-0.69)	(0.66)
Gross margin	0.613***	0.0114	-1.987***	-0.0713	0.426	0.385**
	(3.04)	(0.10)	(-2.88)	(-0.21)	(1.57)	(1.98)
The age of the business	0.859***	0.369***	11.87***	8.281***	0.265	0.207
	(4.41)	(3.54)	(17.93)	(22.45)	(1.01)	(1.12)
Constant terms	-4.897***	0.718	-52.38***	-41.70***	-14.50***	-10.47***
	(-3.52)	(1.17)	(-11.32)	(-21.42)	(-7.75)	(-9.66)
Sample size	628	1376	628	1376	628	1376
r2	0.480	0.524	0.605	0.643	0.211	0.175

5. Conclusions

First, preferential tax policies will significantly promote R&D investment in energy conservation and environmental protection industries. Second, the preferential tax policy will significantly promote the level of innovation output of the energy conservation and environmental protection industry, and the tax incentives have not significantly promoted the improvement of the core technical capabilities of enterprises. Third, R&D investment has a partial mediating effect in the impact of tax incentives on innovation output.

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