Original Research Article

The effect of environmental regulation on the competitiveness of pharmaceutical manufacturing industry

Abstract

Environmental regulation, as a tool for the government and society to reduce environmental pollution and achieve social civilization and sustainable economic development, has long been a key factor in economic development, and it is of great significance to explore the impact of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry on the development of China's manufacturing industry. Based on China's provincial panel data from 2011-2021, an evaluation system is constructed from four dimensions: scale, efficiency, innovation and input, the entropy method is applied to measure the competitiveness indicators of China's pharmaceutical manufacturing industry, and a benchmark regression is constructed through a two-way fixed-effects model, and heterogeneity test, robustness test and mediation test are conducted. It is found that environmental regulation has a significant positive effect on the competitiveness of China's pharmaceutical manufacturing industry, and there are differences in the impact on each region. In addition to direct empowerment, environmental regulation also enhances the competitiveness of pharmaceutical manufacturing industry through technological innovation, and its mediation effect is significant. Finally, based on the above findings, it is recommended that the intensity of environmental regulations and subsidies should be increased, differentiated environmental regulation policies should be formulated, and milder market interventions should be used to create a healthy and positive market

environment, and the introduction of scientific and technological talents should be increased in order to enhance the scientific research strength of China's pharmaceutical manufacturing industry.

Keywords: environmental regulation; pharmaceutical manufacturing industry; technological innovation

1. Introduction and Literature Review

In recent years, the concept of "green mountains are golden mountains" has gradually taken root in people's hearts, and the coordinated development of ecology and economy has become the road to social development[1]. Besides, the 20th National Congress of the Communist Party of China (**CPC**) and the 14th Five-Year Plan have clearly pointed out the need to promote the construction of an ecological civilization and economic development. As early as 2002, the National People's Congress (**NPC**) passed a policy on environmental regulation. Implementation of the Law of the People's Republic of China on the Promotion of Cleaner Production, which regulates production and operation standards in the manufacturing industry[2]. Nowadays, China's proposed "carbon peak, carbon neutral" goal from the relative emission reduction has changed to achieve zero emissions, so ecological and environmental issues in the economic development of the increasingly important, manufacturing industry to achieve competitiveness enhancement in the strict environmental regulations will be the focus of our research. As part of the high-tech industry, the pharmaceutical manufacturing industry is not significant in terms of innovation, and has long been in a low value-added, low-level stage, and produces a large number of chemical and hazardous substances in the production process, causing pollution to the environment[3]. To accomplish the goals of ecological protection and industrial competitiveness enhancement, it is necessary to explore the relationship between environmental regulations and the pharmaceutical manufacturing industry, and put forward corresponding policy recommendations to realize the energy-savingand healthy path of economic development.

Most of the existing literature on environmental regulation focuses on enterprise performance, industrial structure transformation and upgrading, and high-quality

development, with different effects. In terms of enterprise performance, Murty (2003) found through the study of wastewater treatment enterprises that environmental regulation policies promote, to a certain extent, the improvement of enterprises in the process and technological innovation, to achieve the purpose of improving enterprise performance [4]. In addition to technological changes, environmental regulation can also influence enterprises to inject more funds into environmental protection to improve enterprise performance through fines, closure and rectification [5]. In terms of industrial structure adjustment, environmental regulation mainly optimizes the industrial structure so as to realize the green transformation of industries and enhance competitiveness [6]. With the increase in the intensity of environmental regulation, enterprises have to carry out technological research and development and innovation in order not to be eliminated by the market, so as to obtain the transformation of industrial structure [7]. Some scholars also found that compared with informal environmental regulation, formal environmental regulation is more able to incentivize enterprises to transform and upgrade, and has a "U" type relationship with it [8]. On the other hand, some scholars hold the opposite view, they believe that environmental regulation will lead to an increase in the external production costs of enterprises, triggering a decline in industrial competitiveness, which is not conducive to the transformation and upgrading of industrial structure [9]. In terms of industrial high-quality development, most scholars support the view that environmental regulation contributes to industrial high-quality development, and studies have found that the tax and fee system implemented by environmental regulation can constrain the pollution emissions of enterprises and save production resources [10]. In terms of resource allocation, environmental regulation can stimulate the innovation vitality of enterprises, optimize resource allocation, and achieve the improvement of green total factor productivity [11]. In the long run, the impact of environmental regulation on economic development belongs to the type of first suppression and then enhancement, and the implementation of strict policies plays a certain inhibitory effect on the development of small and micro enterprises [12]. It has also been pointed out that environmental regulations to some extent limit the production and business activities

of enterprises, hindering the development of high-quality economy, but there is a spatial spillover effect on the neighboring cities [13].

Exploring the impact of environmental regulation on industrial competitiveness mostly involves the enterprise or industry level such as manufacturing and industry. Kai Wang (2012) collected panel data and concluded that the strengthening of environmental regulations initially inhibits the development of the industrial sector, but in the long run, the increase in the intensity of environmental regulations is accompanied by the growth of trade in the industry [14]. Similarly, strict environmental regulatory policies are detrimental to the international competitiveness of low-carbon manufacturing industries in the short run, an effect that is particularly pronounced in developing countries [15], and their impact on international competitiveness is multidimensional, with both a direct boost to the economy and a mediated technology premium [16]. However, reasonable environmental regulatory policies can bring innovation compensation effects, incentivize enterprises to continuously develop innovation and enhance competitiveness [17]. Strict environmental regulatory policies can also force enterprises to continuously carry out technological research and development, improve product quality and competitiveness, so as to stand firm in the market [18].

As an important part of the national economy, the pharmaceutical manufacturing industry is related to people's health, economic prosperity and social stability. Existing literature on environmental regulation affects the pharmaceutical manufacturing industry is less research, by exploring the role of environmental regulation and pharmaceutical manufacturing competitiveness between the effect of the role of this field of research, and has an important significance for China's scientific development in the field of ecological environment and pharmaceutical industry. Based on this, this paper builds a competitiveness evaluation system by utilizing various indicators of the pharmaceutical manufacturing industry, and empirically examines the mechanisms and paths of the impact of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry by collecting provincial panel data from 2011-2021, with a view to providing new policy ideas for the improvement of the

competitiveness of the pharmaceutical manufacturing industry and the high-quality development of the economy.

2. Theoretical Analysis and Research Hypotheses

The relationship between environmental regulation and the competitiveness of the pharmaceutical manufacturing industry is inextricably linked. "Porter's hypothesis suggests that appropriate environmental regulation can offset the cost of protection, thereby stimulating industrial renewal, improving productivity and enhancing industrial competitiveness. For some heavily polluting firms, environmental regulations can also force them to reform and innovate, which will incentivize the improvement of their competitiveness [19]. For pharmaceutical manufacturing enterprises that comply with environmental regulations, the government will also provide generous subsidies to reduce tax pressure for enterprises to carry out production activities, thus promoting the active development of process research and development within the enterprise, technological innovation and other activities to achieve the transformation of the industrial structure and sustainable development, and enhance the competitiveness of the pharmaceutical manufacturing industry. In the long run, environmental regulation will also give the pharmaceutical manufacturing industry a certain "first-mover advantage" and "innovation compensation effect" [20]. In addition, the implementation of environmental regulations to help the industry in the development of timely correction of the wrong direction of research and development, industrial structure adjustment and industrial chain transformation and upgrading, and over time, to achieve the optimization of the industrial structure of the entire region [21]. Under this effect, the enterprise labor productivity is subsequently increased, the sustainable development force is enhanced, and the competitiveness of the pharmaceutical manufacturing industry is finally realized. In the policy guidance, the production of the industry itself for environmental protection issues weak awareness, and the government through a series of policy promulgation and activities to publicize, can be from the external constraints on the production and management activities of enterprises, environmental awareness to the internal transfer of the enterprise to improve the competitiveness of the industry [22]. Enterprises continue to

improve their cultural soft power, and the industry's reputation rises along with it, which in turn improves the competitiveness within the industry. Based on this, this paper proposes hypothesis 1.

H1: Environmental regulation can promote the development of competitiveness in the pharmaceutical manufacturing industry.

Environmental regulation has different impacts on the competitiveness of the pharmaceutical manufacturing industry in different regions. Different levels of economic development in different regions of China, the scale and development of the pharmaceutical manufacturing industry, there are also differences. The eastern region represented by Jiangsu, Shandong, Zhejiang, pharmaceutical enterprises have an overall advantage, while Gansu, Qinghai and other western regions, talent, capital and other resource elements are scarce, the overall strength is very weak [23]. In terms of policy response, the eastern region of the various infrastructure is relatively perfect, urban planning is more standard, the industry is more likely to respond positively to the system of publicity, which will help to obtain policy assistance, to achieve competitiveness, and in the manufacturing industry competitiveness of the development of a high level of the region, has a rich resource advantage and advanced scientific and technological strength, in the enhancement of the environmental regulations at the same time, the manufacturing industry enterprises are also constantly improving themselves, to promote high-quality development, while in the level of development of more backward regions, slow economic development, policy promotion is difficult to implement, environmental regulations increase the cost of enterprise investment, so that its competitiveness is not as significant as the high level of the region [24]. The effects of environmental regulations vary across market environments. In regions with a higher degree of marketization and better government regulation, the adverse effects of environmental regulations on enterprise productivity can be suppressed to a certain extent, and a well-institutionalized market environment can reduce the additional burden of environmental regulations on enterprises and the transaction costs of production[25], thus achieving an increase in enterprise productivity and competitiveness. Based on this, this paper proposes hypothesis 2.

H2: There is regional heterogeneity in the role of environmental regulation on the competitiveness of pharmaceutical manufacturing industry.

Environmental regulation can be utilized to develop the pharmaceutical manufacturing industry through technological innovation. The implementation of environmental regulation policies has imposed higher requirements on the industrial structure of the industry. In order to survive and generate revenues under strict regulations, enterprises must improve their innovation capabilities, update their processes and green their production processes. The utilization efficiency and green attributes of products are increasing under environmental regulations, which stimulates companies to carry out technological research and development activities, and to a certain extent, offsets the increase in production costs caused by environmental regulations [26]. In addition, environmental regulation also provides a healthy and favorable market environment for pharmaceutical manufacturing enterprises, forcing those high-polluting and low-energy-consuming enterprises to have to withdraw from the market by raising the technological barriers in the market, and providing a greater market advantage for those enterprises that are actively updating their R&D. For example, environmental regulation can utilize external factors: market structure, technological spillovers, etc. to influence the innovative activities of enterprises, thus stimulating industrial development [27]. From the perspective of the entire production cycle, the enhancement of environmental regulation raises the standard of sewage discharge in production, resulting in an increase in production costs, and enterprises have to develop new technologies to reduce costs and improve utilization efficiency, thus obtaining an increase in profits, and the resulting enterprise performance will be used for technological research and development, and the cycle repeats itself, realizing competitiveness enhancement and upgrading of industrial structure. When environmental regulation reaches a certain level, it will stimulate the technological innovation activities of enterprises, reduce production energy consumption, maximize the output level, eliminate backward production capacity, and drive the high-quality development of the manufacturing industry [28]. Based on this, this paper puts forward hypothesis 3.

H3: Environmental regulation enhances the competitiveness of pharmaceutical manufacturing industry by promoting technological innovation.

3. Research design

3.1 Model design

In order to test the influence mechanism of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry, a general econometric model (1) is established to study the direction and intensity of the role of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry on the basis of controlling the degree of openness to the outside world, the level of economic development and the transformation of industrial structure.

$$Mc_{it} = C + \alpha_0 En_{it} + \sum_{j=1}^{n} \alpha_j Control_{it}^{j} + \mu_t + \varphi_i + \varepsilon_{it} (1)$$

Where Mc_{it} is the explained variable pharmaceutical manufacturing competitiveness, En_{it} is the explanatory variable environmental regulation, and $Control_{it}^{j}$ is the control variables, including the degree of opening to the outside world (Open), the level of economic development (GDP) and industrial structure transformation (In). The subscripts i and t represent provinces and years, respectively; **C** is the intercept term; α is a parameter; μ_t is time fixed and ϕ_i is province and city fixed; and ε_{it} is a random perturbation term.

In addition, in order to test whether environmental regulation can promote the competitiveness of pharmaceutical manufacturing industry by enhancing technological innovation, pharmaceutical manufacturing industry competitiveness (Mc) and environmental regulation (En) are still taken as the explained variables and explanatory variables, the mediating variable is the level of technological innovation (Pa), and the control variables are kept unchanged.

$$Mc_{it} = C_1 + \theta_1 En_{it} + \sum_{j=1}^{n} \alpha_j Control_{it}^{j} + \mu_t + \varphi_i + \varepsilon_{it} (2)$$

$$Pa_{it} = C_2 + \theta_2 En_{it} + \sum_{j=1}^{n} \alpha_j Control_{it}^{j} + \mu_t + \varphi_i + \varepsilon_{it} (3)$$

3.2 Variable Selection and Indicator Description

(1) Explained variable: pharmaceutical manufacturing competitiveness (Mc). Drawing on the research of Hu Kun (2020) [29] and Lei Yu (2022) [30], etc., the data related to

the pharmaceutical manufacturing industry from 2011-2021 were selected from the Statistical Yearbook of China's High-technology Industry, and the entropy method was utilized to carry out the measurements. The specific operational steps are as follows:

Step 1: Standardized treatment:

$$\text{Positive indicators: } X_{ij}' = \frac{X_{ij} - minX_{ij}}{maxX_{ij} - minX_{ij}} \quad (3.1)$$

$$\text{Negative indicators: } X_{ij}' = \frac{maxX_{ij} - X_{ij}}{maxX_{ij} - minX_{ij}} \quad ((3.2)$$

$minX_{ij}$、$maxX_{ij}$ are the minimum and maximum values in the indicator j, respectively; the value range of each element is $0 \leqslant X_{ij}' \leqslant 1$; the value range ofj in X_{ij} is $1 \leqslant j \leqslant n$。

Step 2: Calculate the weights

Calculate the contribution value of each indicator:

$$p_{ij} = \frac{X_{ij}'}{\sum_{i=1}^{n} X_{ij}'} \quad (3.3)$$

Calculate the entropy value of each indicator:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (3.4)$$

i=1，2，…，m；j=1,2，…，n

Calculation of the degree of variability of indicators

$$G_j = 1 - e_j \quad (3.5)$$

j=1,2，…，n

Determination of weights for indicators

$$W_j = \frac{G_j}{\sum_{j=1}^{n} G_j} \quad (3.6)$$

Analyzing the competitiveness of pharmaceutical manufacturing industry, which mainly includes scale competitiveness, efficiency competitiveness, innovation competitiveness and input competitiveness, the entropy value method is utilized to construct the pharmaceutical manufacturing industry competitiveness evaluation index system from four dimensions, which contains 4 first-level indexes and 13 second-level indexes, as shown in Table 1.

Table 1 Competitiveness evaluation index system of pharmaceutical manufacturing industry

first-level	second-level indexes	Indicator	weights

indexes		properties	
scale competitiveness A1	Number of enterprises A11 (units)	+	0.0459
	Average number of employees A12 (persons)	+	0.0475
efficiency competitiveness A2	Revenue from main business A21 (RMB billion)	+	0.0618
	Total profits A22 (RMB billion)	+	0.0783
innovation competitiveness A3	Number of patent applications A31 (cases)	+	0.0716
	Number of active invention patents A32 (cases)	+	0.0734
	Revenue from sales of new products A33 (RMB million)	+	0.0981
	Number of enterprises with research and development organizations A34 (units)	+	0.0717
	Number of institutional personnel A35 (persons)	+	0.0770
input competitiveness A4	R&D personnel equivalent full-time equivalent A41 (person/year)	+	0.0658
	Internal expenditure on R&D funding A42 (RMB million)	+	0.0948
	Expenditure on new product development A43 (RMB million)	+	0.0950
	Expenditure of agency funds A44 (RMB million)	+	0.1189

Source: Statistical Yearbook of China's High-Tech Industries.

The competitiveness of the pharmaceutical manufacturing industry is categorized into four main dimensions:

Scale competitiveness: Reflects the level of industrial scale and the size of employees in the pharmaceutical manufacturing industry.

Efficiency competitiveness: Reflects the pharmaceutical manufacturing industry's level of income and profitability.

Innovation competitiveness: Reflects the pharmaceutical manufacturing industry's ability to develop new products and the level of resources invested in research and development work.

Input competitiveness: Reflects the pharmaceutical manufacturing industry's R&D investment and government support for innovation.

(2) Explanatory variables: environmental regulation (En), expressed in terms of the proportion of completed investment in industrial pollution control to GDP. Environmental regulation reflects the strength of environmental protection in a country or region, and is the government's mandatory supervision, intervention and regulation of the production and business activities of enterprises, so as to realize the dual purpose of sustainable economic development and ecological protection.

Generally speaking, the larger the coefficient of environmental regulation, the stricter the environmental protection.

(3) Mediating variable: technological innovation (Pa),is an important means of R&D in the pharmaceutical manufacturing industry, which can enhance productivity and resource utilization, thus improving the competitiveness of the pharmaceutical manufacturing industry, as expressed by the number of authorized patent applications per capita.

(4) Control variables: including the degree of opening to the outside world (Open), the level of economic development (GDP) and industrial structure transformation (In). Among them, the degree of opening to the outside world (Open) is expressed by the proportion of total import and export of goods to GDP,which represents a region's foreign trade and acceptance of foreign investment.The level of economic development (GDP) is the gross domestic product of each province, whichrepresents the results of the region's production operations over a certain period of time. The transformation of industrial structure (In) is expressed by the added value of the tertiary industry divided by the added value of the secondary industry, which represents the flow of productive and labor resources.

3.3 Data sources and descriptive statistical analysis

Due to the serious missing data of Tibet and Ningxia provinces, this paper selects the panel data of 29 Chinese provinces (except Hong Kong, Macao, Taiwan, Tibet and Ningxia) from 2011-2021 as the research sample, and the data are obtained from China Statistical Yearbook, China High-Tech Industry Statistical Yearbook and National Bureau of Statistics. Individual missing values in the sample are supplemented by linear interpolation, and the descriptive statistics of the variables are shown in Table 2.

Table 2 Descriptive statistics of variables

variables	sample size	averages	standard deviation	minimum	maximum
Mc	319	0.1227	0.1181	0.0054	0.4527
En	319	0.0009	0.0007	0.0002	0.0026
Pa	319	3.1226	0.4448	2.3389	3.8983

Open	319	0.2610	0.2550	0.0423	0.9753
GDP	319	4.3157	0.3228	3.5685	4.8641
In	319	1.2056	0.5194	0.6360	2.7511

As can be seen from Table 2, the mean values of environmental regulation and the competitiveness level of the pharmaceutical manufacturing industry are 0.1227 and 0.0009, and the gap between the maximum value and the minimum value is large, which initially indicates that the intensity of environmental regulation and competitiveness level of different regions are differentiated.

4. Empirical results and analysis

4.1 The test of the impact of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry

Before carrying out the regression, this paper first carried out the covariance test, and the results show that there is no serious covariance, and the following regression can be carried out. In addition, all variables also passed the F test and Hausman test, so the fixed effect model was selected for empirical analysis, and the regression results are shown in Table 3.

Table 3 Regression results of environmental regulation on the competitiveness of pharmaceutical manufacturing industry

	(1)	(2)	(3)	(4)
	Mc	Mc	Mc	Mc
En	19.261***	16.604***	18.578***	19.068***
	(3.167)	(3.728)	(4.637)	(5.046)
Open		-0.257***	-0.251**	-0.235**
		(-3.202)	(-2.585)	(-2.562)
GDP			0.165***	0.137**
			(2.926)	(2.323)
In				-0.032**
				(-2.250)
_cons	0.057***	0.135***	-0.556**	-0.417
	(4.608)	(5.430)	(-2.235)	(-1.590)
N	319	319	319	319
R^2	0.463	0.540	0.586	0.596
Area control	YES	YES	YES	YES
time control	YES	YES	YES	YES

Note: "***", "***", and "*" indicate significance at the 1%, 5%, and 10% levels, respectively, and values in parentheses are standard errors of the estimated coefficients. Same below.

Table 3 reports the results of the panel regression from 2011-2021. As can be seen from Table 3, the effect of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry is significant without considering the control variables, and the competitiveness of the pharmaceutical manufacturing industry increases by 19.261% unitswhen the intensity of environmental regulation increases by every 1%units. The increase in the intensity of environmental regulations will promote the optimization of the industrial structure in the region in the long run, thus achieving the transformation and upgrading of the pharmaceutical manufacturing industry and the improvement of its competitiveness [31].With the gradual addition of control variables, the significance of the effect of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry remains unchanged, which therefore verifies that **H1** holds. Among them, the degree of opening up to the outside world and the transformation of industrial structure have a negative effect on the competitiveness of the pharmaceutical manufacturing industry, probably due to the fact that the increase in the level of opening up to the outside world causes other cost-effective pharmaceutical manufacturing enterprises to enter the domestic market and seize the market share, and the industrial structure is gradually shifted to the tertiary industry, which leads to the flow of the labor elements to the tertiary industry as well, thus reducing the human capital of the pharmaceutical manufacturing industry and triggering the decline in competitiveness. Economically, with the rise in the level of economic development, the pharmaceutical manufacturing industry is provided with perfect infrastructure and government support to help the pharmaceutical manufacturing industry develop.

4.2 Heterogeneity test

In order to test whether environmental regulation will enhance the competitiveness of the pharmaceutical manufacturing industry in each region, this paper divides China according to the three parts of the East, Central and West, and the results of the regression analysis are shown in Table 4.

Table 4 Sample regression results by region

	East	Central	West

	Mc	Mc	Mc
En	27.135*	9.954**	2.187
	(1.960)	(2.388)	(0.931)
_cons	0.155	-1.204***	-0.299*
	(0.124)	(-8.533)	(-1.840)
Control variables	YES	YES	YES
N	110	99	110
R^2	0.744	0.877	0.588
Area control	YES	YES	YES
time control	YES	YES	YES

As can be seen from Table 4, the region with the largest coefficient of influence of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry is in the east, with a better coefficient of influence in the center, while environmental regulation has the lowest influence on the competitiveness of the pharmaceutical manufacturing industry in the western region, and it is not significant. It may be because the eastern region itself has a higher level of economic development and regional innovation, better human capital and transportation and logistics efficiency, and better natural resource protection measures, so when the environmental policy began to be implemented, pharmaceutical manufacturing-related enterprises were more likely to adapt to the market changes brought about by the strict policy and actively utilize the governmental support to achieve industrial transformation and upgrading.

For the central region, all aspects of infrastructure and resource conditions are in the development stage. When environmental regulations are strictly implemented, they will appropriately crack down on some pharmaceutical manufacturing-related operators in the gray fringe areas, thus optimizing the business environment and helping to enhance industrial competitiveness. The central region compared to the east, the level of economic development and market environment is more backward, when foreign enterprises enter the market coupled with the lack of human capital level, will lead to the competitiveness of the central pharmaceutical manufacturing industry is constrained.

For the western region, the imperfections of its own infrastructure and resource

constraints will limit the development of the pharmaceutical manufacturing industry, while the western industrial structure is relatively homogeneous, the level of innovation is backward, and the environmental regulatory policies make the market operating environment more stringent, which leads to the bankruptcy of some small and medium-sized micro-pharmaceutical manufacturing enterprises. This also verifies the establishment of **H2**, indicating that environmental regulation has different impact effects on pharmaceutical manufacturing industry in different development regions.

4.3 Robustness test

Considering that the results of the equation benchmark regression may be affected by potential endogeneity or by the selection of indicators, this paper will carry out the robustness test from the following two aspects.

(1) Endogeneity problem

In order to further alleviate the problem of model endogeneity, this paper lags the explanatory variables and the explained variables by one period respectively as instrumental variables for two-stage least squares regression test. The regression results are shown in columns (1) and (2) in Table 5, and both results show that they are significant at the 1% level, indicating that the endogeneity test is passed.

(2) Replacement of explanatory and explained variables

Referring to Yumei He et al [32] on the measurement of environmental regulation, the completed investment in industrial pollution control is expressed as a proportion of industrial added value, which is brought into the model (1) for calculation to get the results in column (3) of Table 5. Since there is no uniform standard for the construction of indicators of pharmaceutical manufacturing competitiveness, this paper replaces the secondary indicators for measuring the competitiveness of pharmaceutical manufacturing industry, and the regression results are shown in column (4) of Table 5.

In columns (3) and (4), the environmental regulation on the competitiveness of the pharmaceutical manufacturing industry is still significant at the 1% level, and as the degree of environmental regulation increases, the competitiveness of the pharmaceutical manufacturing industry also expands, which indicates that the

regression results have a certain degree of robustness, and further verifies **H1**.

Table 5 Robustness test

	(1)	(2)	(3)	(4)
	Mc	Mc	Mc	Mc
En	18.450***	13.593***	5.042***	17.830***
	(4.980)	(3.450)	(4.013)	(4.380)
_cons	-0.433	-0.285	-0.340	-0.452
	(-1.493)	(-1.010)	(-1.296)	(-1.556)
Control variables	YES	YES	YES	YES
N	290	290	319	319
R^2	0.566	0.573	0.593	0.550
Area control	YES	YES	YES	YES
time control	YES	YES	YES	YES

4.4 Mediating effects test

In order to further explore the specific way of the role of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry, using the two-step method of TingJiang [33], the mechanism of environmental regulation to enhance the competitiveness of the pharmaceutical manufacturing industry through the promotion of technological innovation is identified and tested, and the results are shown in Table 6.

Table 6 Mediating effects test

	(1)	(2)
	Mc	Pa
En	19.068***	0.133**
	(5.046)	(2.195)
_cons	-0.417	0.002
	(-1.590)	(0.553)
Control variables	YES	YES
N	319	319
R^2	0.596	0.744
Area control	YES	YES
time control	YES	YES

As can be seen from Table 6, the role of environmental regulation on technological innovation is significantly positive at the 5% level, in which the regression coefficient of technological innovation is 0.133, indicating that when environmental regulation increases by 1% units, technological innovation will be

improved by 0.133% units. Qualified environmental regulation policy can promote the technological innovation of enterprises. Under the constraints of environmental regulation, enterprises will reduce the emission of pollutants and process improvementin order to long-term development, so as to improve their own level of technological innovation [34]. In addition, a high level of technological innovation can make enterprises in the trade market to increase the advantage and competitiveness of the enterprises to be significantly enhanced.Therefore, the mechanism of "environmental regulation-technological innovation-competitiveness of pharmaceutical manufacturing industry" is established, which also verifies **H3**.

5. Conclusion and Policy Recommendations

5.1 Conclusion

By studying the mechanism of environmental regulation on the competitiveness of the pharmaceutical manufacturing industry, this paper draws the following conclusions:

(1) From the perspective of the overall effect, the implementation of environmental regulation policy is conducive to the enhancement of the competitiveness of the pharmaceutical manufacturing industry, under the premise of not taking other factors into account, the environmental regulation on the competitiveness of the pharmaceutical manufacturing industry there is an impact, and the positive effect is significant.

(2) Environmental regulation in different regions of the significance of the existence of significant differences, the role of the eastern region of the pharmaceutical manufacturing industry competitiveness of the largest, the role of the central region of the effect of the significant effect on the western region of the pharmaceutical manufacturing industry competitiveness enhancement does not have a significant effect.

(3) Environmental regulation mainly enhances the competitiveness of pharmaceutical manufacturing industry by promoting technological innovation, and the mediating effect is significant.

5.2 Policy recommendations

First, increase the intensity of environmental regulations and subsidies. Currently, China does not have a high level of environmental regulation, and should increase the management of pollutant emissions from production, provide sufficient financial support and environmental subsidies to pharmaceutical manufacturing enterprises. Besides, China should also promote the use of innovative technologies to improve production efficiency and resource utilization. The government could start from itself and strictly follow the statute of environmental regulation, with clear rewards and penalties. In addition, the public can be encouraged to participate and monitor to ensure the sustainable development of the ecological environment and the physical and mental health of the population.

Second, formulating differentiated environmental regulation policies. Formulate and implement environmental regulation according to the actual situation of each region to ensure that the role of environmental regulation can be maximized to achieve the desired effect. From the empirical results, environmental regulation has a differentiated impact on the competitiveness of pharmaceutical manufacturing industry in different regions. Therefore, the government should be targeted to different regions to implement different environmental regulatory measures, moderately adjust the strength of environmental regulations in the western region, to avoid the inhibition of environmental regulations on the western region of the pharmaceutical manufacturing industry, while actively encouraging the central and eastern region of the pharmaceutical manufacturing enterprises to technological innovation, in order to promote the coordinated development of industry and the environment.

Third, the milder market intervention is adopted. In order to green and healthy development of the pharmaceutical manufacturing industry, should be realized through the flexible market mechanism and appropriate policy assistance. When foreign direct investment enterprises enter the domestic market, the government needs to give some timely help to domestic pharmaceutical enterprises. Therefore, the government must prudently control the strength of environmental regulation while increasing investment in environmental governance, reduce the strength of taxation,

actively encourage pharmaceutical manufacturing enterprises to spontaneously join in the action of green production, and improve the environmental awareness of production enterprises, so as to provide a harmonious market environment for the development of the entire pharmaceutical manufacturing industry, to avoid its negative impact on the competitiveness of the pharmaceutical manufacturing industry, and to realize the environmental and economic Green and harmonious co-progress.

Fourth, accelerate the introduction of talents to the pharmaceutical manufacturing industry. Pharmaceutical manufacturing industry is a technology-intensive industry, environmental regulation can promote enterprise technology innovation, and then enhance the pharmaceutical manufacturing enterprises of scientific and technological research and development strength, enhance competitiveness. On the one hand, enterprises should actively introduce scientific and technological talents with technological innovation ability, and pay attention to their training, and regularly organize various forms of talent exchange activities and training. On the other hand, to strengthen the national and regional technical exchanges, learning and reference to advanced experience, combined with the characteristics of different regions, the formation of innovative technologies with regional characteristics, and then build a unique regional competitive advantage in the pharmaceutical manufacturing industry.

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