Academic Journal of Management and Social Sciences
ISSN: 2958-4396 | Vol. 4, No. 2, 2023

Research on the Impact of Environmental Regulation on the Upgrading of Manufacturing Industry Structure in the Yangtze River Economic Belt

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Abstract: It is of great practical significance to explore the environmental regulation on the upgrading of the manufacturing industry structure in the Yangtze River Economic Belt. This paper covers the panel data of 11 provinces in the Yangtze River Economic Belt during the period of 2011-2022 and applies the fixed effect model to explore the impact of environmental regulation on the upgrading of the manufacturing industry structure in the Yangtze River Economic Belt in the form of empirical research. The results reveal that environmental regulations have a negative impact on the upgrading of the manufacturing industry structure in the Yangtze River Economic Belt; green technology innovation has a mediating effect between environmental regulations and the upgrading of the manufacturing industry structure in the Yangtze River Economic Belt; and there is regional heterogeneity in the upgrading of the manufacturing industry structure in the Yangtze River Economic Belt, with the strongest inhibition in the middle reaches of the Yangtze River Economic Belt, the second in the middle reaches of the Yangtze River Economic Belt and the weakest in the upper reaches of the Yangtze River Economic Belt. Conclusions are drawn: tax relief policies should be provided appropriately; the Yangtze River Economic Belt should adopt differentiated regional environmental regulation policies to adapt to the environmental characteristics of each place, and the promotion of green technological innovation should be strengthened at the same time.

Keywords: Environmental Regulation; Green Technology Innovation; Manufacturing Industry Structure Upgrade; Heterogeneity.

1. Introduction

Environmental regulation is the implementation of laws and regulations for the purpose of environmental protection to manage various behaviors that cause pollution to the public environment. In the face of increasingly stringent laws and regulations, the manufacturing industry is affected and constrained by environmental regulations because of its high energy consumption and high emissions. As the world's largest manufacturing country, China has surpassed the United States and ranked first in the world in terms of manufacturing scale since 2011. Manufacturing is an important pillar of China's national economy. According to the 2021 China Industrial Statistical Yearbook, the manufacturing output value of the Yangtze River Economic Belt accounts for 46.40% of the country's total, which is an important position in China's manufacturing industry development, and General Secretary Xi clearly proposed at the Symposium on Comprehensively Promoting the Development of the Yangtze River Economic Belt that the Yangtze River Economic Belt should become the main battleground of domestic ecological priority and green development. Although China's manufacturing industry in the capital and technology-intensive industries has made significant progress, but overall, China's manufacturing industry is still characterized by "big but not strong", the core manufacturing industry is relatively weak. Therefore, it is necessary to upgrade the industrial structure of the manufacturing industry in order to realize the development of the industrial structure of the manufacturing industry to a higher level. (Lu Xianxiang, 2021) [1]. The manufacturing industry of the Yangtze River Economic Belt also has the problem of being large but not strong, while the Report on the Industrial Development of the Yangtze River Economic Belt (2020) points out that the manufacturing industry of the Yangtze River Economic Belt has the challenge of imbalance in regional development, and that the green technological innovation covers two connotations of the five development concepts, namely "green" and "innovation", which are relatively different from the five development concepts of "green" and "innovation". Green technological innovation covers the two major connotations of "green" and "innovation" in the five development concepts, and it pays more attention to environmental protection and sustainability than traditional technological innovation (Ma Yuan, 2014)[2], and green technological innovation helps to realize the coordinated development of the economy and the environment, which is beneficial to manufacturing enterprises in terms of both environmental protection and upgrading of industrial structure. Therefore, it is crucial to explore the role of environmental regulation and green technological innovation for the upgrading of the industrial structure of the manufacturing industry.

2. Literature Review

Currently, researchers at home and abroad have studied the link between environmental regulation and industrial structure upgrading in two main areas: the "compliance cost effect" and the "innovation compensation effect". Regarding the "compliance cost effect", Gray W B (2010) found that environmental regulations increase the expenditure of enterprises on pollution control and environmental compliance, which further has a reverse effect on the innovative behavior and organizational governance of

enterprises, and thus hinders the upgrading of industrial structure[3]. Regarding the "innovation compensation effect", De Vries F P (2005) found that rational environmental regulation encourages firms to actively integrate external expenditures on environmental regulation into their internal operations, which stimulates technological research and development, and enhances the use of resources and output returns. These innovative activities can partially or fully balance the increased costs due to environmental regulations, thereby realizing net gains and triggering an innovation-driven effect, which promotes the upgrading of industrial structure, i.e., the "Porter's hypothesis" put forward by the revisionist school of thought[4]. Han Jianyu and Zhang Chuanbo (2021) confirm that firms will promote the upgrading of manufacturing industry structure only when the innovation compensation effect caused by environmental regulation exceeds the compliance cost effect through panel data. In a short period of time, the compliance cost effect is smaller than the innovation compensation effect; over time, the compliance cost effect is larger than the innovation compensation effect, proving that there is a nonlinear relationship between environmental regulation and industrial structure upgrading [5].

There are also different findings when exploring the mechanism of the impact of environmental regulation on industrial structure upgrading, Yin Yufei and Yang Xuefeng (2022) take panel data of 113 cities in China as the research object, and the results show that technological innovation plays a positive mediating effect in the relationship between environmental regulation and industrial structure upgrading [6]. Zhang Qian and Lin Yingzhen (2022) used the threshold model to show that the impact of environmental regulation on industrial structure advanced will show different effects depending on the differences in the level of technological innovation [7]. Zheng Zuyuan et al. (2023) empirically verified two paths through mechanism analysis, and the main paths of environmental regulation and industrial structure upgrading are forced technological progress and foreign investment [8]; Huang Shanshan et al. (2023) analyzed the mechanism of domestic environmental regulation and industrial structure upgrading in-depth, and demonstrated that environmental regulation can promote the upgrading of China's industrial structure through the paths of technological innovation and adjustment of consumption structure, while through the paths of foreign investment, the impact of environmental regulations on the upgrading of China's industrial structure will be different depending on the level of scientific and technological innovation. (2023) showed that environmental regulations can promote China's industrial structure upgrading through technological innovation and consumption structure adjustment, while they may inhibit industrial structure upgrading through foreign trade and foreign investment[9].

In summary, from the perspective of green technological innovation, research on the link between environmental regulation and industrial structure upgrading is still relatively limited and mainly focuses on the national macro level or a specific province. In view of this, this study incorporates green technology innovation as a mediating variable, and explores the mechanism of environmental regulation on the upgrading of manufacturing industrial structure in the Yangtze River Economic Belt and its regional differences with the help of empirical analysis, in order to provide us with a more profound and comprehensive understanding of the mechanism of environmental regulation on the upgrading of manufacturing industrial structure.

3. Research Design

3.1. Model Construction

In order to deeply explore the role of environmental regulation in promoting the transformation and upgrading of industrial structure, we must consider the interaction effect between environmental regulation and green technology innovation. However, a simple interaction term regression may only show the internal interaction between environmental regulation and green technological innovation, but does not fully elaborate the transmission mechanism of green technological innovation. In order to accurately identify this transmission mechanism, this study constructs the following sequential recursive model with reference to the validation strategy of the mediation effect, aiming to test the consecutive transmission process from environmental regulation to green technological innovation, and then to the upgrading of manufacturing industry structure:

$$ISH_{it} = \alpha_1 + c\ln_{ER_{it}} + \sum_{i=1}^{6} \alpha_{it} Z_{it} + \varepsilon_{it} \quad (1)$$

$$\ln_{TECH_{it}} = \alpha_2 + a\ln_{ER_{it}} + \sum_{i=1}^{6} \alpha_{it} Z_{it} + \varepsilon_{it} \quad (2)$$

$$ISH_{it} = \alpha_3 + c'\ln_{ER_{it}} + b\ln_{TECH_{it}} + \sum_{i=1}^{6} \alpha_{it} Z_{it} + \varepsilon_{it} \quad (3)$$

Where the coefficient c in equation (1) is the total effect of environmental regulation on the upgrading of manufacturing industry structure; the coefficient a in equation (2) is the effect of environmental regulation on the mediating variable TECH; and the coefficients, b, in equation (3) are the effects of environmental regulation and mediating variables together on the upgrading of manufacturing industry structure. Where the subscript i denotes each province and t represents time; ISH_{it} represents the degree of manufacturing industry structure heightening, ER_{it} represents the coercion of environmental regulation, $TECH_{it}$ represents the intensity of green technology innovation, Z_{it} represents the set of control variables; ε_{it} is the residual term, $\alpha_1, \alpha_2, \alpha_3$ are all constants.

3.2. Variable Setting and Data Sources

3.2.1. Explained Variables

Manufacturing industry structure heightened (ISH). At present, there exists a certain analysis on the measurement of the indicators of manufacturing industry structure upgrading, and most scholars start from the two perspectives of rationalization and advanced industrial combination system to comprehensively assess the comprehensive level of industrial structure upgrading. The advanced manufacturing industry structure can be regarded as a key indicator of the upgrading of the manufacturing industry structure. In order to accurately capture the gradual increase in the technology intensity of the manufacturing industry, this study adopts the ratio of the output value of the high-end technology industry to the output value of the mid-range technology industry as an indicator of the upgrading of the manufacturing industry structure, based on the strategy proposed by Chunhui Gan et al. (2011) [10]. It is worth noting that, since the data of total industrial output value by industry are no longer publicized after 2012, and the industrial sales output value has a high similarity with the total industrial output value, this paper chooses the industrial sales output value as a substitute indicator for the total industrial output value to calculate the index of heightened manufacturing structure.

3.2.2. Explanatory Variables

Environmental Regulation Intensity (ER). In today's academic field, researchers have shifted from simple single indicators to comprehensive index measurements in measuring environmental regulation intensity. The main approach is to construct a comprehensive index method based on the amount of investment in pollution control and pollution emissions. Given the completeness and availability of data, this paper draws on the method of Xu Changping and Wu Minjie (2016) to measure environmental regulatory intensity, which is measured in terms of the amount of investment in pollution control per 10,000 yuan of gross industrial output value in each province [11].

3.2.3. Mediating Variables

Green technological innovation (TECH). For different research fields, the measurement standard of green technological innovation may present some heterogeneity. Academic methods of measuring green technological innovation can be mainly categorized into two main groups: one is to measure it through both inputs and outputs; the other is to measure green total factor productivity to measure green technological innovation. In view of the availability of data, this paper draws on Xu Xiaoshu et al. (2022) to select the number of green invention patents granted as an indicator for measuring green technological innovation [12].

3.2.4. Control Variables

Urbanization level (URB). On the one hand, urbanization can enhance the quality of human capital to accelerate the introduction and integration of technology, which in turn has an impact on the upgrading of industrial structure; on the other hand, with the promotion of urbanization, the deepening of the industrial division of labor also affects the upgrading of industrial structure. This paper adopts the proportion of urban resident population to total resident population to measure the level of urbanization.

Foreign Direct Investment (FDI). On the one hand, FDI introduces a large amount of capital, such as setting up factories in the region, which in turn stimulates the growth of the local manufacturing industry and the evolution of the industrial structure. On the other hand, FDI is accompanied by technological spillover benefits, and its impact on industrial structure upgrading is a combination of the above effects. In order to accurately reflect the level of foreign investment, this study chooses the ratio of FDI to GDP as a measurement indicator.

Openness to the outside world (OPEN). The degree of economic openness, technological openness and social openness of domestic openness to the outside world will have an impact on industrial structure upgrading. This paper adopts the proportion of total import and export to GDP to measure the degree of openness to the outside world.

3.2.5. Data Sources

As a leading country in the global manufacturing industry, China has surpassed the United States and ranked first in the world in terms of manufacturing scale since 2011. Therefore, this paper selects the 2011-2022 data of 11 provinces in the Yangtze River Economic Belt for research. The data in this paper mainly come from “China Research Data Service Platform (CNRDS)”, “Provincial Statistical Yearbook”, “China Industrial Statistical Yearbook”, “China Environmental Statistical Yearbook”, and National Research Network. Linear interpolation was used to fill in some of the missing values.

4. Empirical Analyses

4.1. Descriptive Statistics and Model Selection

4.1.1. Descriptive Statistics

In order to ensure the robustness of the research results, and effectively avoid the impact of potential factors such as heteroskedasticity, while enhancing the stability of the data, this study has carried out a logarithmic transformation of the existing absolute amount of data. The descriptive statistics of the relevant variables are detailed in Table 1.

Table 1. Statistical description of the main variables

Variable	N	Mean	SD	Min	Max
Y	121	2.448	1.504	0.389	7.850
lnX	121	2.805	0.722	0.502	4.346
lnM	121	6.255	1.336	1.609	8.841
URB	121	0.554	0.156	0.281	0.896
FDI	121	0.025	0.013	0.001	0.053
OPEN	121	0.322	0.343	0.0290	1.606

4.1.2. Model Selection

Table 2. Panel data regression results

	(1)	(2)	(3)
	OLS	FE	RE
lnX	-0.617***	-0.506***	-0.477***
	(0.112)	(0.104)	(0.115)
	8.007***	4.045***	9.147***
	(1.014)	(1.479)	(1.160)
K2	3.062	-20.461*	-0.146
	(8.081)	(10.625)	(9.708)
K3	-0.613	-5.597***	-1.346**
	(0.521)	(0.794)	(0.604)
_cons	-0.140	3.953***	-0.844
	(0.671)	(1.078)	(0.755)
N	121.000	121.000	121.000
r2	0.673	0.579	
r2_a	0.662	0.524 Prob > chi2 = 0.0006	

Note: t/z statistics are in parentheses, *, ** and *** correspond to 1%, 5% and 10% significance levels, respectively.

Using STATA 17.0 software, this study estimated the mixed regression model, fixed effects model (FE) and random effects model (RE) on the data. The corresponding estimation results are presented by Equation 1, Equation 2 & Equation 3 respectively and detailed in Table 2.

Before performing panel data regression, it is necessary to establish a suitable model first. First, the F-test was conducted and the result of "P>F=0" was obtained, according to which the mixed regression model was rejected and the fixed effect model was selected. Further, the Hausman test showed that the original hypothesis was rejected and thus the fixed effect model was determined.

4.2. Estimated Results and Analysis of Mediating Effect Models

Based on the panel data of 11 provinces in the Yangtze River Economic Belt from 2011 to 2022, this study conducted regression analysis on each of the three aforementioned models with the aim of exploring whether green technology innovation has a mediating role in the process. The results of the regression analysis conducted with the help of STATA 17.0 software are detailed in Table 3.

Table 3. Regression results of the mediated effects model

	(4.1)	(4.2)	(4.3)
	Y	lnM	Y
lnX	-0.506***	-0.178**	-0.426***
	(0.104)	(0.075)	(0.101)
URB	4.045***	5.891***	1.421
	(1.479)	(1.067)	(1.597)
FDI	-20.461*	2.253	-21.464**
	(10.625)	(7.661)	(10.114)
OPEN	-5.597***	-2.146***	-4.641***
	(0.794)	(0.572)	(0.804)
lnM			0.445***
			(0.128)
_cons	3.953***	4.125***	2.115*
	(1.078)	(0.777)	(1.154)
N	121.000	121.000	121.000
r2	0.579	0.432	0.623
r2_a	0.524	0.357	0.569

Note: *, **, and *** shown in the table represent significant correlations at the 10%, 5%, and 1% levels (two-sided), respectively, with robust standard errors in parentheses.

Model (4.1) conducted a regression analysis of the overall relationship between environmental regulation and the structural upgrading of the manufacturing industry. According to the analyzed data presented in the table, environmental regulation presents a significant negative effect on the structural upgrading of the manufacturing industry. Specifically, whenever the intensity of environmental management strategy increases by 1 unit, the structural heightening of manufacturing industry will decrease by 0.506 units. Among the control variables, the coefficient of urbanization level is positive and significant, which indicates that urbanization level positively promotes the upgrading of manufacturing industry structure in the Yangtze River Economic Belt. On the contrary, the regression coefficients of OFDI and economic openness are significantly negative. This may be related to the fact that this study adopts the proportion of OFDI to GDP to measure OFDI and the ratio of total import and export to GDP to measure the degree of economic openness, which is not conducive to the upgrading of the manufacturing industry structure, considering that China currently imports and exports more high-tech manufacturing products.

Model (4.2) aims to explore the role of environmental regulation on green technology innovation. The data analysis shows that environmental regulation has a significant negative effect on green technology innovation. This indicates that under the background of stricter environmental regulations, enterprises encounter increased end-of-pipe pollution control expenses, and thus the "innovation compensation effect" fails to exceed the "compliance cost effect" caused by environmental regulations. Model (4.3) mainly adds the mediating variable green technology innovation. Based on the data, the regression parameter of green technology innovation shows a significant positive effect, however, the parameter of environmental regulation still shows a negative correlation. However, its effect on the heightened industrial structure of manufacturing industry is significantly weakened. This clearly shows that environmental regulation not only indirectly affects the upgrading of manufacturing industry structure through the mediating role of green technology innovation, but also directly restricts the process of upgrading of manufacturing industry structure.

4.3. The Impact of Environmental Regulation on the Upgrading of Manufacturing Industry Structure based on Regional Heterogeneity

The economic and manufacturing development level of each region is affected by a variety of factors such as the degree of urbanization, talent cultivation and the degree of opening to the outside world, so there is significant heterogeneity. This inter-regional heterogeneity may further lead to differences in the role of environmental regulations on the upgrading of manufacturing industry structure among

regions. In order to study this heterogeneous effect in more detail, this study divides the 11 provinces in the Yangtze River Economic Belt into upstream, middle and downstream regions according to their geographic locations, and conducts regression analysis for each region. The specific regression results are as follows: in the upstream, for every 1 unit of environmental regulation, the level of manufacturing industry structure heightening decreases by 0.043 units; in the middle reaches, the negative effect of environmental regulation on the upgrading of the manufacturing industry structure is the most significant, with a specific regression coefficient of -0.853; in the downstream, the corresponding regression coefficient is -0.7, which also shows the significant inhibitory effect of environmental regulation on the upgrading of the manufacturing industry structure. The significant inhibitory effect of environmental regulation on the upgrading of manufacturing industry. The regression results obtained by STATA 17.0 software are shown in Table 4.

Table 4. Regression results for the upper, middle and lower regions

	Upstream	Middlestream	Downstream
	Y	Y	Y
lnX	-0.043***	-0.850**	-0.700***
	(0.100)	(0.332)	(0.191)
URB	7.509***	2.183	7.462**
	(1.661)	(3.011)	(3.281)
FDI	-27.215***	0.271	3.858
	(9.630)	(34.550)	(22.026)
OPEN	-0.661	-12.023	-6.780***
	(1.268)	(10.321)	(1.157)
_cons	-1.134**	4.597*	4.346**
	(1.211)	(3.183)	(2.688)
N	44.000	33.000	44.000
r2	0.800	0.237	0.753
r2_a	0.761	0.061	0.705

Note: ***, **, and * indicate significant at 1%, 5%, and 10% significance levels, respectively.

From the above analysis, it can be seen that environmental regulation has an inhibitory effect on the upgrading of the manufacturing industry structure in the Yangtze River Economic Belt, and the inhibitory effect of environmental regulation on the upgrading of the manufacturing industry structure is strongest in the middle reaches of the Yangtze River Economic Belt, followed by the downstream, and weakest in the upstream. This phenomenon may be due to the fact that the downstream has a higher level of manufacturing development compared with the middle reaches, and the constraining effect of the same intensity of environmental regulation on the downstream manufacturing industry structure upgrading in the Yangtze River Economic Belt is weaker. The upstream has the lowest level of manufacturing development, so the negative impact of environmental regulations on the upstream's manufacturing industrial structure intensification is the weakest.

5. Conclusion and Recommendations

5.1. Conclusion

Using panel data of 11 provinces in the Yangtze River Economic Belt from 2011-2022, this paper empirically investigates the role of environmental regulation on the industrial structure of manufacturing industry within the region by using a fixed-effects model. On this basis, the following points are concluded:

First, regarding the relationship between environmental regulation and the upgrading of manufacturing industry structure: the empirical data reveals that environmental regulation exhibits a significant reverse effect on the upgrading of manufacturing industry structure in the Yangtze River Economic Belt. This finding further highlights the importance of how to deal with the relationship between environmental regulation and the upgrading of manufacturing industry structure in the region in the development strategy of the Yangtze River Economic Belt.

Second, the mediating role of green technology innovation: the study further finds that green technology innovation plays a mediating role in the relationship between environmental regulation and the upgrading of manufacturing industry structure in the Yangtze River Economic Belt. Specifically, although environmental regulations still have a negative impact on industrial structure upgrading, the positive regression coefficient of green technological innovation can reduce this negative effect to a certain extent. In the long run, strengthening green technological innovation can make environmental regulations have a more positive impact on the upgrading of manufacturing industry structure.

Third, the impact of regional heterogeneity: further analysis shows that the impact of environmental regulations on the upgrading of manufacturing industry structure is heterogeneous in different regions of the Yangtze River Economic Belt. Specifically, the negative impact of environmental regulations is strongest in the midstream region, followed by the downstream region, while the impact is relatively weak in the upstream region. This heterogeneity may stem from the variability in the degree of environmental regulation and the development dynamics of the manufacturing industry across regions.

5.2. Recommendations

First, considering the reverse impact triggered by environmental regulation on the manufacturing industry structure of the Yangtze River Economic Belt, the government can appropriately provide preferential policies, such as tax breaks, to reduce the production costs of enterprises.

The second is to strengthen the interaction between environmental regulation and green technological innovation

to promote the development of the heightened manufacturing structure of the Yangtze River Economic Belt. Specifically, green technological innovation as an effective way of environmental regulation on the heightening of the manufacturing industry structure, its depth of promotion can not only offset the short-term negative impact of environmental regulation, but also from a long-term perspective, can make environmental regulation and the upgrading of the industrial structure of the manufacturing industry to form a mutually beneficial and win-win relationship between. To this end, it is necessary to increase the financial support for research and development of high-tech industries, in order to solve the problem of capital shortage that enterprises may encounter in the process of technological innovation, and further stimulate the motivation of technological innovation of enterprises.

Thirdly, when formulating and implementing environmental regulation strategies, due consideration should be given to regional differences, and differentiated environmental regulation strategies should be designed for each region of the Yangtze River Economic Belt, so as to minimize its potential obstacles to the process of heightening the manufacturing industry.

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