



Environmental Regulation for Transfer of Pollution-Intensive Industries: Evidence From Chinese Provinces

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How environmental regulations affect the transfer of pollution-intensive industries is the core issue of balanced regional development and pollution reduction in China. This paper analyses the theoretical mechanism of the impact of environmental regulation on industrial transfer based on the distinction between formal environmental regulation and informal environmental regulation. To this aim, the paper selects panel data of 30 provinces in China from 2008 to 2018 and uses the fixed effect econometric model to test the impact of environmental regulation on the transfer of pollution-intensive industries, then uses a threshold regression model to study the threshold characteristics and spatial heterogeneity of environmental regulation on pollution-intensive industrial transfer. The results show a significant inverted U-shaped relationship between formal environmental regulation and the transfer of pollution-intensive industries. The increase of formal environmental regulation intensity affects restraining and then promoting the transfer out of pollution-intensive industries. The promoting effect also shows the characteristics of first increasing and then decreasing, verifying that there are threshold characteristics and spatial heterogeneity. Overall, informal environmental regulation promotes the transfer of pollution-intensive industries and shows the informal regulation's economic effect. The paper then puts forward the corresponding policy suggestions, including utilizing clean energy-saving technologies in the industrial sector, which is incredibly significant to realize the coordinated development of environmental protection and economy.

Keywords: environmental regulation, pollution intensive industry, industrial transfer, threshold effect, governance, sustainable cities

INTRODUCTION

“Sustainable cities and communities” is one of the 17 sustainable development goals (SDGs) proposed by the United Nations to make cities and human settlements safe, resilient, and sustainable. However, when comparing emerging economies with developed countries, due to the faster economic growth and more reliance on fossil fuels, the first group has more difficulties in achieving the goal. In China, with rapid development in this middle, the contradiction between environmental protection and economic development has become increasingly prominent in recent

years. The industrial transfer is the key path to coordinate economic development and environmental protection for achieving sustainable development. With the implementation of China's central and western regions' development strategy, the eastern industry has begun to shift to the central and western regions, and the central and western regions have issued relevant policies to attract industrial migration. However, the practice has proved that most of the industries transferred in the eastern region are pollution-intensive industries with severe pollution and low technology. Environmental problems are increasingly prominent in industrial transfer. Under the increasing pressure of environmental protection, industry enterprises should consider the factor cost and the degree of transportation convenience and the environmental cost (Zhang, 2019). The total cost of environmental regulation is the critical factor of pollution-intensive industrial transfer, including pollution control cost and transaction cost (Li et al., 2020). Therefore, it is of great significance for the coordinated development of environmental protection and regional economic growth to study the impact of environmental regulation on the transfer of pollution-intensive industries.

However, how environmental regulations affect the transfer of pollution-intensive industries in urban areas is the core issue of realizing balanced development among regions and reducing pollution transfer in China. With the increasingly strict environmental regulations, many scholars hold different opinions on whether environmental regulation can promote industrial transfer. Some scholars point out that environmental regulation has no significant impact on regional industrial transfer, while others support the "Pollution Haven Hypothesis" and believe that pollution-intensive industrial transfer exists. Therefore, how does environmental regulation affect the transfer of pollution-intensive industries? It still needs further theoretical research and empirical test. Moreover, how can the government use environmental regulation tools to promote pollution-intensive industries' transfer and realize the regional economy and environment's coordinated development? It is also a hot issue to be concerned about.

This paper takes the pollution-intensive industry as the research object and test the impact of different environmental regulations on the transfer of pollution-intensive industry. The paper builds a panel data econometric model and further provide decision-making suggestions for the government to formulate industrial transfer policies. This paper's main research contents include five parts: the first part is the literature review, the second part is mechanism analysis, the third part is the empirical analysis, the fourth part is threshold effect analysis, and the fifth part is conclusion and policy implications.

LITERATURE REVIEW

For the research on the relationship between environmental regulation and industrial transfer, scholars mainly focus on the following two aspects: one is whether environmental regulation can cause industrial transfer, the other is the analysis of the motivation of environmental regulation leading to industrial transfer.

Discussion on Whether Environmental Regulation Promotes the Industrial Transfer

Some scholars point out that environmental regulation has no significant impact on regional industrial transfer. Even if environmental regulation's intensity increases, the industrial transfer will not occur (Acemoglu et al., 2012). Other scholars support the "Pollution Haven Hypothesis." They believe that some pollution-intensive enterprises will transfer from countries or regions with strict environmental regulations to countries or regions with loose environmental regulations. When environmental standards are not unified (Walter and Ugelow, 1979). Levinson (1996) and Wheeler (2001) studied the correlation between international trade and environmental regulation and concluded that pollution-intensive industrial transfer existed. However, the impact of environmental regulation on industrial transfer could not be determined. Kellenberg suggested that the "Pollution Haven Hypothesis" also existed in analyzing some pollution-intensive industries in the United States. However, whether the "Pollution Haven Hypothesis" exists in China, the conclusions drawn by domestic scholars are not consistent. From the perspective of new economic geography, some scholars believe that high-intensity environmental regulation, as the centrifugal force of industrial agglomeration, promotes the emergence of nearby industrial transfer (Low and Yeats, 1992; Dam and Scholtens, 2012; Hosoe and Naito, 2006). The difference in environmental regulation intensity influences industrial competitiveness, industrial innovation behavior, and industrial transfer (Fredriksson and Gaston, 2000; Rauscher, 2019; Song et al., 2019). However, there are few studies on the impact of informal environmental regulation on industrial transfer.

Analysis of the Influence Factors of Environmental Regulation on Industrial Transfer

The existing literature focuses on the influence factors of environmental regulation on industrial transfer, mainly discusses the influence of production cost, policy system, industrial structure, and other factors on industrial transfer, such as the cost of dealing with environmental regulation (Frank, 2001; Smarzynska and Wei, 2005; Hayes and Preacher, 2010). Lang analyzed the factors influencing industrial transfer from the perspective of enterprise cost, including transportation cost and environmental regulation cost. Walter discussed the impact of the government's mandatory environmental policies on industrial transfer and believed that environmental regulation policies prompted enterprises to make strategic choices again, which led to industrial transfer. Kheder and Zugravu (2012) pointed out that environmental regulation was the centripetal force of industrial agglomeration, which led to industrial transfer. Kyriakopoulou and Xepapadeas (2013) pointed out that the short-sighted environmental policy was the centripetal force of industrial agglomeration, and the optimal environmental policy was the centrifugal force of industrial agglomeration. The interaction between the two policies causes the phenomenon of industrial transfer. Sun et al., (2018), Sun et al., (2019), and Sun

et al., (2020) found that a relatively loose environmental regulation policy was an important driving force to attract the transfer of polluting industries. Song and Zhao, (2019) further summarized the differences in the impact of different types of environmental regulation policies on industrial transfer. Zhang et al., (2018) pointed out that water pollution control policies caused enterprises to transfer across regions, and enterprises had different sensitivity to regional environmental supervision policies.

In summary, the existing literature focuses more on the relationship and influencing factors between environmental regulation and industrial transfer. In contrast, the research on the impact of environmental regulation on the transfer of pollution-intensive industries is rare. The mechanism analysis and empirical test of environmental regulation affecting pollution-intensive industrial transfer are still rare. However, how does environmental regulation affect the transfer of pollution-intensive industries? and what is the impact of environmental regulation on the transfer of pollution-intensive industries? Due to the significant difference between pollution-intensive industry and manufacturing industry, under the background of strict environmental regulation, this paper systematically analyses the internal mechanism of the impact of different environmental regulations on industrial transfer from the perspective of the pollution-intensive industry. It empirically tests the impact of environmental regulation on the transfer of pollution-intensive industry, which provides decision-making reference for the government to formulate reasonable environmental regulation policies.

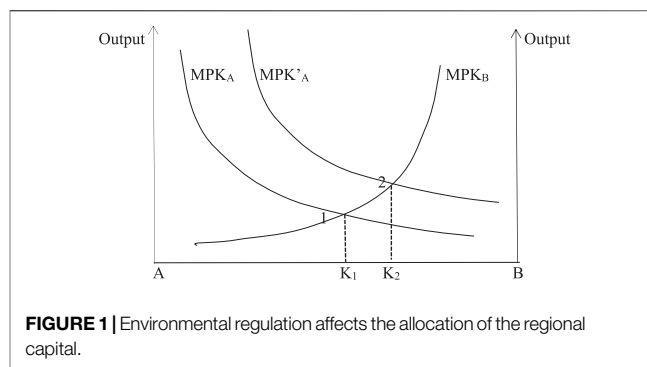
MECHANISM ANALYSIS

This paper draws on relevant literature research. It divides environmental regulation into formal environmental regulation and informal environmental regulation, then analyses the influence mechanism of different environmental regulations on the transfer of polluting industries.

Mechanism Analysis of Formal Environmental Regulation Affecting the Industrial Transfer

Formal environmental regulations force enterprises to weigh the cost of pollution control and the number of sewage charges. However, no matter which way is adopted, it will increase the enterprise's cost and reduce the profit of the enterprise. Therefore, enterprises reduce environmental costs and maximize profits through transfer.

Assuming that there are only region A and region B in one country, capital flows freely in region A and region B. The total amount of capital is K , and there is no current cost. Region A and region B produce the same product with negative externality, and the government regulates the negative externality. At the same time, we assume that $Q(K,E)$ is the production function of regions A and regions B, where E represents other input factors except capital. With other input factors unchanged, the marginal return



of capital in regions A and B decreases, and the marginal capital curves MPK_A and MPK_B are shown in **Figure 1**.

In the initial state, the environmental regulation intensity of region A is the same as that of region B. The capital marginal curve MPK_A intersects with the capital marginal curve MPK_B , and the intersection point is 1. At this time, region A's corresponding capital amount is AK_1 and the capital volume of region B is BK_1 . If regional A relaxes environmental regulation to attract external capital inflow, the cost of enterprises in region A will decrease and the marginal output of capital will rise, and its MPK_A will move up to MPK'_A , and MPK'_A and MPK_B will intersect at point 2. At this time, the capital volume of regions A and B becomes AK_2 and BK_2 , respectively. According to the production function $Q(K,E)$, the increase of capital leads to the increase of output value of region A and the decrease of the output value of region B.

According to **Figure 1**, when there are differences in the intensity of formal environmental regulation among regions, the capital and output value of regions with strong environmental regulation will transfer to regions with weak environmental regulation, which indicates that formal environmental regulation causes industrial transfer through influencing enterprise costs.

Mechanism Analysis of Informal Environmental Regulation Affecting the Industrial Transfer

Informal environmental regulation affects industrial transfer mainly through the following three ways:

The first way reflects the relationship among the public, government departments, and enterprises, and its mechanism is that the public express their interest demands to the government environmental protection agencies through petitions or letters. This force is polluting enterprises to compensate for the loss of residents and face the risk of being ordered to move out of the region.

The second way reflects the relationship between the public, media opinion, and enterprises. Its influence mechanism is that the public expands the influence effect through media public opinion, enhances social attention to the environmental pollution of enterprises, and then puts pressure on the polluting enterprises, forcing the polluting enterprises to save energy, do

energy transition (Shi et al., 2020; Taghizadeh-Hesary and Rasoulinezhad, 2020) and reduce emissions move out. For small and medium-sized enterprises, the effect of implementing pressure on enterprises through media public opinion is more significant.

The third way reflects the relationship between the public, environmental protection organizations, and enterprises. Its influence mechanism is that environmental protection organizations coordinate with the public to form a strong force. The public negotiates with polluting enterprises through environmental protection organizations, affecting enterprises' production activities and increasing enterprises' negotiation costs. To avoid this risk, polluting enterprises move from strong environmental protection organizations to areas with weak environmental protection organizations. In recent years, chemical, environmental events have proved that informal environmental regulation has an increasing impact on industrial transfer.

Based on the above analysis, informal environmental regulation has become an essential factor in enterprises' location choice. Because different pollution-intensive enterprises have different sensitivity to environmental regulation, pollution-intensive enterprises tend to move to areas with loose environmental regulations. This paper takes pollution-intensive industries as the object to study the impact of environmental regulations on industrial transfer.

According to the above mechanism analysis, both formal and informal environmental regulations are essential driving forces of the industrial transfer. However, environmental regulation is not the only influencing factor of the industrial transfer. The industrial transfer is also affected by labor cost, industrial agglomeration, market scale, and other factors. Therefore, this paper puts forward the following two main assumptions:

Hypothesis 1: Environmental regulation can promote the transfer of pollution-intensive industries, but many factors will affect its role.

Hypothesis 2: The impact of environmental regulation on the transfer of pollution-intensive industries has spatial heterogeneity.

EMPIRICAL ANALYSIS

Model Setting and Variable Selection

Based on the existing relevant research, this paper constructs the following econometric model to study the impact of different environmental regulations on polluting industries' transfer.

$$\begin{aligned} \ln ITR_{ijt} = & \alpha_0 + \alpha_1 \ln FER_{jt} + \alpha_2 \ln FER_{jt}^2 + \alpha_3 \ln IER_{jt} \\ & + \alpha_4 \ln IA_{ijt} + \alpha_5 \ln LC_{jt} + \alpha_6 \ln MS_{jt} \\ & + \alpha_7 \ln MO_{jt} + \alpha_8 \ln TC_{jt} + \varepsilon_{jt} \end{aligned} \quad (1)$$

Among them, j represents the provinces, i represents pollution-intensive industries, and t stands for time respectively, ITR represents industrial transfer, FER and IER represent formal environmental regulation and informal

environmental regulation respectively, IA means industrial agglomeration, LC represents labor cost, MS , MO , and TC stand for market scale, market openness and traffic conditions respectively, α_0 means a constant term, and ε_{jt} represents an error term.

Explained Variable

Industrial transfer (ITR). The industrial transfer will increase the transfer area's output value and decrease the output value of the transfer out area. ITR_{jt} is measured by the proportion of the j provincial output value of pollution-intensive industries in its total national output value.

Explanatory variables

- (1) Formal environmental regulation (FER). Most of the existing literature measures the intensity of formal environmental regulation from the perspectives of investment in pollution discharge control and pollution control effect (Mielnik and Goldember, 2002; Sohag et al., 2017; Qin and Ge, 2018; Acheampong, 2018). Considering each index data's availability, this paper uses the proportion of regional pollution control investment in regional GDP.
- (2) Informal environmental regulation (IER). In the existing research, informal environmental regulation is mainly measured by relevant proxy variables. Due to the public's different environmental awareness in different regions, the public in areas with strong environmental awareness pays more attention to environmental pollution, and the number of people participating in the environmental petition is also large. This paper selects the index of the environmental petition to measure informal environmental regulation.

Control variables

In addition to environmental regulation factors, the factors affecting enterprise migration also include industrial agglomeration, labor cost, market scale, market openness, and traffic conditions. To reduce the regression error, these factors are introduced into the model as control variables.

- (1) Industrial agglomeration (IA). Industrial agglomeration can expand the scale of local industrial development and attract more pollution-intensive industries to transfer in, form the industrial agglomeration effect, realize the sharing of product information, and reduce transportation costs. This paper uses the number of regional industrial enterprises to measure the industrial agglomeration degree.
- (2) Labor cost (LC). The higher the wage level is, the higher the labor cost of enterprises is, and the fewer enterprises enter the region. This paper uses the average wage of regional employees to measure the labor cost.
- (3) Market scale (MS). Market scale is an essential factor affecting the location choice of enterprises. Regions with large market scale have higher economic development level and environmental requirements, which can promote the transfer of pollution-intensive industries. This paper uses the

TABLE 1 | Regression estimation results at the national level.

Variable	FE	RE
LnFER	0.328*** (2.184)	0.296*** (2.042)
LnFER ²	-0.057*** (-2.325)	-0.048*** (-2.139)
LnIER	-0.352*** (-2.628)	-0.343*** (-2.327)
LnIA	0.177*** (3.439)	0.173*** (3.276)
LnLC	-0.506*** (-5.048)	-0.497*** (-4.841)
LnMS	0.008*** (0.115)	0.006*** (0.104)
LnMO	0.011* (0.121)	0.009* (0.094)
LnTC	0.103** (1.891)	0.095** (1.557)
C	3.437*** (5.231)	4.155*** (5.676)
R ²	0.846	0.832

Note: ***, **, * represent significant at the statistical levels of 1%, 5%, and 10%, respectively. The values in brackets are t-test values.

total retail sales of consumer goods to measure the market scale.

- (4) Market openness (MO). The higher the degree of regional market opening, the more enterprises will be attracted to enter, and the scale of regional industrial agglomeration will be enhanced. This paper uses the proportion of FDI in GDP to measure market openness.
- (5) Traffic conditions (TC). Good transportation facilities are conducive to enterprise procurement and product transportation and reduce enterprises' transaction costs. The better the traffic conditions, the more attractive the enterprises will be to move in, and the higher the industrial agglomeration degree will be. This paper uses traffic density to measure regional traffic conditions.

Industry Selection and Data Sources

According to the standard of pollution emission intensity, this paper defines the current pollution-intensive industries in China, including the petroleum processing and coking industry, chemical raw materials and chemical products manufacturing industry, ferrous metal smelting and rolling industry, nonferrous metal smelting and rolling industry, chemical fiber manufacturing industry, non-metallic mineral manufacturing industry, power, gas and water production and supply industry, paper, and paper products industry.

The research data mainly uses the panel data of 30 provinces and autonomous regions except for Tibet, Hong Kong, Macao, and Taiwan from 2008 to 2018. The relevant data are collected and calculated from the China Statistical Yearbook, China Environmental Statistical Yearbook, China Industrial Economic Statistical Yearbook, China industrial economy database, China regional statistical yearbook, and statistical yearbooks of various provinces. The missing data were supplemented by the interpolation method. In this paper, all variables take a natural logarithm to reduce the data fluctuation.

Analysis of Empirical Results

Based on the panel data of pollution-intensive industries in China, this paper tests the correlation of the variables in the model(1), and the results show no correlation between the variables. According to the Hausman test results, the random

effect model's rejection shows that the fixed effect model is more effective than the random effect model. Based on the results, this paper uses the fixed-effect model for regression estimation. The national and regional regression results are shown in **Table 1** and **Table 2**, respectively.

FER means formal environmental regulation, IER means informal environmental regulation; IA, LC and MS mean industrial agglomeration, labor cost and market scale respectively; MO and TC means market openness and traffic conditions; C means constant, R² indicates the goodness of fit of the model.

Analysis of Test Results at the National Level

It can be seen from **Table 1** that according to the regression results of the fixed-effect model, the first term estimation coefficient of formal environmental regulation (FER) is positive and the second term estimation coefficient is negative, and both of them are significant at the 1% level, which indicates that the impact of formal environmental regulation intensity on the transfer of pollution-intensive industries presents an inverted "U" type nonlinear relationship. This shows that when the formal environmental regulation intensity is low, the pollution-intensive industry will transfer in. With the increase of the formal environmental regulation intensity, the pollution-intensive industry will gradually slow down until it reaches the maximum value point. After crossing the maximum value point, the pollution-intensive industry will gradually transfer out. The reason is that when the cost of formal environmental regulation is higher than the cost of enterprise migration, the enterprise will choose to migrate. The coefficient of informal environmental regulation (IER) is -0.352, and its significance level is 1%, which indicates that the informal environmental regulation promotes the transfer of pollution-intensive industries as a whole.

Furthermore, the coefficient of labor cost (LC) is -0.506 and its significance is at the level of 1%, which indicates that the increase of regional labor cost promotes the transfer of pollution-intensive industries. The industrial agglomeration (IA) coefficient is 0.177 and significant at the level of 1%, which indicates that industrial agglomeration has a significant role in promoting industrial transfer. It also shows that the greater the degree of regional industrial agglomeration, the more pollution-intensive industries can be attracted. Besides, the coefficient of market scale (MS) is 0.008 and significant at the level of 1%, which indicates that the expansion of market scale can restrain the transfer out of pollution-intensive industries by improving the level of industrial agglomeration. The degree of market opening (MO) is positive and significant at the level of 10%, which indicates that the improvement of the market opening level can enhance the level of industrial agglomeration and inhibit the migration of pollution-intensive industries. The coefficient of regional traffic condition (TC) is positive and significant at the level of 5%, which indicates that the developed traffic conditions have an attractive effect on the transfer of pollution-intensive industries, and the raw material input and product output of pollution-intensive industries also need the support of developed transportation network. The above analysis results verify hypothesis 1, that is,

TABLE 2 | Regression estimation results of regions.

Variable	Eastern region		Central region		Western region	
	FE	RE	FE	RE	FE	RE
LnFER	1.178 ^{***} (3.406)	1.021 ^{***} (3.272)	0.325* (2.452)	0.336* (2.621)	0.162* (1.952)	0.171* (1.965)
LnFER ²	-0.047 ^{***} (-1.885)	-0.039 ^{***} (-1.750)	0.041* (1.525)	0.048* (1.642)	0.125* (1.539)	0.129* (1.797)
LnIER	-0.421 ^{***} (-3.341)	-0.408 ^{***} (-3.179)	-0.219 (-2.156)	-0.231 (-2.590)	-0.141 (-2.106)	-0.147 (-2.143)
LnIA	-0.058* (-1.812)	-0.053* (-1.763)	0.327 ^{**} (3.204)	0.312 ^{**} (3.102)	0.103 ^{**} (2.038)	0.096 ^{**} (2.019)
LnLC	-0.195 ^{***} (-1.867)	-0.174 ^{***} (-1.651)	-0.416 (2.168)	-0.397 (-2.012)	0.067 (0.665)	0.062 (0.614)
LnMS	-0.004* (-0.491)	-0.003* (-0.463)	0.011* (0.647)	0.008* (0.613)	0.006 (0.556)	0.005 (0.517)
LnMO	0.008 (0.112)	0.006 (0.069)	0.015 ^{**} (0.154)	0.012 ^{**} (0.131)	0.023 ^{**} (0.225)	0.021 ^{**} (0.209)
LnTC	0.051* (0.483)	0.046* (0.457)	0.136 ^{**} (1.375)	0.129 ^{**} (1.287)	0.062* (0.616)	0.058* (0.572)
C	4.963 ^{***} (5.825)	4.831 ^{***} (5.676)	4.126 ^{***} (5.178)	4.025 ^{***} (5.013)	3.273 ^{***} (4.835)	3.162 ^{***} (4.546)
R ²	0.815	0.827	0.882	0.893	0.890	0.896

Note: ***, **, * represent significant at the statistical levels of 1, 5, and 10%, respectively. The values in brackets are t-test values. Source: Authors' calculation.

environmental regulation can promote industrial transfer, but its role is affected by many factors.

Analysis of Test Results at Regional Level

It can be seen from **Table 2** that according to the regression results of the fixed-effect model, environmental regulation has significant differences in industrial transfer in eastern, central, and western regions, which verifies hypothesis 2. The regression coefficients of the first term and the quadratic term of the formal environmental regulation in eastern China are 1.178 and -0.047, respectively. Their significance levels are 1%, which indicates that the formal environmental regulation and pollution-intensive industrial transfer in the eastern region present an inverted “U” shape. When the intensity of environmental regulation is small, the transfer of intensive industries is gradually transferred. With the intensity of environmental regulation reaching a certain critical point, pollution-intensive industries begin to transfer out. However, the central and western regions show a “U” shape, which indicates that with the increase of formal environmental regulation, the level of industrial transfer first decreases and then increases. Specifically, the regression coefficients of the first term of formal environmental regulation in the central and western regions are 0.325 and 0.162, respectively, and their quadratic regression coefficients are 0.041 and 0.125, respectively, while their significance level both are 10%. This shows that with the increase of formal environmental control intensity in central and western regions, intensive pollution industries have changed from transfer out to transfer in. The reason is that environmental control in the central and western regions is relatively loose. At the same time, the migration of polluting industries will bring economic growth, an increase of employment, and residents' income. Therefore, the central and western regions meet the transfer of pollution-intensive industries by reducing environmental standards, thus become the “pollution shelter” in the eastern region.

The regression coefficient of informal environmental regulation in the eastern region is -0.421, and the significance level is 1%, which indicates that the informal environmental regulation in the eastern region promotes the transfer out of pollution-intensive industries. The main reason is that the

residents in the eastern region have a high awareness of environmental protection. They exert pressure on polluting enterprises and force enterprises to move out through petitions to environmental protection organizations or realize interest demands through negotiation between environmental protection organizations and polluting enterprises. However, the regression coefficients of informal environmental regulation in central and western regions are -0.219 and -0.141, respectively, but they are not significant, indicating the impact of informal environmental regulation on the transfer out of pollution-intensive industries is not apparent. The possible reason is that the central and western residents pay more attention to economic growth, employment, and income increase and pay less attention to environmental pollution. Simultaneously, the central and western regions are relatively vast and sparsely populated, and it is challenging to organize the public to participate in an environmental petition to resist environmental pollution.

The regression coefficient of the industrial agglomeration degree in eastern China is -0.058. Its significance level is 10%, which indicates that industrial agglomeration has a significant role in promoting the transfer out of pollution-intensive industries. The regression coefficients of industrial agglomeration degree in central and western regions are all positive. The significance level is 5%, indicating that industrial agglomeration has a significant role in promoting industrial transfer. pollution-intensive industries tend to move to areas with strong industrial agglomeration, share infrastructure, and reduce transaction costs. The regression coefficient of labor cost in eastern China is -0.095. The significance level is 1%, which indicates that high labor cost forces enterprises to migrate to the central and western regions with lower labor costs and promote the transfer of pollution-intensive industries. The regression coefficients of labor cost in the central and western regions are -0.416 and 0.067, respectively, but they are not significant, which indicates that the labor cost in the central and western regions has no significant impact on industrial transfer. The regression coefficient of the market scale in the eastern region is -0.004 and the significance level is 10%, which indicates that the expansion of the market scale promotes the transfer out of pollution-intensive industries to a certain extent; the regression coefficient of the market scale in the central region is 0.011 and

TABLE 3 | SYS-GMM estimation results at the national level.

Variable	Parameter estimates	T Statistic
LnITR (-10)	0.827***	5.875
LnFER	0.058***	2.426
LnFER ²	-0.012***	-1.731
LnIER	-0.061***	-2.785
LnIA	-0.035***	-0.472
LnLC	-0.087***	-1.625
LnMS	0.004***	0.621
LnMO	0.005**	0.559
LnTC	0.013**	2.157
Cons	0.517***	1.141
AR(1)	0.001	—
AR(2)	0.637	—
Sargan	0.362	—

Note: ***, **, * are significant at the statistical levels of 1, 5, and 10%, respectively.

the significance level is 10%, which indicates that the market scale in the central region promotes the industrial transfer in. While the regression coefficient of the market scale in the western region is 0.005, but not significant, it shows that the western region's market scale has no significant impact on industrial transfer. The regression coefficient of market openness in eastern China is 0.008. However, it is not significant, which indicates that the market opening inhibits the transfer of pollution-intensive industries to a certain extent. The regression coefficients of market openness in the central and western regions are 0.015 and 0.023, respectively, and the significance levels are all 5%. This shows that the market opening in the central and western regions can attract pollution-intensive industries. Traffic conditions in the eastern, central, and western regions significantly inhibit the migration of pollution-intensive industries.

Results of SYS-GMM Estimation at the National Level

To verify the results' robustness, we consider the case of the first-order lag of the explained variables. Since the explanatory variables' endogenous problem may exist in the dynamic panel's actual estimation, we use the system generalized moment estimation (GMM) to verify. In this paper, Sargan over recognition test is used to judge and estimate the weight matrix of GMM more effectively. The specific estimation results are shown in **Table 3**.

According to the estimation results in **Table 3**, the first-order lag term with the industrial transfer as the explained variable is positive, and the significance level is 1%, which indicates that the explained variable industrial transfer has strong persistence and cumulative effect. Sargan test showed no over-identification of tool variables, and the results of AR(1) and AR(2) tests showed the effectiveness of tool variable selection. From the estimation results, the first term estimation coefficient of environmental regulation is positive, and the second term estimation coefficient is negative, and both pass the significance level of 1%. This shows an inverted "U" type dynamic relationship between formal environmental regulation and industrial transfer, which is similar to the national regression result. This further verifies that the formal environmental regulation and industrial transfer are nonlinear relationships with an increase first and then a decline. From the estimation coefficient of explanatory variables, the estimation

coefficient of informal environmental regulation is significantly negative, which indicates that informal environmental regulation promotes the transfer out of pollution-intensive industries. For other control variables, the coefficients of market scale (MS), market openness(MO), and traffic conditions(TC) are positive and significant, while the coefficients of labor cost(LC) and industrial agglomeration(IA) are negative and significant. Among them, the industrial agglomeration(IA) coefficient is just opposite to the positive coefficient in the national regression results, but it just shows that the industrial agglomeration has significant differences on the industrial transfer in different regions, especially in developed areas, the higher the industrial agglomeration degree, the more stringent the environmental control requirements, and the more pollution-intensive industries transfer out.

THRESHOLD EFFECT ANALYSIS

Although empirical results show a nonlinear relationship between environmental regulation and polluting industries transfer, there are differences between different regions. However, a large number of facts have proved that enterprises in the eastern region did not migrate to the central and western regions, but the underdeveloped areas or neighboring provinces. Therefore, there may be several "thresholds" in regional environmental regulation, which may have different impacts on the transfer of polluting industries according to whether the provinces and cities across the threshold. This paper uses a panel threshold regression model to expand the above problems.

Model Setting

In this paper, the formal environmental regulation(FER) is taken as the threshold variable to expand the model(1) and construct the panel threshold model, as shown in the model(2).

$$\begin{aligned} \text{LnITR}_{jt} = & \alpha_0 + \alpha_1 \text{LnFER}_{jt} \times d(M \leq \lambda) + \alpha_2 \text{LnFER}_{jt} \\ & \times d(M > \lambda) + \alpha_3 \text{LnIER}_{jt} + \alpha_4 \text{LnIA}_{ijt} \\ & + \alpha_5 \text{LnLC}_{jt} + \alpha_6 \text{LnMS}_{jt} + \alpha_7 \text{LnMO}_{jt} \\ & + \alpha_8 \text{LnTC}_{jt} + \epsilon_{jt} \end{aligned} \quad (2)$$

In model(2), the meaning of the corresponding variables remains unchanged. $d(\cdot)$ is the indicative function, M is the threshold variable, and λ is the threshold level value coefficients are different. When $M \leq \lambda$, the impact coefficient of formal environmental regulation on the transfer of pollution-intensive industries is α_1 . When $M > \lambda$, the impact coefficient of formal environmental regulation on the transfer of pollution-intensive industries is α_2 . If $\alpha_1 \neq \alpha_2$, it shows that the influence of crossing threshold on the coefficient is different, and there is a threshold effect.

Test of Threshold Effect

This paper uses the bootstrap self-sampling method and stata12 software for the threshold test. The test results are shown in **Table 4**. Taking the intensity of formal environmental regulation as the threshold variable, the single threshold, double threshold, and three threshold tests were conducted respectively. The

TABLE 4 | Threshold test results of formal environmental regulation.

Model	F value	p-value	Threshold value			Critical value		
			I	II	III	1%	5%	10%
Single threshold	26.5668***	0.0100	0.0039	—	—	28.5162	24.9278	19.8757
Double threshold	22.9525***	0.0000	0.0025	0.0039	—	23.2553	19.6267	15.5132
Triple threshold	9.8109**	0.0571	0.0025	0.0039	0.0042	18.8229	15.1094	13.3989

Note: (Acemoglu et al., 2012) ***, **, and * are significant at the level of 1, 5, and 10% respectively. The method is self-sampling. (Acheampong, 2018) In each threshold test, the identified threshold value revises the previous threshold value.

TABLE 5 | Regression results of the threshold model.

Explanatory variables	Parameter estimates	T Value
LnFER (FER ≤ 0.0025)	0.317***	3.35
LnFER (0.0025 < FER ≤ 0.0039)	-0.405***	-2.87
LnFER (FER > 0.0039)	-0.289***	-3.91
LnIER	-0.193***	-4.23
LnIA	0.364***	3.65
LnLC	-0.307**	-2.07
LnMS	0.005**	1.21
LnMO	0.009*	1.13
LnTC	0.026*	1.59
C	4.217**	2.65

Note: ***, **, and * are significant at the level of 1, 5, and 10% respectively.

single threshold and double threshold passed the 1% significance test, and the three thresholds did not pass the significance test. The results show that the estimated values of the two threshold variables in the model are 0.0025 and 0.0039, respectively. Therefore, the samples can be divided into three groups for analysis: weak regulation (FER ≤ 0.0025), moderate regulation (0.0025 < FER ≤ 0.0039), and strong regulation (FER > 0.0039), respectively, corresponding to the western region, the central region, and the eastern region. Therefore, a double threshold model with formal environmental regulation (FER) as a threshold variable is established. The model is as follows:

$$\begin{aligned} \text{LnITR}_{jt} = & \alpha_0 + \alpha_1 \text{LnFER}_{jt} \times d(\text{IFER} \leq 0.0025) \\ & + \alpha_2 \text{LnFER}_{jt} \times d(0.0025 < \text{IFER} \leq 0.0039) \\ & + \alpha_3 \text{LnFER}_{jt} \times d(\text{IFER} > 0.0039) \\ & + \alpha_4 \text{LnIER}_{jt} + \alpha_5 \text{LnIA}_{jt} + \alpha_6 \text{LnLC}_{jt} \\ & + \alpha_7 \text{LnMS}_{jt} + \alpha_8 \text{LnMO}_{jt} + \alpha_9 \text{LnTC}_{jt} + \varepsilon_{jt} \quad (3) \end{aligned}$$

Analysis of Threshold Regression Results

In this paper, the double threshold model's threshold regression analysis (Hayes and Preacher, 2010) is carried out. The regression results are shown in Table 5.

It can be seen from Table 5 that the impact of different formal environmental regulations on the transfer of pollution-intensive industries is significant (in line with Zhao and Song, 2018), which indicates that there is a nonlinear relationship between the formal environmental regulations and the transfer of pollution-intensive industries, and its impact increases first and then decreases with the increase of formal environmental regulations.

When the region is weak regulation, the formal environmental regulation has a significant positive correlation with the transfer of pollution-intensive industries, and loose environmental regulations will promote the transfer of pollution-intensive industries. When the formal environmental regulation exceeds the first threshold value of 0.0025, the formal environmental regulation has a significant negative correlation with the transfer of pollution-intensive industries, indicating that the formal environmental regulation promotes the transfer out of pollution-intensive industries its promoting effect increases to 0.405. The main reason is that enterprises choose industrial transfer nearby to avoid environmental costs, and the improvement of formal environmental regulations plays a greater role in promoting the transfer of pollution-intensive industries. When the formal environmental regulation exceeds the second threshold value of 0.0039, its role in promoting the transfer of pollution-intensive industries decreases to 0.289. This may be that when the intensity of formal environmental regulation exceeds the second threshold, enterprises choose technological innovation more to avoid high environmental costs, or are forced to be eliminated by the market (Liu et al., 2018; Qin et al., 2018; Liu et al., 2020). Among the main influencing factors, the coefficients of four control variables such as industrial agglomeration (IA), market size (MS), market openness (MO) and traffic conditions (TC) are all positive and significant. This shows that regional industrial agglomeration has a significant role in promoting industrial transfer. The expansion of market scale can enhance the level of industrial agglomeration and inhibit the transfer of pollution-intensive industries, expanding the degree of market opening can enhance the level of industrial agglomeration and inhibit the migration of pollution-intensive industries (Petrakis et al., 2015). Developed traffic conditions have a stunning effect on the transfer of pollution-intensive industries.

CONCLUSION AND POLICY IMPLICATIONS

This paper discusses the impact mechanism of different environmental regulations on industrial transfer, and empirically analyzes the relationship between environmental regulation and industrial transfer and its main influencing factors from the national and regional levels. The research shows that there is an inverted "U" nonlinear relationship between formal environmental regulation and pollution-intensive industrial transfer. The impact

of formal environmental regulation on the transfer of pollution-intensive industries has regional differences and double threshold effects. Specifically, formal environmental regulation has the effect of restraining and then promoting the transfer of pollution-intensive industries, and its promotion effect increases first and then decreases with the further improvement of formal environmental regulations. While the informal environmental regulations promote the transfer of pollution-intensive industries as a whole. Based on this, this paper proposes the following policy implications:

First of all, government departments should strengthen the top-level design and promote coordinated development among regions. Governments at all levels should improve the system of environmental laws and regulations and build an environmental regulation policy system to promote the coordinated development among regions. Government departments should also establish an assessment mechanism with green GDP as the core, strengthen the management and standardization of local environmental regulations, coordinate the environmental policies of transfer out and receiving areas, and standardize the same functional areas' environmental regulations to realize the balanced development among regions.

Secondly, enterprises should strengthen the investment in scientific and technological innovation and use clean energy-saving technologies, and vigorously promote harmless production technologies. At the same time, internalize the cost of environmental regulation through technological innovation, and promote the transformation and upgrading of polluting enterprises. It can not only reduce pollution and the environmental cost of the industrial transfer undertaking area but also make enterprises avoid low-cost competition to obtain long-term development.

Thirdly, government departments should enrich the means of environmental regulation and strengthen the effect of environmental regulation on industrial transfer. Due to government intervention failure, residents need to participate in environmental protection and supervise the government and enterprises. Therefore, we should improve residents' awareness of environmental protection, encourage residents to participate in environmental protection, build a trinity environmental governance model of government, enterprises, and residents, and improve the industrial transfer effect of environmental regulation.

Fourthly, according to the principles of optimal allocation and effective utilization of resources, all regions fully consider environmental protection. To achieve the win-win situation of economic development and environmental protection, government departments should rationally distribute the industrial productivity, slow down its transfer speed, and strive to solve the pollution problem from the regional source.

Finally, the covid-19 epidemic's impact on China's economy and the international community is still in continuous development, full of uncertainty. However, it can be predicted that the longer the epidemic lasts, the more significant the impact on China and the global macro-economy, and it may even cause damage to the economic structure. We suggest that the fiscal policy be more active and that the monetary policy should be stable and flexible. It is necessary to strive to expand domestic demand, invest and consume at the same time, strengthen structural adjustment and promote the upgrading of industrial structure, and reduce the burden of enterprises and stabilize employment, properly handle various risks and maintain the stability of the financial market.

The contribution of this paper is to analyze the impact of environmental regulation on industrial transfer from the perspective of pollution-intensive industries. In terms of content, it analyzes the impact mechanism of environmental regulation on industrial transfer from two aspects of formal environmental regulation and informal environmental regulation. It carries out the empirical test from national and regional levels and then puts forward constructive policy suggestions according to the empirical conclusion.

In the future, we need to analyze whether there is a threshold effect in the impact of industrial agglomeration and other factors on the transfer of pollution-intensive industries and further analyze the reasons.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

Data curation, WL; Formal analysis, WL; Investigation, HS and YD; Project administration, ZL; Validation, FT-H; Writing – original draft, WL; Writing – review and editing, HS, YD, ZL and FT-H.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer ER declared a past co-authorship with one of the authors FT-H to the handling editor.

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