Research on the impact of environmental regulation and government support on green technology innovation

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Abstract. Green technology innovation is an important guarantee for my country to achieve high-quality development in the new era. Taking the 2010-2018 Chinese provincial panel data as a sample, the spatial error model and the panel threshold model are used to study the impact of environmental regulation and government support on green technology innovation. The results show that: the green technology innovation in each province has certain spatial agglomeration characteristics, there is a knowledge spillover effect, the environmental regulation area has a positive impact on green technology innovation, and the government support has no significant impact; environmental regulation and government support have a threshold effect on green technology innovation. , the impact of the two on green technology innovation has a marginal diminishing effect; compared with environmental regulation, government R&D support can promote internal green technology innovation activities.

Keywords: environmental regulation; government support; green technology innovation; spatial error model; threshold model

1. Introduction

Since the reform and opening up, my country's economy has maintained rapid growth, and has achieved rapid development from "catching up with the times" to "leading the times". However, the extensive economic development model has led to the deterioration of the ecological environment. In order to achieve rapid development faster, my country has been actively exploring a new green development path. At the same time, in recent years, the problem of global technology blockade has been serious, the shortcomings of insufficient product innovation capabilities in my country's high-tech fields have been infinitely amplified, and the industry is facing the problem of low-end lock-in. In this context, the report of the 19th National Congress of the Communist Party of China emphasized the importance of "green development" and adhering to the "innovation-driven development strategy"; And the commitment to carbon neutrality in 2060; in December of the same year, the Central Economic Work Conference listed “accelerating the construction of a new development pattern”, “doing a good job of carbon peaking and carbon neutrality”, and “enhancing the independent and controllable capabilities of the industrial chain and supply chain”. key tasks. Adhering to green development and accelerating the realization of harmonious coexistence between man and nature have become the only way for development in the new era. Green technology innovation can bring dual benefits of technological progress and environmental protection, and is an effective means to achieve parallel economic development and environmental protection.

The government usually uses a combination of environmental regulation policies and government support policies to stimulate green innovation behaviors of enterprises through the optimal policy combination. On the one hand, green technology innovation has the shortcoming of “dual externalities”, and on the other hand, it is a positive externality related to knowledge spillovers and the publicity of innovative knowledge. When new technology innovation is actually used, some or all of its knowledge will become public knowledge, and its spillover effect will generate positive externalities, but original innovation enterprises bear all innovation costs, resulting in insufficient originality. The second is that waste discharge will have an impact on the environment and then bring significant negative externalities to the society. The cost of pollution discharge of enterprises is often

seriously underestimated, which causes enterprises to reduce the emphasis on green innovation behaviors and reduce the willingness of enterprises to green innovation behaviors. On the other hand, a large number of studies have shown that the combination of regulatory policies and support policies will produce a "coupling effect", which will generate additional innovation incentives for enterprises. The theory of government intervention believes that government R&D support can improve the positive externality of green technology innovation to a certain extent, ease the financial pressure of enterprises, and improve the efficiency of resource allocation in the market. The theory of environmental regulation believes that the negative externalities related to environmental pollution can be restrained through environmental regulation policies, such as taxation and other measures, and the problem of market failure can be solved. Knowledge spillovers, market mechanisms and government intervention policies can all have an impact on the green innovation behavior of enterprises, so what impact will environmental regulation and government support have on green technology innovation of enterprises? Are there certain spatial spillover effects and threshold effects in green technology innovation? How to avoid the "double externalities" of green technology innovation in the future to achieve the best coupling effect of regulatory policies and support policies? We will discuss these issues next.

2. Literature review

Environmental regulation can force enterprises to carry out green innovation activities and increase their support for green innovation activities, which is based on the "Porter Hypothesis". The "Porter Hypothesis" believes that appropriate environmental regulation promotes enterprise innovation activities, thereby increasing the productivity of enterprises, thereby offsetting the costs caused by environmental protection and improving the profitability of enterprises in the market. Opponents believe that environmental regulation will exert pressure on enterprises in terms of environmental protection, affect the allocation of funds of enterprises, and then reduce the innovation behavior of enterprises, resulting in a "crowding out effect", which is not conducive to the implementation of green technology innovation of enterprises. Supporters believe that increasing the intensity of environmental regulation can improve the efficiency of enterprise resource allocation and promote enterprise innovation activities, thereby producing a "crowding-in effect". Later, more scholars believe that the relationship between the two is a non-linear relationship, and according to the research, a "U" type, an inverted "U" type, and a multi-threshold relationship are proposed. To sum up, with the change of the intensity of environmental regulation, environmental regulation will promote or inhibit green technology innovation, which can only be realized if it reaches a certain intensity interval "Porter Hypothesis". The effect of environmental regulation on innovation depends on the effect of environmental regulation on innovation. strength.

There are two opposing views on the influence of government support intensity and enterprise innovation behavior. The "compensation effect" believes that the R&D support from the government will stimulate the innovation vitality of enterprises and enhance the support of enterprises for innovation activities. The information rent obtained by enterprises obtaining high R&D subsidies will promote the increase of enterprises' innovation investment and produce more innovation results. The "crowding-out effect" believes that the R&D support from the government will inhibit the innovation activities of enterprises, and will have a "substitution effect" on the innovation investment of enterprises. If the government blindly subsidizes the planned investment projects of enterprises, the innovation activities will be inefficient, thereby inhibiting the desire for R&D and innovation of enterprises. To sum up, the government's R&D support will bring uncertainty to the innovation activities of enterprises, and the change of the intensity of government support affects the innovation willingness of enterprises.

According to the Tinbergen Criterion, the data for policy instruments must be no less than the number of policy objectives. There will be a positive coupling effect between environmental regulation and government support, which will promote the innovation activities of enterprises. This

paper uses the provincial panel data from 2010 to 2018 as sample data, and uses the spatial error model to analyze the spatial spillover and spatial heterogeneity of green technology innovation, and the threshold effect examines the impact of environmental regulation and government support on green technology innovation.

3. Study Design

3.1 Research methods

3.1.1 Spatial Autocorrelation Test

Based on the first law of geography, everything is related to other things. To examine the spatial correlation of green technology innovation, we choose Moran's I for consideration. The Moran index is used to examine the spatial dependence and clustering characteristics of green innovation capabilities, and the expressions are as follows:

$$Moran's\ I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{(\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Among them, x_i and x_j represent the regional green innovation capabilities of regions i and j, X is the average value of green innovation capabilities of all n regions, Wij is the spatial weight matrix, and the global Moran index takes a value between -1 and 1, when When the value is 0, it means that there is no spatial correlation; when Moran's I>0, it means that there is a positive correlation in space, and the larger the value, the more significant the correlation; when Moran'sI<0, it means that there is a negative correlation in space, And the smaller the value, the more significant the difference.

3.1.2 Spatial measurement model

When there is spatial correlation in regional economy, spatial econometric methods can be used for analysis. The main spatial measurement models are spatial lag model (SLM), spatial error model (SEM), and spatial Durbin model (SDM). The spatial lag model studies the impact of activities in a certain area on adjacent areas; the spatial correlation of the spatial error model is reflected in the random disturbance term, and the disturbance in a certain area will affect other areas with the spatial effect; the spatial Durbin model adds The effect of independent variables with spatial lags on the dependent variable. Combined with the actual research, we choose the spatial error model and build the following model:

$$GTIEit=\alpha+\alpha1\ ERit+\alpha2\ GSit+\alpha3IEit+\alpha4OPENit+\alpha5RDit+\alpha6PAit+\mu \quad \text{(Model 1)}$$

Where $\mu=\lambda W+\varepsilon$, W is the spatial weighting matrix, λ is the spatial autoregressive coefficient, ε is the random disturbance term.

3.1.3 Panel threshold model

Based on the panel threshold model, we analyze the threshold effect of environmental regulation and government support on green technology innovation activities, and at the same time divide the intensity range according to the characteristics of the data. Build the following model:

$$GTIEit=\alpha1IEit+\alpha2OPENit+\alpha3RDit+\alpha4PAit+\gamma1ERit\times I(ERSit\le\lambda1)+\gamma2ERit\times I(\lambda1<ERSit\le\lambda2)+\gamma3ERit\times I(ERSit>\lambda3)+a+\varepsilon it \quad \text{(Model 2)}$$

$$GTIEit=\beta1IEit+\beta2OPENit+\beta3RDit+\beta4PAit+\delta1GSit\times I(IGSit\le\mu1)+\delta2GSit\times I(\mu1<IGSit\le\mu2)+\delta3GSit\times I(IGSit>\mu3)+b+\varepsilon it \quad \text{(Model 3)}$$

Among them, i represents the region, t represents the year; $GTIE_{it}$ is the explained variable; IE_{it}, $OPEN_{it}$, RD_{it}, and PA_{it} are the control variables, and I is the indicator function. ERit in model 3 is the explanatory variable affected by ERS_{it}, ERS_{it} represents the intensity of environmental regulation,

and α is the coefficient of the influence degree of the explanatory variable ER_{it} on the explained variable $GTIE_{it}$ when the threshold variable ERS_{it} is in different intervals. GS_{it} in model 4 is the explanatory variable affected by IGS_{it}, IGS_{it} represents the intensity of government R&D subsidies, and β is the influence degree coefficient of the explanatory variable GS_{it} on the explained variable $GTIE_{it}$ when the threshold variable IGS_{it} is in different intervals.

3.2 Variable selection

3.2.1 Explained variables

Green Technology Innovation Efficiency (GTIE): The number of green patent applications in each province and city is used as a measure, the number of green patent applications is from the CNRDS database, and the number of green utility patent applications is used as a robustness test.

3.2.2 Explanatory variables

(1) Environmental Regulation (ER): The investment in industrial pollution control in each region represents environmental regulation; Environmental Regulation Intensity (ERS): The ratio between the investment in industrial pollution control in each region and the main business income of industrial enterprises above designated size.

(2) Government support (GS): government funds in industrial R&D expenditures above designated size; intensity of government support (IGS): the ratio of government funds in internal expenditures of industrial R&D funds above designated size to the total internal expenditures of industrial R&D funds above designated size.

3.2.3 Control variables

Innovation Environment (IE): The technology market turnover in each region; Openness to the outside world (OPEN): The ratio of total import and export trade to regional GDP; R&D capability (RD): The ratio of scientific research to total employment; Profitability (PA)): the ratio of the current profits of industrial enterprises above designated size to the net assets at the beginning of the period.

3.3 Data sources

We selected the data from 2010-2018 of 30 provinces in the mainland as the sample. Because the data in Tibet is seriously missing, we propose that the data mainly come from the "China Statistical Yearbook", "China Science and Technology Statistical Yearbook", "China Environmental Statistical Yearbook" and "China Industrial Statistical Yearbook" ” and data from the National Bureau of Statistics website.

4. Empirical Analysis

4.1 Spatial correlation analysis

4.1.1 Global Moran Index Analysis

Table 1. Global Moran's I index of regional green technology innovation

Year	Moran Index	P value	Z value
2010	0.171	0.036	1.797
2011	0.198	0.018	2.099
2012	0.201	0.017	2.125
2013	0.181	0.027	1.923
2014	0.198	0.018	2.093
2015	0.239	0.008	2.399
2016	0.249	0.007	2.435
2017	0.190	0.026	1.944
2018	0.181	0.031	1.866

GeoDa software was used to calculate the global Moran index of green technology innovation in each province in China. The results are shown in Table 1. The Moran index value of regional

innovation capability from 2010 to 2018 was between 0.171 and 0.249. passed the significance test at the level of . The results show that the green technology innovation ability of each province has a certain positive spatial correlation and has certain spatial agglomeration characteristics. The development strategy of regional integration strengthens the flow of knowledge between regions, strengthens the knowledge spillover effect between provinces, helps regional collaborative innovation, and forms a spatial cluster of green technology innovation.

4.1.2 Analysis of local Moran index

Through the local Moran index scatter plot, we can analyze the differences in green technology innovation capabilities within the region, and some of the results are shown in Figure 1 (the provinces represented by each point are manually recorded). The first quadrant represents high-high agglomeration areas, and the representative areas are Jiangsu, Zhejiang, Shanghai, etc. The regional characteristics are that its own innovation ability is strong, the green technology innovation ability of surrounding areas is strong, and the regional innovation atmosphere is good; the second quadrant is low - High agglomeration area, representative areas include Fujian, Tianjin, Jiangxi, Guangxi, etc. The regional characteristic is that its own green technology innovation capability is insufficient, and the surrounding strong innovation areas have a general innovation driving effect on the area; the third quadrant is low-low agglomeration The representative regions are Inner Mongolia, Jilin, Ningxia, Shaanxi, Heilongjiang, etc. The region's own innovation ability is not strong, the green technology innovation ability of surrounding areas is not strong, and the regional collaborative innovation ability is poor; the fourth quadrant is high-low The agglomeration area is represented by Beijing, Guangdong, etc. The area has strong green technology innovation capabilities, but the surrounding areas have average innovation capabilities and regional collaborative innovation capabilities. In the future, it is necessary to give full play to the construction of a regional collaborative innovation system with Beijing, Shanghai and Guangdong as the core, give play to the radiating role of core regions, strengthen regional exchanges and cooperation, drive surrounding regions to improve regional green innovation capabilities, and further promote the improvement of green technology innovation capabilities.

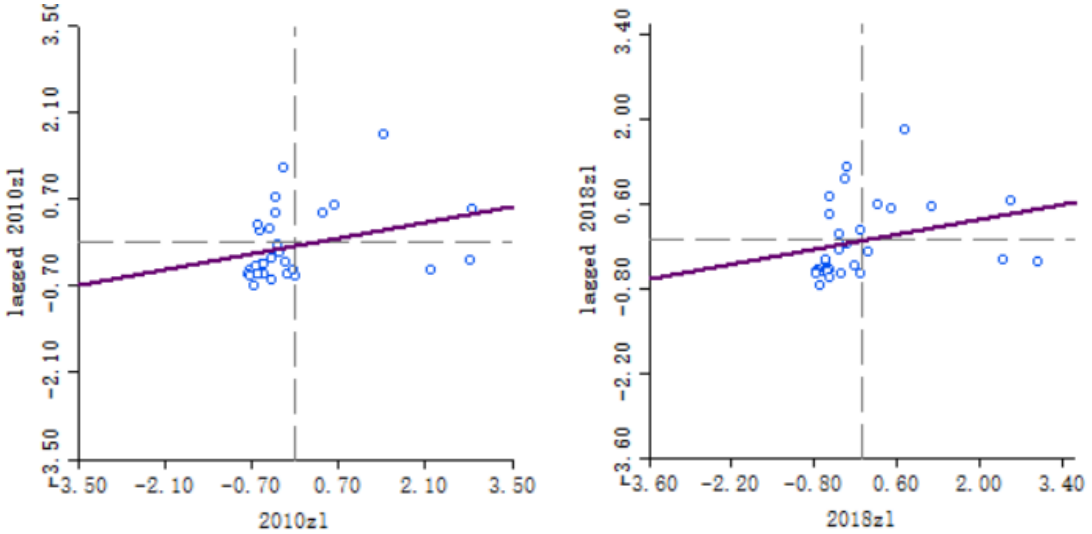

Figure.1 Scatter plot of local Moran index of regional green technology innovation in 2010 and 2018

4.2 Analysis of Spatial Econometric Model

4.2.1 Econometric model selection

The Lagrange multiplier test was used to test the spatial model, and the results are shown in Table 2. The test results of LM-E and Robust LM-E were both significant at the 5% significance level, so the spatial error model was selected as the spatial econometric model for analysis. Since the test results of LM-E and Robust LM-E were not significant, the spatial lag model and the spatial Durbin model could not be selected.

Table 2. Analysis of LM test results

Test	Statistics	P value
LM-E	5.903	0.024
Robust LM-E	4.899	0.027
LM-L	0.268	0.605
Robust LM-L	0.073	0.787

4.2.2 Spatial effect analysis

The coefficient of the spatial lag term is 0.685, which is significant at the 1% level of significance, indicating that there is a positive spatial correlation in inter-provincial green technology innovation, which is reflected in the error term. Environmental regulation, innovation environment and R&D investment positively affect regional green technology innovation, and there is a positive spatial correlation. Environmental regulation means between regions may affect policies in adjacent regions. A good innovation environment and high R&D investment help Form a regional collaborative innovation effect and promote the improvement of regional green technology innovation capabilities. The influence of government R&D support, openness and corporate profitability is not significant. The government's R&D support is affected by the economic development level of each region, and the degree of inter-regional influence is small; in terms of openness, it may be due to the fact that developed countries will place companies with lower technical levels Transferred to developing countries, the green technology innovation level of such enterprises is relatively low; the improvement of corporate profitability has less impact on green technology innovation, which may be because enterprises are unwilling to take innovation risks.

Table 3. Spatial error model analysis

Variable	Coefficient	Z value	P value
ER	0.093^{***}	2.87	0.004
GS	-0.040	-0.76	0.446
IE	0.076^{***}	3.48	0.001
OPEN	0.265	1.05	0.292
RD	0.171^{**}	2.33	0.020
PA	-0.862	-0.68	0.499
SL	0.685^{***}	35.71	0.000
R^2	0.7064		

4.3 Threshold effect test

Table 4. Threshold effect test

Model	Threshold variable	Threshold quantity	F value	P value
Model 2	Intensity of environmental regulation	Single Threshold	25.73^{***}	0.0067
		Double threshold	22.78^{**}	0.0167
Model 3	Intensity of government support	Single Threshold	42.24^{***}	0.0000
		Double threshold	22.97^{**}	0.0300

Table 5. Threshold estimates and confidence intervals

Model	Threshold quantity	Threshold value	95% confidence interval
Model 2	Single Threshold	3.2282	(3.1872,3.2423)
	Double threshold	6.3985	(6.1020,6.4536)
Model 3	Single Threshold	0.0400	(0.0400,0.0401)
	Double threshold	0.0846	(0.0845,0.0854)

We take the intensity of environmental regulation and the intensity of government support as the threshold variables to analyze whether there is a threshold, and then determine the number of thresholds and the threshold interval. The results are shown in Table 4 and Table 5. Model 2 takes the intensity of environmental regulation as the threshold variable, and Model 3 takes the intensity of government R&D subsidies as the threshold variable. From the results in Table 3, it can be seen that

there are double thresholds for the intensity of environmental regulation, and there are also double thresholds for the intensity of government support, which proves that there is a nonlinear relationship between environmental regulation and green technology innovation, and between government support and green technology innovation. From the perspective of the threshold interval, the intensity of environmental regulation has three intervals, the first interval ERS≤3.2282, the second interval 3.2282<ERS≤6.3985, the third interval ERS>6.3985; the government support intensity also has three intervals, IGS≤0.0400, the second interval the interval 0.0400<IGS≤0.0846, the third interval IGS>0.0846.

4.4 Threshold regression results

From Model 2, we can see that environmental regulation is positively promoting green technology innovation, which is in line with the content of the "Porter Hypothesis". However, the impact of environmental regulation on green technology innovation has a marginal decreasing trend. When the intensity of environmental regulation is in the first range, the impact coefficient on green technology innovation is 0.374. When the intensity of environmental regulation reaches the second and third ranges, the impact on green technology The impact of technological innovation will gradually diminish. Appropriate environmental regulation policies can force enterprises to carry out green technology innovation and weaken the negative externalities of the dual externalities of green technology innovation. Industry "crowding-out effect" affects the tendency of internal resources of enterprises and weakens the green technology innovation activities of enterprises. At the same time, government R&D support, industrial scale, and innovation environment have a positive effect on green technology innovation, while the degree of openness and profitability will have a negative effect on enterprise green technology innovation. When using foreign technologies, some developed countries tend to relocate pollution-intensive enterprises to developing countries with relatively weak environmental regulations, resulting in serious environmental pollution in some areas of my country. In terms of profitability, the higher the profitability of a company, the more conservative it is, and the path dependence gradually develops. It is unwilling to invest more in innovation and take the risk of innovation failure.

Table 6. Threshold regression results

Model 2				Model 3			
Variables	Coefficients	t	p>t	Variables	Coefficients	t	p>t
GS	0.134**	1.98	0.049	ER	0.080**	2.00	0.046
IE	0.556***	14.07	0.000	IE	0.491***	12.77	0.000
OPEN	-1.079***	-3.86	0.000	OPEN	-0.923***	-3.84	0.001
RD	0.319***	3.09	0.002	RD	0.213**	2.11	0.036
PA	-8.848***	-6.45	0.000	PA	-7.304***	-5.62	0.000
ERS1	0.374***	6.19	0.000	IGS1	0.481***	6.73	0.000
ERS2	0.346***	6.03	0.000	IGS2	0.434***	6.26	0.000
ERS3	0.318***	5.88	0.000	IGS3	0.403***	5.98	0.000
Constant	-5.170***	-5.45	0.000	Constant	-4.888***	-5.46	0.000
R^2	0.7808			R^2	0.7972		
F value	103.28***			F value	114.01***		

From Model 3, government support is also promoting green technology innovation, and there is a marginal decreasing trend in government support for green technology innovation activities. When the government support intensity is in the first range, the influence coefficient on green technology innovation is 0.481, and when the government support intensity is in the second and third ranges, the impact on green technology innovation will gradually weaken. This shows that with the increase in the intensity of government support, it will gradually produce a certain degree of "crowding-out effect" on the innovation activities of enterprises, reducing the willingness of enterprises to innovate in green technology, and is not conducive to the emergence of more green technology innovation

achievements. At the same time, environmental regulation, industrial scale, and innovation environment are positively promoting the green technology innovation activities of enterprises, and the degree of openness and profitability will have a certain inhibitory effect on the green technology innovation industry.

5. Conclusions and Implications

5.1 Research conclusions

Based on the provincial panel data from 2010 to 2018, this paper studies and analyzes the relationship between environmental regulation, government support and green technology innovation. The research found that: (1) There is a certain spatial agglomeration of green technology innovation, which has a certain spatial knowledge spillover effect. (2) Both environmental regulation and government support can promote green technology innovation. In terms of promoting the efficiency of green technology innovation, the two have a marginal diminishing effect, and at the same time, they have a threshold effect on green technology innovation. When the intensity of environmental regulation does not exceed 3.2282, When the government support does not exceed 0.040, it can promote the green innovation behavior of enterprises to the greatest extent. (3) Compared with environmental regulation, government support can promote the emergence of green technology innovation.

5.2 Revelation

At the national level, give full play to the impact of government R&D support on green technology innovation of enterprises, keep the intensity of government support within the optimal range, strengthen supervision of government R&D support policies, and ensure that government funds are fully allocated to the enterprise level. At the same time, the environmental regulation policy should be appropriately relaxed, the environmental regulation tools should be further improved, and the role of environmental regulation in promoting green technology innovation of enterprises should be better played. Give full play to the positive "coupling effect" of environmental regulation and government support.

Regionally, strengthen the exchange and cooperation of knowledge and technology between regions, improve the construction of regional collaborative innovation system, give play to the radiation role of core regions, drive surrounding regions to improve regional green innovation capabilities, and further promote the improvement of green technology innovation capabilities.

At the enterprise level, enterprises should make full use of the research and development support from the government to avoid the "crowding out effect" of funds from the government, and at the same time increase the inclusiveness of enterprises' innovation activities, and adhere to a long-term perspective to view enterprises' innovation activities. Avoid the "path dependence" mentality, and continue to increase support for corporate green technology innovation activities.

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