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Environmental Regulation, Government RD Investmentand Green Technology Innovation Performance in theYangtze River Economic Belt

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Keywords: Environmental regulation; government R&D investment; green technology innovation performance in the Yangtze River Economic Zone; optimal intensity

Abstract: Based on the panel data of 11 provinces and cities in the Yangtze River Economic Belt from 2008 to 2018, this paper uses the SBM model that considers undesired output to measure and analyze the impact of environmental regulations and government R&D investment on the performance of green technology innovation in the Yangtze River Economic Belt, and uses the panel threshold model. Analyze the optimal intensity interval of environmental regulations and government R&D investment. The research found that: (1) In the process of green technology innovation in the Yangtze River Economic Belt, environmental regulations and government R&D investment can promote innovation performance; (2) Environmental regulations and government R&D investment have a significant threshold for green technology innovation performance, and The optimal range of government R&D investment intensity is above 0.078, and the optimal intensity of environmental regulation is above 0.0013.

1. Introduction

The frequent occurrence of smog in China in recent years reflects the severity of the country's environmental problems and ecological fragility. According to the 2018 Global Environmental Performance Index released by Yale University, China ranks 120th out of 180 countries in the environmental performance index. According to the Plan for Ecological and Environmental Protection of the Yangtze Economic Belt, the Yangtze Economic Belt has a large and intensive total pollution discharge, accounting for more than 40% of the country's total waste water discharge, and the intensity of chemical oxygen demand, sulfur dioxide and nitrogen oxide emissions per unit area is 1.5 to 2.0 times the national average level. Serious environmental pollution has not only caused serious impact on the health and life of residents, but also caused huge economic losses to people's normal life. Central and local governments at all levels have realized the importance of the ecological environment, in January 2016, xi jinping, general secretary of the symposium was held in chongqing Yangtze river economic belt development, emphasis on promoting the development of the Yangtze river economic belt, must consider the long-term interests of the Chinese nation, ecological priority, walk the path of green development, the repair of the Yangtze river ecological environment in the down position, catch big protection, no development. To keep the mother's river alive forever. However, in reality, the policy of "neither" nor "this" is not only unable to achieve a win-win situation between "environment" and "economy", but also will become a hindrance to economic development and reduce the space for environmental protection. In this context, with the continuous improvement of environmental protection technology as the goal, the innovation of green technology is not only the first force of development, but also an inevitable choice for the sustainable green development of the Yangtze River.

Green technology innovation is the motive force of sustainable development of the Yangtze river economic belt, technology innovation has significant externalities, would result in a monopoly and information asymmetry of R&D resources such as "market failure" phenomenon exists, and the government R&D input to a certain extent, to rectify the externality of green technology innovation, and become the important means of green technology innovation support area [1]. The government tries to realize the "win-win" between regional economic growth and environmental protection, and the key is to find the optimal intensity interval of government R&D investment and environmental regulation. In other words, moderate environmental regulation has induced effect on government R&D investment, and thus has "innovation compensation effect" on regional green technology innovation. Therefore, to ensure the optimization of environmental regulation and government R&D investment has become the key to improve the performance of green technology innovation in the Yangtze River Economic Belt.

2. Review of relevant studies

Green innovation is also known as "environmental innovation" and "sustainable innovation". At present, scholars at home and abroad have not reached a unified conclusion on the impact of environmental regulation on technological innovation. There are three viewpoints as follows: first, environmental regulation promotes technological innovation. Porter(1991,1995) [2, 3] proposed the famous "Porter hypothesis", arguing that appropriate environmental rules can encourage enterprises to encourage technological innovation through the compensatory role of innovation, thus offsetting the extra cost brought by environmental rules and improving the competitiveness of enterprises. Jaffe(1997) [4] and Johnstone[5]et al. found through empirical studies that environmental regulation was indeed beneficial to enterprises' green innovation. Domestic scholars Shen Neng, Zhao Li et al. [6] also verified this view through empirical evidence. Second, environmental regulation reduces innovation performance. Environmental regulation increases enterprise operating costs, forms the "crowding out effect" on enterprise innovation resources, and reduces enterprise innovation output. Research by BECHER R A [7], STOEVER J [8] and Gray(1987 [9] believe that environmental regulations reduce the productivity of manufacturing industry. Chen Xiao [10] also showed that environmental regulation hindered the improvement of technological innovation ability through crowding out effect. Third, the impact of environmental regulation on innovation performance is uncertain, and its impact is nonlinear, rather than directly increasing or decreasing innovation output (Barbera, A.J [11] Boyd and McClelland [12]). Using the panel data of 30 provinces in China from 2005 to 2016, Yu Peng and Li Xin [13] found that with the increase of environmental regulation intensity, the technological innovation level presents an "inverted U-shaped" change, and the influence effect changes from "offset effect" to "compensation effect" as the environmental regulation intensity changes from weak to strong. Li Bo Xin [14] he Yumei [15] et al. verified this conclusion through empirical evidence.

On the impact of government R&D on innovation performance, there are three viewpoints in academic circles: first, government R&D promotes the improvement of innovation performance and has leverage effect. How and Mc Fetridge (1976) [16] put forward the theoretical analysis framework of the impact of government R&D subsidy on enterprise innovation efficiency, and pointed out that when other conditions remain unchanged, government R&D subsidy will affect the marginal cost constraint line of enterprise R&D input, improve the utilization rate of R&D input, and encourage enterprises to carry out more technological innovation activities. Liu Jibing et al. (2014) [17] used DEA method to evaluate the innovation efficiency of strategic emerging industries, explored the impact of government subsidies on their innovation output and efficiency, and found that government subsidies could significantly improve the innovation efficiency of enterprises. 2. Government R&D investment is not conducive to the improvement of innovation performance, and has crowding out effect. The investment efficiency of enterprises is higher than that of the government. Government R&D investment will increase enterprises' demand for R&D resources. In the case of inelastic supply of R&D resources, enterprises' investment will be squeezed out, thus reducing innovation efficiency (Guellec D [18], Strobl E [19], bai junhong [20]. Xiao Wen and Lin Gaobang (2014) [21] used stochastic frontier analysis method to measure the innovation efficiency of 36 industrial industries, and found that the overall average innovation efficiency of China was around 0.5, while the R&D investment of the government did not improve the innovation efficiency. Third, the impact of government R&D investment on innovation performance is uncertain, and the impact of environmental regulation on enterprise innovation is nonlinear. Ye Qingming and Wang Kunqing [22] studied the impact of government R&D investment on the innovation performance of high-tech enterprises in Shanghai from 2008 to 2011, and found that the impact of government R&D investment on the innovation performance of high-tech enterprises showed an "inverted U" shape, and the incentive effect of low and medium government funding rate on the innovation performance of enterprises was the most significant.

The "double externality" of green innovation leads to the "double market failure" of green innovation in the market, which leads to the fact that the single market force is not enough to encourage enterprises to carry out green innovation, so it is necessary for the government to regulate and encourage green innovation. According to the "Dingbergen criterion", the number of policy instruments must equal the objective of the policy [23]. Therefore, in the process of green innovation, the government should adjust the policy orientation flexibly according to different situations. Through sorting out the existing literature, it is found that most of the existing studies study the effect mechanism of environmental regulation or government R&D investment on green innovation from the perspective of a single policy, while only a few scholars study the impact of environmental regulation and government R&D investment on green innovation from the perspective of game. Guo Jie and Yang Licheng [24] used the panel data of 31 provinces and cities in China's mainland from 2009 to 2017 to explore the impact of environmental regulation and government R&D funding on green technology innovation, and found that environmental regulation and government funding are conducive to promoting green technology innovation. Zhao Lijuan (2019) [1] studied the impact of environmental regulation and government R&D investment on the efficiency of agricultural science and technology innovation by using the superlogarithmic SFA model based on the panel data of 30 provincial levels in China from 2004 to 2015, and found that environmental regulation and government R&D investment can promote the efficiency of agricultural science and technology innovation.

In general, the existing literature mostly considers the impact on green technology innovation from the single perspective of environmental regulation or government R&D investment. In terms of research methods, linear regression model is mostly adopted, ignoring the effect of both on innovation performance and the possible threshold effect of some factors on innovation performance. This paper breaks through the single perspective of previous research on green technology innovation performance, and explores the compound policy effect of environmental regulation and government R&D investment on green technology innovation centering on different policy means of government to prevent market failure. The SBM model to measure the Yangtze river economic belt of green technology innovation performance, and with the Yangtze river economic belt of green technology innovation performance as the research object, using the panel threshold model, the research on environmental regulation and government R&D input and nonlinear relationship of the Yangtze river economic belt of green technology innovation performance for environmental regulation and government R&D input intensity of the optimal range.

3. Research design

3.1 Research Methods

3.1.1 SBM model

DEA is a relative effectiveness evaluation method based on input-output data. Using the observed sample data, DEA has significant advantages in evaluating the relative effectiveness among the same type of decision making units with multiple inputs and multiple outputs. Because the traditional DEA model (such as CCR and BCC) is based on linear segmentation and radial theory to measure efficiency, it does not consider the problem of input-output relaxation, nor does it consider the existence of undesired output. To make up for the defects, the Tone is proposed considering the expected output of DEA - SBM models, the slack variable into the objective function, think in terms of input and output of two inefficiency situation, very good solution to the input and output slack sexual problems, and contains the expected output efficiency evaluation, and is widely applied in ecology and environment, etc. The specific model is expressed as follows:

Suppose there are N decision making units, m inputs, element x∈R^m, define x∈ (x_1,x_2... X_n) ∈ R ^ (m * n) and x_i > 0; S types of output, where s_1 expected output (element y^g∈R^s1) and s_2 unexpected output (element y^b∈R^s2) are defined as:

$$Y^g = (y_1^g, y_2^g \dots y_n^g) \in R^{S1*n}$$

$$Y^b = (y_1^b, y_2^b \dots y_n^b) \in R^{S2*n}$$

And y_i^g>0,y_i^b b>0, then the dea-sbm model can be expressed as:

$$p^* = minp = min\frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{i0}}}{1+\frac{1}{s_1+s_2}\left\{\sum_{i=1}^{s1}\frac{s_i^g}{y_{i0}^g+\sum_{i=1}^{s_2}\frac{s_i^b}{y_{i0}^b}}\right\}}$$

$$\text{s.t.}\, x_0 = X\lambda + s^-$$

$$y_0^g = Y^g\lambda - s^g$$

$$y_0^b = Y^g\lambda + s^b$$

$$\lambda \geq 0, s^- \geq 0, s^g \geq 0, s^b \geq 0 \tag{1}$$

S ^-, s^g and S ^b are the relaxation variables of input, expected output and unexpected output respectively. The objective function strictly subtracts the variables s^-, s^g, s^b, and the value of the objective function p^*∈[0,1]. When p^*=1, s^-, s^g and S ^b are all 0, indicating that the DMU is valid; When P ^*<1, it means that the DECISION-MAKING unit is invalid, and the efficiency should be improved by increasing expected output, reducing input or unexpected output.

3.1.2 Entropy weight method

Several output indexes are selected to evaluate the output benefit of green innovation. In the quantitative analysis of multiple indicators, different indicators may have different degrees of influence on the evaluation results, so the weight of each output indicator should be given accordingly. Generally speaking, index weights can be divided into subjective and objective. Considering that the evaluation of green innovation output benefits is mainly based on objective indexes and the characteristics of multiple indexes, this paper selects entropy weight method to assign weights to each output index. The so-called entropy weight method is a mathematical method to determine the weight of each index according to the amount of information provided by each index, synthesize each index and calculate a comprehensive index. Among them, the smaller the entropy value is, the greater the information provided by the index is, and the higher the index weight is. The specific calculation steps are as follows:

1. Calculate the characteristic proportion p_ij of the ith evaluation object under the JTH index of the object to be evaluated:

$$p_{ij} = \frac{v_{ij}}{\sum_{i=1}^{m} v_{ij}} \tag{2}$$

$$\text{Since}0 \leq v_{ij} \leq 1{,}0 \leq v_{ij} \leq 1$$

2. The entropy value of the JTH index was calculated by using the measured characteristic proportion of the index e_{ij}:

$$e_{ij} = -\frac{1}{lnm}\sum_{i=1}^{m} p_{ij} lnp_{ij} \tag{3}$$

When $p_{ij} = 0, p_{ij} = 0, p_{ij}lnp_{ij} = 0$.

3. Calculate the entropy weight of the JTH indexw_{ij}:

$$w_{ij} = \frac{1-e_{ij}}{n-\sum_{j=1}^{n} e_{ij}} \tag{4}$$

4. Determine the comprehensive score of each evaluation objectz_i:

$$Z_i = \sum_{j=1}^{n} w_i\, v_{ij} \tag{5}$$

3.1.3 Panel threshold model

In order to better study the impact of environmental regulation and government R&D investment on green technology innovation performance, this paper adopts the panel threshold data model proposed by Hansen to analyze the nonlinear relationship between environmental regulation, government R&D investment and green technology innovation performance. Suppose the government spends on R&D μ_{it}^{grd}, Intensity of environmental regulation μ_{it}^{er} as the threshold variable, Then take double thresholds as an example to construct the regression model as follows;

$$u_{it} = \lambda_0 + \lambda \ln Z_{it} + p_1 lngrd_{it} * I(\mu_{it}^{grd} \leq \eta_1^{grd}) + p_2 lngrd_{it} * I(\eta_1^{grd} \leq \mu_{it}^{grd} \leq \eta_1^{grd}) + p_3 lngrd_{it} * I(\mu_{it}^{grd} > \eta_2^{grd}) + \varepsilon_{it} \tag{6}$$

$$u_{it} = \lambda_0 + \lambda \ln Z_{it} + \gamma_1 lner_{it} * I(\mu_{it}^{er} \leq \eta_1^{er}) + \gamma_2 lner_{it} * I(\eta_1^{er} \leq \mu_{it}^{er} \leq \eta_1^{er}) + \gamma_3 lner_{it} * I(\mu_{it}^{er} > \eta_2^{er}) + \varepsilon_{it} \tag{7}$$

Where, I stands for individual variable (I =1,2... , m), t represents the time variable (t= 1, 2, …, n), μ_{it} is the explained variable, $\ln Z_{it}$Is the explained variable with significant influenceμ_{it} Other variables, namely control variables,I(.)Is an indicator function, ε_{it}~ iddN (0, σ^2). In (3) formula, $lngrd_{it}$ is the explanatory variable affected by μ_{it}^{grd}, μ_{it}^{grd} denotes the intensity of government R&D investment, ρis the threshold variable the influence coefficient of explanatory variable μ_{it}^{grd} on explained variable μ_{it}^{er} at different intervals. $lner_{it}$ is the explanatory variable affected by μ_{it}^{er}.

3.2 Description of variable indicators

The calibre of China's statistical yearbook has been changed many times. In order to ensure the continuity of data, this data is taken from the panel data of all provinces and cities from 2008 to 2018. Considering the time lag of research and development, the lag period is taken as one year. The data used are from China Statistical Yearbook, China Science and Technology Statistical Yearbook and statistical yearbooks of provinces and cities.

Input-output factors should be determined when measuring the green technology innovation performance of the Yangtze River Economic Belt. In this paper, 11 provinces and cities of the Yangtze River Economic Belt are selected as the decision-making units, and the input-output indexes are shown in the following table.

Table 1 Performance evaluation index system of green Technology Innovation

Level indicators	**Target classification**	**The secondary indicators**	**The data source**
Investment in green technology innovation	Human input	The r&d staff is full time equivalent	China Science and Technology Statistical Yearbook
	Capital investment	Internal expenditure of R&D funds	China Science and Technology Statistical Yearbook
		New product development funds	China Science and Technology Statistical Yearbook
	The energy input	Total industrial energy consumption	China Statistical Yearbook
Green technology innovation output	Economic benefits	Number of valid invention patents	China Science and Technology Statistical Yearbook
		New product sales revenue	China Science and Technology Statistical Yearbook
		Industrial added value	China Statistical Yearbook
	Environmental benefits	Industrial wastewater discharge	Statistical yearbook of provinces and cities
		Industrial exhaust emission	Statistical yearbook of provinces and cities
		Industrial solid waste discharge	Statistical yearbook of provinces and cities

Among them, green technology innovation input from human resources, capital, energy three aspects selected six secondary indicators, green innovation output from economic benefits and environmental benefits selected six secondary indicators. Among them, the input indicator personnel input adopts the index of "r&d personnel equivalent to full time equivalent". Capital investment is subject to the two indexes of "internal expenditure on R&D" and "expenditure on new product development", and energy input is subject to the index of "total industrial energy consumption". For economic benefit, the three indicators are "number of effective invention patents", "sales revenue of new products" and "industrial added value"; for environmental benefit, the three indicators are "industrial wastewater discharge", "industrial waste gas discharge" and "industrial solid waste discharge".

3.2.1 Selection of factors influencing performance of green technology innovation

(1) Explanatory variables

Government R&D input: "GRD of internal expenditure on R&D" is selected to measure the intensity of government R&D input.

Environmental regulation (ER): Measured by the proportion of environmental pollution control investment in industrial output value.

(2) Control variables: By referring to several literatures and considering that the influencing factors cannot include the input factors of green technology innovation performance, the following variables are selected here;

Enterprise Size (SCA): Schumpeter assumed that the high risk and high investment of RESEARCH and development activities determined that only large enterprises had the ability to innovate. Expressed by the natural logarithm of the sales revenue of enterprise products;

Ownership structure (OWN): Measured by the proportion of state-owned industrial sales value in the industrial sales value of the industry;

Economic openness: expressed in terms of per capita foreign direct investment;

Regional development level (DEV): measured by regional PER capita GDP. In order to reduce endogenous problems caused by adverse causality, the indicator is treated one time later.

Human capital level (LUM): Measured in logarithms of the years of education per capita in each region;

Innovation environment (ENV): Measured by the annual technology market turnover of each region.

4. Empirical analysis

4.1 Measurement and analysis of green technology innovation performance in the Yangtze River Economic Belt

This paper calculates the green technology innovation performance of the Yangtze River Economic Belt from 2008 to 2018 according to the SBM model. The measurement results are shown in Table 2. The mean value of the Yangtze River Economic Belt and the mean value of the upper, middle and lower reaches are shown in Figure 3. The green innovation performance of the lower reaches of the Yangtze River Economic Belt is higher than the population average, while that of the upper and middle reaches is lower than the population average. The level of green innovation performance shows a trend of polarization among regions. Selecting the first and last years, 2008, 2018 and the middle years, 2013 as the representative years (FIG.4), it is concluded that the green technology innovation performance of the Yangtze River Economic Belt in 2013 increased by 18.4% compared with that of 2008, among which the upper, middle and lower reaches increased by 15.8%, 20.4% and 18.7% respectively. The green technology innovation performance of the Yangtze River Economic Belt will grow by 22.5% in 2018 compared with 2013, with the upper, middle and lower reaches growing by 22.4%, 32.1% and 18.6%, respectively. The reasons are as follows: the downstream region has strong economic foundation, developed technological level, good innovation environment and superior green innovation development conditions, but the coordination between resources, technology and environment is not optimistic. In the middle reaches, resource endowment advantages and national policies are prominent. Meanwhile, it has a good industrial foundation and relatively large investment in innovation, so the innovation performance level is significantly improved. Due to good resource conditions, the upstream region is limited by slow industrial development and lack of scientific and technological human resources and advanced technologies, which leads to insufficient vitality for green development and slow improvement of performance level.

Table 2 Green technology innovation performance of the Yangtze Rive Economic Belt

Green technology innovation performance	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
Shanghai	0.424	0.801	1.000	0.356	0.316	0.558	0.644	0.398	0.502	0.515	0.602	0.556
jiangsu	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
zhejiang	0.439	0.370	0.355	0.617	0.467	0.707	0.700	0.971	0.965	0.823	0.885	0.664
Anhui	0.261	0.262	0.270	0.189	0.209	0.243	0.237	0.191	0.223	0.245	0.216	0.231
jiangxi	0.219	0.199	0.192	0.161	0.174	0.266	0.230	0.191	0.203	0.225	0.248	0.210
Hubei	0.438	0.351	0.269	0.194	0.231	0.327	0.251	0.182	0.200	0.214	0.254	0.265
Hunan	0.220	0.392	0.308	0.235	0.274	0.367	0.339	0.313	0.320	0.325	0.346	0.313
Chongqing	0.245	0.212	0.236	0.261	0.285	0.404	0.338	0.281	0.326	0.313	0.334	0.294
Sichuan	0.207	0.209	0.198	0.273	0.284	0.380	0.290	0.265	0.283	0.289	0.238	0.265
Yunnan	0.228	0.278	0.216	0.180	0.222	0.280	0.263	0.229	0.183	0.195	0.204	0.225
Guizhou	0.663	0.642	0.495	0.383	0.364	0.376	0.279	0.262	0.301	0.284	0.292	0.395
The mean	0.395	0.429	0.413	0.350	0.348	0.446	0.416	0.389	0.410	0.403	0.420	0.402
Upstream of the mean	0.336	0.335	0.286	0.274	0.289	0.360	0.293	0.259	0.273	0.270	0.267	0.295
Middle mean	0.292	0.314	0.256	0.197	0.226	0.320	0.273	0.229	0.241	0.255	0.283	0.262
Downstream of the mean	0.531	0.608	0.656	0.541	0.498	0.627	0.645	0.640	0.673	0.646	0.676	0.613

4.2 Correlation analysis

Table 3 shows the correlation test of panel data of 11 provinces and cities in the Yangtze River Economic Belt from 2008 to 2018. It can be found from Table 3 that government R&D investment, environmental regulation and green technology innovation performance are positively correlated, and significant at the level of 0.01, indicating that government R&D investment and environmental regulation play a promoting role in improving the green innovation performance of the Yangtze River Economic Belt. In the control variables, enterprise size, openness, development level, human capital level and innovation environment are positively correlated with green technology performance, indicating that the larger the enterprise size, openness, development level, human capital level and innovation environment are, the higher the green technology innovation performance will be. The ownership structure passed the significance test, but the coefficient was -0.5122, indicating that private enterprises are more conducive to the improvement of green technology innovation performance.

The above analysis shows that government R&D investment and environmental regulation can promote the improvement of green technology innovation performance in the Yangtze River Economic Belt to a certain extent. Then, is there a reasonable intensity interval between government R&D investment and environmental regulation that can give full play to their positive effects on the green technology innovation performance of the Yangtze River Economic Belt? For this reason, this article will test respectively using panel threshold model both for the Yangtze river economic belt affect the threshold effect of green technology innovation performance, and further discuss the characteristic of the threshold effect, according to the threshold value analysis to determine the government R&D input intensity and environmental regulation intensity of the optimal range, to the administrative department of the government and related scientific and effective agricultural science and technology innovation efficiency policy provide decision-making reference.

*Table 3 Correlation analysis (note: *, **, and *** are significant at 0.1, 0.05, and 0.001, respectively)*

	per	grd	er	sca	own	open	dev	lum	env
per	1.00								
grd	0.21***	1.00							
er	0.63***	0.22**	1.00						
sca	0.74***	0.32***	0.66***	1.00					
own	-0.34***	-0.19**	-0.36***	-0.67***	1.00				
open	0.66***	0.30***	0.36***	0.45***	-0.38***	1.00			
dev	0.59***	0.61***	0.52***	0.61***	-0.41***	0.72***	1.00		
lum	0.34***	0.57***	0.31***	0.39***	-0.40***	0.67***	0.84***	1.00	
env	0.33***	0.75***	0.34***	0.52***	-0.25***	0.37***	0.76***	0.67***	1.00

4.3 Threshold model test and empirical results analysis

4.3.1. The threshold test

First check whether there is a threshold and the number of thresholds. After 360 sampling, the F value and P value are obtained. The test results are shown in Table 4. It can be seen from Table 4 that the single-threshold effects of explanatory variables grd and er passed the significance test, while the double-threshold effect and the triple-threshold effect did not pass the significance test. This shows that the impact of grd and er on the performance of green technology innovation in the Yangtze River Economic Zone does have a threshold effect. Among them, the explanatory variable grd has a single threshold effect on the green technology innovation performance of the Yangtze River Economic Zone, and the explanatory variable er also has a single threshold effect.

*Table 4 Threshold effect test (Note: *, **, ** indicate the significance level of 10%, 5% and 1% respectively)*

	per	grd	er	sca	own	open	dev	lum	env
per	1.00								
grd	0.21***	1.00							
er	0.63***	0.22**	1.00						
sca	0.74***	0.32***	0.66***	1.00					
own	-0.34***	-0.19**	-0.36***	-0.67***	1.00				
open	0.66***	0.30***	0.36***	0.45***	-0.38***	1.00			
dev	0.59***	0.61***	0.52***	0.61***	-0.41***	0.72***	1.00		
lum	0.34***	0.57***	0.31***	0.39***	-0.40***	0.67***	0.84***	1.00	
env	0.33***	0.75***	0.34***	0.52***	-0.25***	0.37***	0.76***	0.67***	1.00

4.3.2 Threshold value estimation and test

After the threshold effect test, the threshold value needs to be estimated and tested. Table 5 lists the threshold estimated values and 95% confidence intervals of the two threshold models. It can be seen from Table 5 that the estimated threshold value of explanatory variable GRD is 0.078, which is within the null hypothesis acceptance domain, indicating that in the panel threshold model of explanatory variable GRD, the threshold value is equal to the actual estimated value. The threshold value corresponding to explanatory variable ER is 0.0013. In the threshold model of explanatory variable ER, the threshold value is equal to the actual estimated value.

Table 5 Threshold regression results

variable	The threshold value one		The threshold value two		The threshold value three	
	The estimate	95% confidence interval	The estimate	95% confidence interval	The estimate	95% confidence interval
grd	0.0788	[0.0745,0.0807]	-	-	-	
er	0.0013	[0.00130.0015]	-	-	-	-

4.3.3 Parameter estimation and empirical results analysis

In this paper, the intensity of government R&D input is taken as the threshold variable to estimate the panel threshold model of each explanatory variable. The estimated results are shown in Table 6.

It can be seen from Figure 8 that the impact of government R&D investment on the green technology innovation performance of the Yangtze River Economic Belt has a threshold. Only when the intensity of government R&D investment is in a reasonable range can the government R&D investment fully play its role in promoting the green technology innovation performance of the Yangtze River Economic Belt. When the intensity of government R&D input is lower than the threshold value of 0.0788, the impact coefficient of government R&D input on the innovation performance of green technologies in the Yangtze River Economic Belt is 0.03, indicating that government R&D input has a positive impact on innovation performance. For every 1% increase in government R&D input, innovation performance increases by 0.03%. When the intensity of government R&D investment crosses the threshold value of 0.0788, the impact coefficient of government R&D investment on green innovation performance technology in the Yangtze River Economic Belt is 0.52%, and the promotion effect of government R&D investment on green technology innovation performance is greatly enhanced. Therefore, the impact of government R&D investment on innovation performance depends on the intensity of government R&D investment, and when the intensity is greater than the threshold value, the promotion effect of government R&D investment on innovation efficiency is constantly enhanced. The reason is that the regional green technology innovation performance has great externality and risk, there is phenomenon of "market failure", the private sector is not willing to provide to the government as a powerful backing to R&D input, to provide necessary financial support for regional development, increase government R&D input intensity will also motivate enterprise R&D resources, has the leverage effect, makes the government R&D funds play a role of "four two dial one thousand jin", thus improve the Yangtze river economic belt of green technology innovation performance, to achieve maximum economic benefits.

Figure 6 Panel threshold model estimation results of government R&D input

variable	**The coefficient of**	**Standard error of**	**T statistic**	**P values**	95% confidence interval
er	10.09	25.36	0.4	0.691	[-40.24,60.43]
sca	3.34	3.61	0.09	0.926	[6.82,7.47]
own	0.194	0.29	0.67	0.504	[-0.381,0.77]
open	0.687	0.59	1.16	0.249	[0.487,1.856]
dev	12.31	2.95	2.61	0.011	[2.95,21.60]
lum	-0.046	0.055	-0.84	0.404	[-0.156,0.0634]

env	-0.0001	0.0009	-1.98	0.051	[-0.0003,0.001]
grd(u≤0.0788)	-0.033	0.05	-0.63	0.528	[-0.138,0.071]
grd(u＞0.0789)	-0.522	0.05	-1.09	0.279	[-0.162,0.047]

The table 7 shows that environment plays a significant role in regulation of the Yangtze river economic belt of green technology innovation performance threshold, from the point of test results, the intensity of environmental regulation in any interval, environmental regulation of agricultural science and technology innovation has a positive role in promoting efficiency, this has to do with the concept "porter hypothesis" content is consistent, namely the appropriate environmental regulation will stimulate technological innovation. When the intensity of environmental regulation is lower than the threshold value of 0.0013, environmental regulation has a significant positive impact on the efficiency of agricultural science and technology innovation, with an impact coefficient of 0.0042. When the environmental regulation intensity crosses the threshold value of 0.0013, the influence coefficient is 0.054, and the promoting effect of environmental regulation on the innovation efficiency of agricultural science and technology is enhanced. From the above analysis, it can be seen that with the increase of environmental regulation intensity, the promoting effect of environmental regulation on the green technology innovation performance of the Yangtze River Economic Belt is gradually increasing. The reason lies in: under the environmental regulation, the government aims to realize the optimization of economic benefit and social benefit. On the one hand, the government controls environmental pollution, improves ecological environment and maximizes social benefits through environmental regulation and related policies. Green technological innovation, on the other hand, the R&D funds mainly come from government department, the environmental regulation intensity reaches the critical value, the government will finance R&D funding for green technology innovation, increase investment in science and technology, promoting regional green technology innovation, improve the regional product international competitiveness, thus maximizing economic benefit.

Figure 7 Panel threshold model estimates for environmental regulation

variable	The coefficient of	Standard error of	T statistic	P values	95% confidence interval
grd	8.34	4.05	2.06	0.043	[2.75,8.29]
sca	-8.13	3.55	-2.27	0.025	[-15.12,-10.32]
own	-0.58	0.25	-2.26	0.026	[-1.08, -0.071]
open	-0.431	0.63	-0.68	0.496	[-1.68,0.82]
dev	24.31	4.49	0.54	0.587	[6.47,11.30]
lum	0.079	0.056	1.42	0.16	[-0.031,0.190]
env	0.0009	0.0009	0.98	0.329	[-0.001,0.002]
er(u≤0.0013)	0.042	0.052	0.82	0.41	[-0.06,0.146]
er(u＞0.0013)	0.054	0.055	0.96	0.33	[-0.056,0.163]

Comprehensive analysis of the government in helping to bring about the Yangtze river economic belt of green technology innovation performance threshold characteristics of R&D input and environmental regulation, this paper argues that 11 provinces and cities in the Yangtze river economic belt will now government R&D input intensity, the optimal interval is set to 0.0788 above, the strength of the environmental regulation, the optimal range of 0.0013 above, can promote the growth of the Yangtze river economic belt of green technology innovation performance.

5. Research conclusions and policy recommendations

5.1 Research Conclusion

In order to better study the impact of environmental regulation and government R&D investment on the green technology innovation performance of the Yangtze River Economic Belt, this paper selects 11 provincial panel data of the Yangtze River Economic Belt from 2008 to 2018 for empirical analysis. The main conclusions are as follows:

(1) Environmental regulation and government R&D investment are conducive to green technology innovation in the Yangtze River Economic Belt. Environmental regulation creates favorable production conditions and ecological environment for regional production, and the government, as a powerful backing for regional research investment, provides necessary financial support for green technology innovation.

(2) There is a threshold effect on the impact of environmental regulation and government R&D investment on the efficiency of agricultural science and technology innovation. Only when the intensity of government R&D investment and the intensity of environmental regulation are within a reasonable range, that is, the optimal interval of government R&D investment intensity is above 0.0788 and the optimal interval of environmental regulation intensity is above 0.0013, can the green technology innovation performance of the Yangtze River Economic Belt be maximally improved. Environmental regulation increases regional production cost and government investment in R&D of green technology innovation, which has "innovation compensation effect" and "leverage effect", thus enhancing the driving force of regional green technology innovation.

(3) The impact of enterprise size, openness, development level, human capital level and innovation environment on green technology performance is significantly positive, while the impact of ownership structure on green technology performance is significantly negative.

5.2 Policy Suggestions

(1) The government should effectively leverage R&D investment to realize the coordinated growth of investment scale and intensity. By continuing to expand the scale of government R&D input, the gap between the government and the developed countries is narrowed rapidly. Give full play to the "leverage effect" of government R&D funds, appropriately enlarge social capital, so that the intensity of government R&D investment into a reasonable range and stable; At the same time, the intensity control of government R&D investment should be strengthened to improve the efficiency of R&D investment and solve the problem of low efficiency and inefficiency of government R&D investment.

(2) Policies should combine the depth and breadth of environmental regulation based on national conditions. In practice, we should formulate feasible environmental regulation policies to reduce environmental cost. Explore a new way to solve the market failure caused by technological innovation with environmental regulation policy as the focus and market means complementing each other, so as to realize the "win-win" of regional economic growth and environmental protection.

(3) in the policy formulation and implementation to take into account the enterprise scale, the degree of openness, the development level, level of human capital and innovation environment effect on the performance of green technology have a positive effect, therefore, by strengthening the international technology exchange, to create good innovation environment, intensify regional green innovation, and promote the performance of green technology innovation is the Yangtze river economic belt.

References

[1] Zhao Lijuan, ZHANG Yuxi, PAN Fanghui. Government R&D investment, environmental regulation and innovation efficiency of agricultural science and technology [J]. Scientific research management, 2019, 40 (02): 76-85.

[2] Porter M E.Towards a dynamic theory of strategy [J]. Strategic management. Journal, 1991, 12 (S2); 95-117

[3] Porter ME, Linde C. Toward a New Conception of the Envi ronment-Competitiveness. Relationship [J]. Journal of Economic Perspectives, 1995, 9 (4): 97-118.

[4] Jaffe A B, Newell R G, Stavins R N. A tale of two market failures: Technology and environmental policy [J]. Ecological Economics, 2005, 54 (2): 164-174.

[5] Johnstone N, HašcicI, Kalamova M. Environmental policy characteristics and technologicalinnovation [J]. 2012, 27 (2): 277-301

[6] Zhao Li, Xue Yao, Hu Yiqun. Environmental Regulatory intensity and Technological Innovation -- An Empirical Study from pollution-intensive Manufacturing industry [J]. Science and technology progress and countermeasures, 2019, 36 (10): 59-65.

[7] BECHER R A. Local environmental regulation and plant-levelproductivity [J]. Ecological economics, 2011, 70 (12): 2516-2522

[8] STOEVER J, WECHE J P． Environmental regulation andsustainable competitiveness: evaluating the role of firm-level green investments in the context of the Porter Hypothesis [J].

[9] Gray WB. The cost of regulation; OSHA, EPA and the productivity slowdown [J]. The American Economics Review, 1987, 77 (5); 998-1006

[10] Zhang Zhuangzhuang, Li Meiling. Environmental regulation, industrial structure change and technological innovation capability [J]. Systems engineering, 2019, 37 (03): 59-68.

[11] Rbera, A.J, McConnell, V.D. The impact of environ mental regulations on industry productivity: Direct and indi rect effects [J]. Journal of Environmental Economics and

[12] oyd G A, Mc Clelland J D. The impact of environmen tal constraints on productivity improvement in integratedpaperplants [J]. Journal of Environmental Economicsand Management, 1999, 38 (2): 121-142.

[13] Yu Peng, LI Xin, ZHANG Jian, XUE Ya-wei. The Impact of Environmental Regulation on Technological Innovation and Its Regional Heterogeneity -- An Empirical Analysis based on China's provincial Panel Data [J]. Management Review, 202, 32 (05): 87-95.

[14] Li Bo xin, Han Xianfeng, Song Wenfei. Whether environmental regulations affect China's industrial R&D innovation efficiency [J]. Science of science research, 2013, 31 (07): 1032-1040.

[15] He Yumei, Luo Qiao. Environmental regulation, Technological Innovation and Industrial Total Factor Productivity -- A Re-test of the "Strong Porter hypothesis" [J]. Soft Science, 2008, 32 (04): 20-25.

[16] Howe D, Mc Fetridge D G.The Determinants of R&D Expenditures [J]. Canadian Journal of. Economics 1976, E, 09 (01): 57-71

[17] Liu Jibing, WANG Dingchao, XIA Ling. Research on the impact of government subsidies on innovation efficiency of strategic emerging industries [J]. Science and technology progress and countermeasures, 2014, 31 (23): 56-61.

[18] Guellec D, Bruno Van Pottelsberghe, De La Potteri. The Impact of Public R&D Expenditure. on Business R&D [J] Economics of Inno vation and New Technology, 2003 (12): 225-243.

[19] The Effect of R&D Subsidies on Private R&D [J]. Economica. 2006 (294)

[20] Bai Junhong, JIANG Keshen, Li Jing. Evaluation of Regional R & D and Innovation efficiency in China by stochastic Frontier Model [J]. Management World, 2009 (10): 51-61.

[21] Xiao Wen, Lin Gaobang. Government Support, R&D management and Technological Innovation Efficiency: An Empirical Analysis based on China's Industrial Industry [J]. Management World, 2014 (04): 71-80.

[22] Ye Qingming, Wang Kunqing. The Influence of government R&D Investment on enterprise innovation Performance: An Empirical Study based on Shanghai High-tech Enterprises [J]. Scientific research management, 2019, 40 (07): 78-86.

[23] TinbergenJ.Four alternative policies to restore balance of payments. C [J]. Econometrica, 1952, 20 (3): 372-390.

[24] Guo Jie, Yang Licheng. Impact of environmental regulation and government R&D funding on Green Technology Innovation: An empirical Analysis based on provincial level data in Mainland China [J]. Science and technology progress and countermeasures, 2020, 37 (10): 37-44.