Environmental Regulation, Technological Innovation and Industrial Structure Optimization

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Abstract: Based on panel data from 30 Chinese provinces between 2008 and 2019, this paper empirically analyzes the indirect effect of environmental regulation intensity on the rationalization and advancement of industrial structure in the national, eastern, central and western regions, and the moderating role of regional economic development level in the optimization of industrial structure influenced by environmental regulation intensity, using the mediating effect model and moderating effect model. The results of this study show that environmental regulation in the national, eastern and central regions affects the rationalization and advancement of industrial structure by influencing the intensity of technological innovation, but environmental regulation in the western region does not have a significant effect on the rationalization and advancement of industrial structure.

Key Words: Environmental Regulation Intensity, Technological Innovation Intensity, Industrial Structure

1. Introduction

Industrial structure issues like high energy consumption and severe pollution have grown more challenging as industrialization has progressed, making it difficult for China's economy to grow sustainably. The rationalization and advanced nature of industrial structure are encouraged by the optimization and upgrading of industrial structure, which also helps to lower the proportion of industries with high energy consumption and high pollution, while technological innovation is the main driving force for optimizing resource allocation and promoting the optimization and upgrading of industrial structure. Exploring how environmental regulation affects industrial structure optimization under the dual pressure of environmental issues and sustainable economic development is beneficial for revealing the inner mechanism of industrial structure optimization from a theoretical perspective, as well as for advancing China's sustainable economic development.

Some scholars believe that environmental regulation will drive up business costs more and reducing investment in technological innovation. (Zhang & Lu, 2018[1]; Gutierrez & Teshima, 2018[2]). Some scholars believe that effective environmental legislation can encourage businesses to pursue technological innovation. (Yu & Cui, 2019[3]; Shi & Zhao, 2018[4]). Some scholars believe that environmental regulation's effects on businesses' technical innovation are

defined by cyclical shifts. (Dong & Wang, 2019[5]). In the existing research, numerous research have been done on how technology innovation affects industrial structure, but most scholars' research mainly focuses on the impact of technological innovation on industrial structure transformation and upgrading, and most of them believe that technological innovation can promote industrial structure transformation and upgrading (Bai & Zhou, 2017[6]; Xu & Liu, 2016[7]). Existing research primarily examines the influence of environmental regulation on technological innovation and the impact of technological innovation on the transformation and upgrading of industrial structures. However, comparatively little attention has been given to the effects of environmental regulation on optimizing industrial structures. And the existing literature focuses mainly on the direct impact of environmental regulation on the advancement of industrial structure, while there is a paucity of research on the indirect influence of these regulation on optimizing industrial structure.

2. Theoretical Analysis and Hypothesis Proposed

2.1 The role of technology innovation as a mediator in the optimization of industrial structure influenced by environmental regulation

In the short run, environmental regulation result in higher costs for treating pollution. Nevertheless, over time, environmental regulation are beneficial for fostering technological advancement and encouraging industrialization restructuring. (Xue, 2016[8]). This paper argues that environmental regulation are likely to spur technological innovation in enterprises. Technological innovation can accelerate the agglomeration of production factors, transform the operational and production methodologies of corporations, influence the factor structure and industrial organization, and potentially disrupt the balance of factor allocation, leading to a discordance in industrial structure. (Li & Dong, 2018[9]). And technological innovation can promote the efficient allocation of the input factors, facilitating the transition and advancement of traditional industries and fostering the growth of sustainable emerging industries. (Ren & Yang, 2020[10]). Meanwhile, technological innovation also plays a role in enhancing labor productivity and transforming the structure of societal needs, thus promoting industrial structure upgrading (Cai & Wang, 2018[11]). This paper argues that the increase of environmental regulation intensity will make the production costs of pollution-intensive industries increase, thus leading to the decrease of enterprise profits (Li et al, 2019[12]). But due to the characteristic of technological innovation such as long cycle, high risk and high investment, it makes some high pollution enterprises invest their resources in non-pollution and high-return tertiary industries. In addition, a moderate level of environmental regulation encourages enterprises to use resources effectively and enhance production efficiency by increasing the intensity of technological innovation, thus promoting the development of industrial structure from lower to higher levels.

H1: Technological innovation intensity plays a mediating role in the process of environmental regulation intensity affecting the rationalization of industrial structure/the advancement of industrial structure.

2.2 The role of technological innovation in mediating the optimization of industrial structure influenced by environmental regulation by sub-region

As environmental regulation become more stringent, enterprises tend to obtain new processes and technologies through technology innovation for the purpose of meet the government's environmental requirements. This technology innovation will further influence the rationalization and advancement of industrial structure. Because of the relatively underdeveloped economy and the limited availability of innovation resources in the western region, enterprises' innovation vitality and innovation motivation are insufficient, so when the government adopts strict environmental regulation policies, it tends to force enterprises to meet the government's environmental requirements through measure such as increasing pollution control costs rather than through technical innovation, which will reduce enterprises' technological innovation investment and inhibit their technological innovation behavior. The level of economic development and technological innovation capability in the central region are located between the eastern and western regions. So when the environmental regulation intensity increases, some enterprises may achieve government's environmental requirements through technological innovation, but some enterprises will achieve the government's environmental requirements by "polluting first and treating later" due to insufficient technological innovation capability.

H2a: The influence of technological innovation intensity on industrial structure has regional heterogeneity.

3. Research Design

3.1 Variable selection and measure

This paper draws on the approach of Gan et al. to measure the rationalization of industrial structure by using the Thiel index. The advancement of industrial structure is measured by the ratio of total output value of the tertiary industry to the total output value of the second industry. This study measures the intensity of environmental regulation by the amount of completed pollution control projects investment. The R&D-to-GDP ratio serves as a metric for assessing the degree of technological innovation. The region income level is used as a control variable, measured by the average wage of employee in urban units. Openness was utilized as the independent variable in this study, quantified as the proportion of foreign investment relative to GDP. To address heteroscedasticity and enhance data consistency, natural logarithms were applied to all variables.

3.2 Sample selection and data sources

The panel data from 30 Chinese provinces (excluding Hong Kong, Tibet, Macao, and Taiwan) between 2008 and 2019 has been chosen for the study. All data are obtained from the official website of the National Bureau of Statistics and further processed. To minimize the impact of outliers, all continuous variables are capped at the 1% threshold.

4. Main Model and Mediating Effect Test

4.1 Model constructing

Based on the theoretical analysis and research hypothesis, the following model is developed to test for mediating effects.

$$\ln Struc_{it} = \alpha_0 + \alpha_1 \ln Environ_{it} + \alpha_2 \ln Open_{it} + \alpha_3 \ln Income_{it} + \varepsilon_{it} \tag{1}$$

$$\ln Tech_{it} = \beta_0 + \beta_1 \ln Environ_{it} + \beta_2 \ln Open_{it} + \beta_3 \ln Income_{it} + \varepsilon_{it} \tag{2}$$

$$\ln Struc_{it} = \gamma_0 + \gamma_1 \ln Environ_{it} + \gamma_2 \ln Tech_{it} + \gamma_3 \ln Open_{it} + \gamma_4 \ln Income_{it} + \varepsilon_{it} \tag{3}$$

4.2 Descriptive statistical analysis

The descriptive statistical analysis of the variables of the whole country and the eastern, central and western regions, the findings revealed notable variances in indicators between the regions, suggesting considerable regional disparities in China.

4.3 Correlation analysis

The findings indicate that, at the level of 0.05, there is a significant negative correlation between the Thiel index and the intensity of environmental regulation. The level of stringency in environmental regulation exhibits a significantly negative correlation with the progress of industrial structure, with a significance level of 0.01. The VIF values for the variables are all below 10, indicating the absence of any multicollinearity between them. This allows for the performance of multiple regression analysis.

4.4 Empirical results and analysis
4.4.1 Analysis of the mediating effect of intensity of technological innovation

Table 1 Results of empirical test of the mediating effect of technological innovation intensity

explained variable	*HLH*	*Tech*	*HLH (Tech)*	*GJH*	*Tech*	*GJH (Tech)*
Model	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	（1）	（2）	（3）	（4）	（5）	（6）
Environ	-0.165***	0.478***	-0.126**	0.225***	0.478***	0.026
Tech			-0.083			-0.525***
Open	-0.228***	0.411***	-0.194***	0.252***	0.411***	0.468***
Income	-0.118**	0.226***	-0.099*	0.627***	0.226***	0.745***
R^2	0.734	0.743	0.735	0.772	0.743	0.848
F	15.566***	145.954***	11.980***	174.862***	145.954***	227.358***
DW	1.952	1.967	1.956	2.028	1.967	2.045

Note: * denotes $p<0.1$; ** denotes $p<0.05$; *** denotes $p<0.01$.

Data source: Compiled from Eviews 6.0 regression results.

As can be seen from Table 1, the greater the environmental supervision, the more reasonable the industrial structure, and therefore can be tested in the next step. As the intensity of environmental regulation increase, it will increase the technological innovation intensity of enterprises, and therefore proceed to the next test. However, the coefficient of technological innovation intensity is not statistically significant in column (3). According to Wen et al.'s methodology, the Sobel test is necessary. The Sobel test formula indicates that the Z-statistic is significant. Further test

reveals that the significance is reduced. Thus, it can be observed that the intensity of technological innovation plays the role of transmission of the intensity of environmental regulation affecting the rationalization of industrial structure. As the intensity of environmental regulation increases, the industrial structure will also become advanced, and therefore can be tested in the next step. As the intensity of environmental regulation increase, it will increase the technological innovation intensity of enterprises, so the next test can be continued. There is a full mediating effect of technological innovation intensity. Thus, it can be observed that in the process where the intensity of environmental regulation affects the advancement of industrial structure, the intensity of technological innovation plays a mediating role.

5. Further Analysis

5.1 Test for mediating effect by region

The indirect impact of environmental regulatory intensity on industrial structure optimization in the eastern, central, and western areas will be further explored in this study, and the empirical test findings are presented in Table 2.

Table 2 Results of the empirical test on the mediating effect of technological innovation intensity in the eastern, central and western regions

	explained variable	*HLH*	*Tech*	*HLH (Tech)*	*GJH*	*Tech*	*GJH (Tech)*
	Model	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
eastern region		（1）	（2）	（3）	（4）	（5）	（6）
	Environ	-0.203***	0.764***	0.104	-0.552***	0.764***	-0.003
	Tech			-0.402**			-0.719***
	R^2	0.748	0.903	0.751	0.895	0.903	0.947
	F	13.439***	188.315***	11.707***	171.278***	188.315***	273.643***
	DW	2.042	1.905	2.171	2.128	1.905	2.136
	explained variable	*HLH*	*Tech*	*HLH (Tech)*	*GJH*	*Tech*	*GJH (Tech)*
	Model	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
central region		（1）	（2）	（3）	（4）	（5）	（6）
	Environ	0.396***	0.261***	0.248***	-0.184**	0.261***	-0.097
	Tech			0.571***			-0.333***
	R^2	0.739	0.757	0.760	0.768	0.757	0.739
	F	5.538***	15.289***	13.392***	27.343***	15.289***	27.311***
	DW	2.151	1.950	2.125	2.039	1.950	2.196
	explained variable	*HLH*	*Tech*	*HLH (Tech)*	*GJH*	*Tech*	*GJH (Tech)*
	Model	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
western region		（1）	（2）	（3）	（4）	（5）	（6）
	Environ	0.131	0.075	0.130*	-0.058	0.075	-0.046
	Tech			0.019			-0.168**
	R^2	0.731	0.748	0.731	0.763	0.748	0.765
	F	4.348***	12.856***	3.241**	28.498***	12.8564***	23.1898***
	DW	1.939	2.068	1.938	1.906	2.068	1.913

Note: * denotes p<0.1; ** denotes p<0.05; *** denotes p<0.01.

Data source: Compiled from Eviews 6.0 regression results.

From Table 2, it can be observed that as the intensity of environmental regulation increases, the industrial structure becomes more reasonable, so the next step of testing can be carried out. The more stringent the environmental regulation, the higher the level of technological innovation of the enterprise, so the next test can be continued. The regression coefficient of environmental regulation intensity is not significant, but the regression coefficient of technological innovation intensity is significant. The Sobel test is required. Based on the Sobel test formula, the Z-statistic is significant. It can be seen that the intensity of technological innovation in the eastern region plays the role of transmission of the intensity of environmental regulation affecting the rationalization of industrial structure. The intensity of environmental regulation inhibits the advancement of industrial structure and therefore can be tested in the next step. The technological innovation intensity of enterprises will increase as environmental regulation becomes more stringent., and therefore proceeds to the next test. There is a full mediating impact of technological innovation intensity. Thus, it can be observed that the intensity of technological innovation plays a role of transmission of the intensity of environmental regulation affecting the advancement of industrial structure.

The industrial structure of the central region has become more unreasonable with the increase of environmental regulation, and thus the next test can be conducted. As environmental regulation become more stringent, the level of technological innovation within enterprises will increase, so the next test can be continued. At the level of 0.01, there is a significant and positive correlation between the coefficients of technological innovation intensity and environmental regulation intensity, but the coefficient of environmental regulation intensity in column (3) is significantly lower than the coefficient in column (1), and the Sobel Z value is statistically significant, indicating that technological innovation intensity plays a transmission role of environmental regulation intensity affecting industrial structure rationalization. The intensity of environmental regulation inhibits the advancement of industrial structure and therefore can be tested in the next step. The intensity of technological innovation of enterprises will increase with the increase of the intensity of environmental regulation, and therefore proceeds to the next test. There is a full mediating effect of technological innovation intensity. Thus, it can be observed that the intensity of technological innovation plays a role of transmission of the intensity of environmental regulation affecting the advancement of industrial structure.

The following are the test results for the western region. The amount of technical innovation in the western area is not significantly impacted by environmental regulation intensity. In the western region, there is little impact of environmental regulation intensity on industrial structure optimization.

6. Conclusions

The empirical study's findings indicate that: (1) the intensity of technological innovation in the national, eastern and central regions plays a role in the transmission of the intensity of environmental regulation affecting the rationalization and advancement of industrial structure. However, there is little correlation between the intensity of environmental regulation and the rationalization and development of the industrial structure in the western region.

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