



Regional Environmental Regulation and Industrial Structure Upgrading: Prefecture -Level Evidence from China



ABSTRACT

Environmental regulation is not only an effective method to control pollutants and wastes, but also a vital factor that can be used to influence industrial structure. This study applies the panel data of 285 prefecture-level cities in China from 2004 to 2016 to verify spatial autocorrelation between industrial structure upgrading and regional environmental regulation and then uses dynamic spatial panel model (DSPM) to verify how regional environmental regulation both directly and indirectly influences industrial structure upgrading. There is a close spatial autocorrelation in Chinese cities between industrial structure upgrading and regional environmental regulation. The estimation results of DSPM show that regional environmental regulation only acts on that particular region's industrial structural upgrading but not on the upgrading in other regions. The heterogeneity results show that from economic development, human capital, and foreign direct investment perspectives, regional environmental regulation is also able to reduce the negative impacts of industrial structure upgrading. The strengthening of both infrastructure and government intervention promotes industrial structure upgrading. This study provides effective empirical support for adjustments to China's industrial structure and regional environmental regulation policy making.

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INTRODUCTION

Since the reforms of Deng Xiaoping, the Chinese economy has grown at remarkable speed, creating the modern day “China Miracle”. A downside to this growth, however, is the extensive pattern of industrial development represented by long-term high input, high energy consumption and high emissions and pollution, all of which have led China to become the largest energy consuming and polluting country in the world (Yu 2020). According to statistics from the Development Research Center under the State Council, China's real GDP in 2015 accounted for 15.4% of the world's real GDP, but energy consumption was up to 23.1% of world consumption and up to 50% of total world coal output. Furthermore, energy consumption per unit of GDP was 1.8 times the global average, 2.3 times that of the United States, 4.2 times that of Japan, and 3.6 times that of Germany.

It is well known that high energy consumption may bring with it a series of problems such as pollution of different kinds, environmental deterioration, etc. The 2016 “Global Carbon Budget 2016” reported that China's fossil fuel and CO₂ emissions reached 10.4 billion tons in 2015, were 29.2% CO₂ of global emissions and exceeded both

those of the United States and Europe put together. In addition, per capita carbon emissions reached 7.5 T, far exceeding the world average of 4.9 T per person. The “China Environmental Status Bulletin 2015” pointed out that in 2015, the national New Ambient Air Quality Standard had tested 338 cities, but only 73 of them met the standard while 265 cities were below standard. Moreover, tests in 480 cities showed increases in acid rain up to 22.5%.

With climate change and global warming, the Chinese government is facing greater pressure on energy saving and emissions reduction. In terms of how to achieve the strategic target of both energy saving and emission reduction, the three commonly held views are industrial structure upgrading, energy structure optimization, and technical progress. Industrial structure is the composition of various industries and the relationship and proportional relationship between them. Industrial structure upgrading is the process or trend of the transformation of industrial structure from a low-level form to a high-level form. Of the three factors, industrial structure upgrading contributes more than 70% to meeting carbon intensity targets in China (Wang and

Xiang 2014). The primary cause is therefore industrial structure and refers to the vital carriers of economic activities and ecological environment (*Liu et al. 2015; Rubashkina et al. 2015*). In other words, industrial structure upgrading cannot only promote optimization of resource allocation but can also reduce environmental pollution; a win-win between economic output and environmental improvement.

At present, China is in the rapid development stage of industrialization and urbanization. How to promote the optimizing and upgrading of industrial structure? Most scholars believe that environmental regulation is an efficient mechanism to reverse pressure. However, solid evidence to prove it is lacking (*Grafts 2006; Chang 2015; Li et al. 2016*). The traditionalist school holds the opinion that environmental regulation increases a company's compliance costs by internalizing the external environment. Reducing the input of labor, capital, and other production factors, but leaving other factors, such as production techniques and resource constraints unchanged, compels enterprises to alter their optimal production strategies and reduce production efficiency and competitiveness (*Gollop and Roberts 1983; Gray and Shadbegian 2003; Shadbegian and Gray 2005*). The revisionist school, however, emphasizes the dynamic effects of environmental regulation on the enterprise production process. The most influential theory is the "Porter Hypothesis" (*Porter 1991; Porter and Linde 1995*). This hypothesis postulates that rational environmental regulation can effectively promote both technical progress and allocation efficiency by simultaneously creating innovation offsets that balances part or all the "compliance costs" to increase productivity and competition (*Jaffe et al. 2011; Ambec et al. 2013*).

The effects of environmental regulation on industrial structure upgrading are not similar. One opinion postulates that environmental regulation has a negative influence on any improvements (*Millimet and Osang 2003; Shadbegian and Gray 2005; Li et al. 2016*). As environmental regulations increase, investment in both combating pollution and ensuring environmental protection will increase as well, thus converting investments in production factors, such as capital, labor and energy resources, etc., into environmental pollution control. To some extent, this adds to costs of production, thereby bringing extra expenses for the enterprise (*Barbera and McConnell, 1990; Boyd and Mccelland, 1999; Millimet and Osang, 2003*). The opposing opinion, however, points out that strict and appropriate environmental regulation can effectively promote industrial structure upgrading. The pressure

of environmental regulation causes enterprises to attempt new production processes, improve production technology and better use of production data to maintain and improve intrinsic market advantage. In addition, the added value of production and technical complexity is significantly enhanced while the market for production factors and intermediate product markets are developed. This leads to a deepening of the division of labor, the transformation and upgrading of traditional industry, and the development of the high technology industry. The result is to indicate the direction of future developments in advanced industrial structure (*Hamamoto 2006; Becher 2011; Zhang et al. 2011; Yang et al. 2012; Peuckert 2014; Jorge et al. 2015*).

The reason why the conclusions of above studies differ in their results when looking at environmental regulations and industrial structure upgrading is due to the differences in the selection of indicators, empirical objects, and research methods. In particular, most of the existing research papers test the relationship between environmental regulation and industrial structure improvements from a time dimension instead of a spatial dimension. Under the institutional arrangement of the "Two Overall Situations" strategy (Midwest supports East prior development, then East coast area feeds back Midwest development), China's economic development takes on an unbalanced developmental pattern. When dealing with regional economic development problems, it is not appropriate to ignore spatial correlation between variables (*Rey and Montouri 1999; Rodriguez-Pose and Fratesi 2004*). Therefore, spatial correlation becomes the key factor when understanding a correlation between environmental regulation and industrial structure upgrading. Using spatial econometric methods, *Shen et al. (2017)* have identified remarkable spatial correlation regarding environmental regulations in different regions of China. *Yu and Shen (2020)* verified the industrial structure adjustments that exist. Since there is both obvious spatial correlation and spatial dependency and a wide difference between environmental regulation and industrial structure between Chinese regions (*Zhou et al. 2013; Ge et al. 2018*), it is particularly important to study the effect of environmental regulations on industrial structure upgrading from the view of spatial spillover.

This study attempts to contribute in three ways from a research method point of view, this paper builds a spatial weight matrix by using geographical distance between regions and analyze the effect that regional environmental regulation had on industrial structure upgrading by using a dynamic spatial panel model (DSPM). This not only avoids an endogenous problem between variables but also

overcomes the disadvantage of regarding geographical distance as a “black box” by ignoring regional spatial interaction. The spatial measurement method combines geographical position with spatial connection, identifying and measuring spatial variation and determining factors by measurement, avoiding to some extent, deviations in traditional measurement results. Secondly, from a research perspective point of view, this paper considers not only the direct effect of regional environmental regulation on improvements to industrial structure, but also the indirect influence of regional environmental regulation on industrial structure upgrading through economic development levels, accumulation of human capital, infrastructure construction, foreign direct investment, and government intervention. Lastly, from the aspect of data selection, this paper uses statistics from 285 cities in China from 2003 to 2016. Chinese environmental governance puts responsibility on local government, thereby making local government decision makers (municipal party committee secretary or mayor) subject to a series of assessments. This implies that local government officials implement regional environmental regulations based on pollution levels, environmental capacity, and industrial structure. It follows, therefore, that provincial level statistics may cause errors in the results because of spatial scale selection and internal differences. It should be noted that the regional environmental regulation in this paper refers to the intensity of environmental regulation at the prefecture-level city level.

MATERIAL AND METHODS

Model specification

At present, the commonly used spatial measurement methods include two types: Spatial Autoregressive Model (SAR) and Spatial Error Model (SEM) (Anselin *et al.* 2004).

where SAR and SEM are expressed as Equation 1 and 2:

$$Y_{it} = \alpha_i + \rho \sum_{j=1}^n W_{ij} Y_{jt} + \alpha_j X_{ijt} + \varepsilon_{it}, \quad \varepsilon_{it} \sim N(0, \sigma^2 I) \quad (1)$$

$$Y_{it} = \alpha_i + \alpha_j X_{ijt} + \varepsilon_{it}, \quad \varepsilon_{it} = \lambda \sum_{j=1}^n W_{ij} \varepsilon_{jt} + \mu_{it}, \quad \mu_{it} \sim N(0, \sigma^2 I) \quad (2)$$

where Y and X are explained variable and explanatory variables, ε_{it} and μ_{it} are normally distributed random error terms, ρ and λ are spatial lag coefficient and spatial error

coefficient, W is spatial weight matrix. For the setting of the spatial weight matrix W_{ij} , binary adjacency matrix is generally used. However, the binary adjacency matrix assigns the adjacent region to 1 while non-adjacent region is given 0. In other words, there is no correlation among non-adjacent regions, which is remarkably inconsistent with reality. Thus, this study uses distance weight matrix, representing the reciprocal of the shortest distance between the two places, which can fully reflect the spatial correlation among geographical units. Since industrial structure upgrading is a dynamic process, this paper builds a DSPM, including first-order lag and spatial lag of industrial structure upgrading, in order to combine the SAR and SEM. This is done to obtain the advantages of the two models to achieve a more accurate estimation of the degree to which regional environmental regulation has on industrial structure upgrading. Compared to traditional SAR and SEM, the DSPM considers the dynamic and spatial effects of the industrial structure upgrading while avoiding the endogenous problem of “chicken and egg” between explained variable and explanatory variables; this makes the estimates more accurate and reliable (Elhorst 2012; Zheng *et al.* 2014). Based on the above considerations, the following DSPM is constructed to test the direct effect of regional environmental regulation on industrial structure upgrading (Equation 3):

$$SOP_{it} = \beta SOP_{it-1} + \rho \sum_{j=1}^n W_{ij} SOP_{jt} + \gamma ERI_{it} + \delta X_{it} + \alpha_i + v_{it} + \varepsilon_{it} \quad (3)$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^n W_{ij} \varepsilon_{jt} + \mu_{it}$$

where i and t represent region and time; SOP_{it} is industrial structure upgrading index; ERI_{it} is regional environmental regulation index; X_{it} is control variable. In order to explore the influential effect of other regional environmental regulations on the region's industrial structure upgrading, this paper adds ERI's spatial lag $W_{ij} ERI_{jt}$ in equation (3), reflecting spatial interaction effect of regional environmental regulation. Thus, the following DSPM is formed (Equation 4):

$$SOP_{it} = \beta SOP_{it-1} + \rho \sum_{j=1}^n W_{ij} SOP_{jt} + \gamma ERI_{it} + \eta \sum_{j=1}^n W_{ij} ERI_{jt} + \delta X_{it} + \alpha_i + v_{it} + \varepsilon_{it} \quad (4)$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^n W_{ij} \varepsilon_{jt} + \mu_{it}$$

To further analyze the indirect influential effect of regional environmental regulation on industrial structure upgrading, this paper introduces cross terms of regional environmental regulation and The level of economic development (VGDP), Human capital (EDU), Infrastructure (INF), Foreign direct investment (FDI), Government intervention (GOV), constructing the following dynamic spatial panel model (Equations 5 to 9):

$$SOP_{it} = \beta SOP_{it-1} + \rho \sum_{j=1}^n W_{ij} SOP_{it} + \gamma ERI_{it} \times VGDP_{it} + \delta X_{it} + \alpha_i + v_{it} + \varepsilon_{it} \quad (5)$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^n W_{ij} \varepsilon_{it} + \mu_{it}$$

$$SOP_{it} = \beta SOP_{it-1} + \rho \sum_{j=1}^n W_{ij} SOP_{it} + \gamma ERI_{it} \times EDU_{it} + \delta X_{it} + \alpha_i + v_{it} + \varepsilon_{it} \quad (6)$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^n W_{ij} \varepsilon_{it} + \mu_{it}$$

$$SOP_{it} = \beta SOP_{it-1} + \rho \sum_{j=1}^n W_{ij} SOP_{it} + \gamma ERI_{it} \times INF_{it} + \delta X_{it} + \alpha_i + v_{it} + \varepsilon_{it} \quad (7)$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^n W_{ij} \varepsilon_{it} + \mu_{it}$$

$$SOP_{it} = \beta SOP_{it-1} + \rho \sum_{j=1}^n W_{ij} SOP_{it} + \gamma ERI_{it} \times FDI_{it} + \delta X_{it} + \alpha_i + v_{it} + \varepsilon_{it} \quad (8)$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^n W_{ij} \varepsilon_{it} + \mu_{it}$$

$$SOP_{it} = \beta SOP_{it-1} + \rho \sum_{j=1}^n W_{ij} SOP_{it} + \gamma ERI_{it} \times GOV_{it} + \delta X_{it} + \alpha_i + v_{it} + \varepsilon_{it} \quad (9)$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^n W_{ij} \varepsilon_{it} + \mu_{it}$$

Spatial autocorrelation analysis

Most scholars use Moran's I index to test the spatial autocorrelation of economic development among regions (Moran 1950; Getis and Ord 1992). This study uses Moran's I index to analyze spatial autocorrelation by using two variables, which are industrial structure upgrading and regional environmental regulation, from global and local dimensions to estimate whether it is suitable for the spatial measurement model. The global Moran's I index is calculated as (Equation 10):

$$Moran's I = \frac{n}{\sum_{i=1}^n \sum_{j=1}^n W_{ij}} \cdot \frac{\sum_{i=1}^n \sum_{j=1}^n W_{ij} (Y_i - \bar{Y})(Y_j - \bar{Y})}{\sum_{i=1}^n (Y_i - \bar{Y})^2} \quad (10)$$

where Y is regarded as the attribute value of the study object, $\bar{Y} = \sum_{i=1}^n Y_i / n$, where n is the number of observed cities, W_{ij} represents spatial weight matrix.

Variables description

Explained variable: industrial structure upgrading (SOP)

Industrial structure upgrading is a dynamic evolutionary process whereby industrial structure advances from a low form to an advanced form. This includes direction and quality of industrial structure upgrading plus two other essential ingredients: 1) the constantly changing of the proportions in the relationships between industries and 2) productivity improvements in the industry sector. Previous studies have found that, "economic service" is an important feature of industrial structure upgrading; on the other hand, industrial structure upgrading in China must include productivity, the main driving force for the transformation of China in recent years. Thus, this paper constructs the following industrial structure upgrading index and with the formula (Equation 11):

$$SOP_{it} = TS_{it} \times OP_{it} \quad (11)$$

where i and t represent region and time, TS is the output ratio of the tertiary industry to the secondary industry, and OP is the productivity ratio of the tertiary industry to the secondary industry.

Core explanatory variable: regional environmental regulation (ERI)

Although there are many empirical studies on environmental regulation, there is a lot of controversy concerning the measurement of environmental regulation. Domestic and foreign scholars assess environmental

regulation mainly from representative pollutant discharge, capita income level, pollutant emission density, ratio of pollution control investment to industrial output value, number of environmental regulations, etc. (Levinson 1996; Mani and Wheeler 1998; Cole and Elliott 2003; Chen and Zhang 2012). However, the above indicators exhibit similarity and lack of representativeness. For this reason, this study will build a regional environmental regulation index (ERI) through the removal rate of sulfur dioxide and industrial powder. Specifically, these two individual indicators have to be standardized (Equation 12):

$$px_{ij}^s = [px_{ij} - \min(px_j)] / [\max(px_j) - \min(px_j)] \quad (12)$$

where px_{ij}^s denotes the normalized value of i-city under j-type pollutant, px_{ij} is the original value of i-city under j-type pollutant, $\max(px_j)$ and $\min(px_j)$ represent the maximum and minimum values of j-type pollutant among all cities.

Given that different cities have different types and quantities of pollutants and because the same city may have different pollutant emission intensities, each pollutant control index needs to be given a different weight in order to reflect the difference between environmental regulations of cities. Therefore, the adjustment indexes AI_{ij} of the two single indicators are calculated as follows (Equation 13):

$$AI_{ij} = \frac{px_{ij}}{\sum_{i=1}^n px_{ij}} / \frac{GDP_i}{\sum_{i=1}^n GDP_i} \quad (13)$$

where AI_{ij} is the proportion of j-type pollutant removal rate in i-city to the proportion of j-type pollutant removal rate in all cities and the proportion of i-city GDP in all cities' GDP. According to the standardized value and adjustment index based on the two single indicators above, the regional environmental regulation index is (Equation 14):

$$ERI_i = \frac{\sum_{j=1}^2 AI_{ij} px_{ij}^s}{2} \quad (14)$$

Control variables

This study selects the following control variables to consider other factors that affect industrial structure upgrading (Henderson 2003; Bronzini and Piselli 2009; Yin et al. 2015; Yuan et al. 2017): The level of economic development (VGDP): logarithm of urban per capita GDP; Human capital (EDU): the average year of education in urban through setting different educational years in different educational levels (6 years for primary school, 9 years for junior high school, 12 years for high school, and 16 years for college), getting each region's average years of education by weighting the ratio of each educational level in population; Infrastructure (INF): the area of urban road per capita; Foreign direct investment (FDI): the ratio of actual annual foreign investment to GDP, converting FDI according to the annual average price of the Ren Min Bi (RMB) exchange rate (Table 1); Government intervention (GOV): the ratio of local government financial expenditure to fiscal revenue.

Data sources

The data samples in this study are composed of panel data from 2003 to 2016 on the 285 prefecture-level cities in China from 2003 to 2016, mainly derived from the China City Statistical Yearbook (2004-2017) and China's Regional Economic Statistical Yearbook (2004-2017). A dynamic evolutionary process whereby industrial structure advances from a low form to an advanced form; An environmental regulation index through the removal rate of sulfur dioxide and industrial powder; The logarithm of urban per capita GDP; The average year of education in urban through setting different educational years in different educational levels; The area of urban road per capita; The ratio of actual annual foreign investment to GDP; The ratio of local government financial expenditure to fiscal revenue. Panel data refers to the sample data formed by taking multiple sections in the time series and simultaneously selecting sample observations on these sections. Finally, this study forms a 285×14 data matrix (Table 2).

Table 1. The average exchange rate of RMB to US\$.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Average Exchange Rate	8.2770	8.2767	8.2765	8.0702	7.8073	7.2996	6.8367	6.8281	6.6215	6.3001	6.2897	6.1428	6.2284	6.6423

Table 2. Descriptive statistical analysis of panel data.

Variable	Symbol	Mean	Std. Dev.	Max	Min	Samples
Industrial structure upgrading	SOP	1.2022	1.1869	24.1250	0.0016	3990
Regional Environmental regulation index	ERI	1.6638	1.7948	20.2568	0.1832	3990
Economic development	VGDP	10.1189	0.8684	13.0557	4.5951	3990
Human capital	EDU	1.7369	1.4218	78.5299	0.2064	3990
Infrastructure	INF	10.3114	7.5256	108.3700	1.2312	3990
Foreign direct investment	FDI	0.0400	0.2029	12.4432	0	3990
Government intervention	GOV	0.3926	1.1075	35.9531	0.0005	3990

RESULTS AND DISCUSSION

Spatial autocorrelation results

The mean of the Moran's I index of China's industrial structure upgrading passed the significance test at 1% from 2003 to 2016, thus indicating that there is a significant positive spatial correlation in industrial structure upgrading among Chinese cities (**Table 3**). From the perspective of variations in trend, the spatial autocorrelation of China's industrial structure "fluctuates" over time and the inflection points occur in 2008 and 2012.

Moran's I index of China's regional environmental regulations from 2003 to 2016 are significant at the 1% level, indicating that there was a significant positive spatial correlation in China's environmental regulation among cities (**Table 4**). From the perspective of variations in trend, the spatial autocorrelation of regional environmental regulation in China showed an upward trend over time especially after 2012. There was a substantial increase in spatial autocorrelation of regional environmental regulation. The main reason was the 18th National Congress of the Communist Party of China that took "ecological civilization" as a part of "the overall layout" of the new socialism with Chinese characteristics, requiring the authorities to "put ecological civilization in a prominent position and into the whole process of economic construction, political construction, cultural construction, and social construction". This led both the central government and local governments to improve

the environment by investing in capital and pollution control.

Spatial econometrics results analysis

Estimation of the DSPM can be done by several methods: the unconditional ML method, the QML method, the IV / GMM method and the Bayesian MCMC Method (*Elhorst 2015; Yu and Lee 2008; Parent and Lesage 2010*). However, not every method can fully deal with the endogeneity of explanatory variables and explanatory variables lagged in space and time. *Kukenova and Monteiro (2008)* expanded the system GMM method of *Blundell and Bond (1998)* into the spatial estimation method. As a new estimation method, spatial system GMM is not limited to correcting the endogenous problems of the explanatory variables. It can also solve the endogeneity problems of the explanatory variables space lag and time lag, thus reducing the deviation of the spatial variable parameter estimation. This study also estimated the DSPM with spatial system GMM.

Examining the results of models (1) - (3), both the time lag coefficient β and the spatial lag term ρ of the industrial structure passed significance tests at both 5% and 1% levels, which indicated that there exists both dynamic and spatial effects in China's industrial structure upgrading. Furthermore, it was also confirmed that it was appropriate to use the DSPM to analyze the direct effect of regional environmental regulation on industrial structure upgrading. This study validated the

Table 3. The Moran's I Index of China's industrial structure upgrading.

Year	2003	2004	2005	2006	2007	2008	2009
Moran's I	0.0694***	0.0836***	0.0791***	0.0783***	0.0863***	0.0624***	0.0945***
z-value	3.9403	4.4574	4.2349	4.2213	4.632	3.4193	5.0594
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000
Year	2010	2011	2012	2013	2014	2015	2016
Moran's I	0.0985***	0.1210	0.0630***	0.0806***	0.1041***	0.0952***	0.1056***
z-value	5.2395	7.1635***	3.3401	4.6659	5.6432	5.9802	6.093
p-value	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000

Note:***indicates significant test at 1% level

Table 4. The Moran's I index of China's regional environmental regulation.

Year	2003	2004	2005	2006	2007	2008	2009
Moran's I	0.0657***	0.1085***	0.0902***	0.0750***	0.0906***	0.1051***	0.1129***
z-value	3.6603	5.9204	4.8851	4.0787	4.8593	5.5703	6.0103
p-value	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Year	2010	2011	2012	2013	2014	2015	2016
Moran's I	0.1328***	0.1094***	0.1703***	0.1825***	0.1944***	0.2083***	0.2199***
z-value	7.0167	5.9187	8.9571	9.5934	10.2542	11.8302	13.2414
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note:***indicates pass significant test at 1% level

effect of regional environmental regulation on industrial structure upgrading by introducing regional environmental regulation and its spatial lag items, found that the coefficients and significance of core explanatory variables and control variables have not changed significantly, thus indicating that the results of the dynamic panel model contain strong stabilization.

Regional environmental regulation has a positive effect on industrial structure upgrading and passed the significance test at the 1% level (**Table 5**). The spatial lag term of regional environmental regulation had a significant negative impact on industrial structure upgrading. This means that a region can promote industrial structure upgrading by strengthening environmental regulation although the strengthening of regional environmental regulations in other regions could impede a region's industrial structure upgrading. The possible reasons were: under the reversal pressure influence of regional environmental regulation, local enterprises attempt to use new production technology and new energy technology, eliminate pollution capacity and upgrade production in order to maintain and improve intrinsic market advantage. Eventually, it established a trend of advanced development in industrial structure. On the other hand, the improvement in regional environmental regulation in other areas, to a certain extent, squeezes the region's enterprises on new technology and new technology investment, which has the effect of blocking a region's industrial structure upgrade. Furthermore, this study concluded that the strengthening of regional environmental regulations in other regions could impede a particular region's industrial structure upgrading since the spatial lag term of regional environmental regulation is negative. To sum up, from a spatial aspect, it is "exclusiveness" that promotes industrial structure upgrading following regional environmental regulation.

The impact of infrastructure and government intervention on industrial upgrading was positive and passed the significance test at both the 5% and 1% levels. Since the beginning of the 21st century,

China's construction of infrastructure has proceeded rapidly; this has significantly reduced both the transportation and transaction costs of production factors, spontaneously accelerating industrial transfers and upgrading. To promote the strategic industrial structure adjustment, both central and local governments have introduced a series of industrial policies, such as supply side structural reform. Additionally, under the fiscal decentralization system in China, the central government's assessment of local governments, the promotion of officials, the implementation of industrial policy and other factors will affect changes in regional industrial structure. It is further noted that results for the level of economic development, human capital, and foreign direct investment on the impact of industrial upgrading do not pass the appropriate significance tests.

The industrial structure upgrading has obvious dynamic and spatial effects; this showed that it was appropriate to use the DSPM to analyze the indirect effects of regional environmental regulation on industrial structure upgrading (**Table 6**). Under the influence of regional environmental regulation, the impact of not only economic development, human capital, infrastructure, but also government intervention, on industrial structure upgrading, is significant as both pass the 1% significant test, which indicated that regional environmental regulation can improve the negative effects of economic development and human capital on industrial structure upgrading.

Robust test

Since China is a developing country, there are obvious differences in economic development between regions. This study builds a spatial economic weight matrix to replace the above-mentioned spatial geospatial weight matrix to re-test the empirical results. The formula is:

$$W_{ij}^e = W_{ij}^d \text{diag}(\frac{\bar{Y}_1}{\bar{Y}}, \frac{\bar{Y}_2}{\bar{Y}}, \dots, \frac{\bar{Y}_n}{\bar{Y}}) \quad (15)$$

Table 5. The direct effect of regional environmental regulation on industrial structure upgrading.

Variable	Model (1)	Model (2)	Model (3)
β (Dynamic effect)	0.1055*** (2.72)	0.0907*** (2.56)	0.1031*** (2.68)
(Spatial effect)	-0.6274** (-2.03)	-0.6157** (-1.99)	-0.6295** (-2.04)
ERI	0.0494*** (4.37)		0.0501*** (4.43)
WERI		-0.2296* (-1.92)	-0.2377** (-2.03)
VGDP	0.0034 (1.18)	0.0035 (1.20)	0.0034 (1.16)
EDU	0.0106 (0.50)	0.0057 (0.25)	-0.0069 (-0.30)
INF	0.2834*** (9.57)	0.3246** (10.46)	0.3037*** (9.74)
FDI	-0.0080 (-0.09)	-0.0114 (-0.13)	-0.0047 (-0.05)
GOV	0.2369*** (8.68)	0.2147*** (7.98)	0.2362*** (8.65)
constant	3.8576*** (9.02)	4.0304*** (9.12)	8.3164*** (6.66)
Agj-R ²	0.6370	0.6363	0.6368
AR(1)	0.0128	0.0127	0.0130
AR(2)	0.8456	0.8138	0.8901
Sargan test	0.0000	0.0000	0.0000
LogL	-5341.2320	-5341.4332	-5338.0441
Samples	3990	3990	3990

Note: indicates significance at 10%, 5% and 1%, respectively are T statistic

Table 6. The indirect effects of regional environmental regulation on industrial structure upgrading.

Variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
β (Dynamic effect)	0.1035*** (2.70)	0.0096*** (2.68)	0.1025*** (2.76)	0.1001*** (2.69)	0.0930*** (2.59)
(Spatial effect)	-0.6235** (-2.01)	-0.6335** (-2.05)	-0.6158** (-1.98)	-0.6225** (-2.01)	-0.6114** (-1.97)
ERI×VGDP	0.0039*** (3.38)				
ERI×EDU		0.0282*** (3.74)			
ERI×INF			0.6212*** (3.38)		
ERI×FDI				-0.0010 (-1.05)	
ERI×GOV					0.4157*** (8.00)
VGDP	0.0035 (1.19)	0.0035 (1.12)	0.0043 (1.50)	0.0038b(1.30)	0.0035 (1.22)
EDU	-0.0092 (-0.11)	-0.0092 (-0.11)	-0.0167 (-0.19)	-0.0162b(-0.23)	-0.0140 (-0.16)
INF	0.2945*** (10.00)	0.2849*** (9.59)	0.3072*** (10.42)	0.2974*** (10.06)	0.3062*** (10.35)
FDI	0.0127 (0.60)	0.0109 (0.52)	0.0247 (1.17)	0.0196 (0.93)	0.0249 (0.87)
GOV	0.2331*** (8.50)	0.1996*** (7.38)	0.2107*** (7.67)	0.2211*** (8.23)	0.2110*** (6.17)
constant	3.9822*** (9.33)	3.9684*** (9.24)	4.2448*** (9.81)	4.0982*** (9.61)	4.2050*** (9.75)
Agj-R ²	0.6359	0.6361	0.6364	0.6368	0.6358
AR(1)	0.0126	0.0127	0.0131	0.0132	0.0130
AR(2)	0.6012	0.7642	0.7098	0.7532	0.8022
Sargan test	0.0000	0.0000	0.0000	0.0000	0.0000
LogL	-5343.4139	-5342.4080	-5342.3842	-5338.8039	-5344.0976
Samples	3990	3990	3990	3990	3990

Note: indicates significance at 10%, 5% and 1%, respectively are T statistic

where W_{ij}^d is spatial economic weight matrix, as above,

$\bar{Y}_i = \frac{1}{(t_1 - t_0 + 1)} \sum_{t_1}^{t_0} Y_{ij}$ represents i-city's GDP mean during inspection period, $\bar{Y} = \frac{1}{n(t_1 - t_0 + 1)} \sum_{i=1}^n \sum_{t_1}^{t_0} Y_{ij}$ is mean of GDP during the inspection period.

The empirical results (including the results of the spatial lag of industrial structure upgrading, time lag items and the core explanatory variables, and the control variables) are basically the same, which represents a slight reduction or improvement in some coefficients and

significance levels (Tables 7 and 5; Tables 8 and 6). It is further shown that the direct effect and the indirect effect of regional environmental regulation on industrial structure upgrading are relatively stable.

CONCLUSION AND RECOMMENDATIONS

Does regional environmental regulation promote the industrial structure upgrading? This study applied panel statistics from 285 cities in China from 2003 to 2016 and verifies the spatial autocorrelation of industrial structure upgrading and regional environmental regulation from

Table 7. Stability estimation results of direct affects.

Variable	Model (1)	Model (2)	Model (3)
β (Dynamic effect)	0.1058*** (2.72)	0.0908*** (2.56)	0.1032*** (2.68)
(Spatial effect)	-0.4214*** (-3.14)	-0.4661*** (-3.43)	-0.4849*** (-2.55)
ERI	0.0484*** (4.28)		0.0492*** (4.35)
WERI		-0.2500** (-1.99)	-0.2601** (-2.12)
VGDP	0.0034 (1.17)	0.0035 (1.19)	0.0033 (1.15)
EDU	-0.0106 (-0.12)	-0.0136 (-0.16)	-0.0079 (-0.09)
INF	-0.2865*** (-9.57)	-0.3276*** (-10.51)	-0.3064*** (-9.78)
FDI	0.0090 (0.42)	0.0031 (0.14)	-0.0085 (-0.37)
GOV	0.2376*** (8.71)	0.2159*** (8.02)	0.2368*** (8.67)
constant	3.2188*** (10.92)	3.4073*** (11.12)	3.0724*** (10.08)
Agj-R ²	0.6370	0.6363	0.6369
LogL	-5340.9550	-5341.1739	-5337.7065
Samples	3990	3990	3990

Note: indicates significance at 10%, 5% and 1%, respectively are T statistic

Table 8. Stability estimation results of indirect affects.

Variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
β (Dynamic effect)	0.1037*** (2.70)	0.1000*** (2.68)	0.0897*** (2.55)	0.1042** (2.76)	0.0933** (2.60)
(Spatial effect)	-0.4019*** (-3.31)	-0.4264*** (-3.18)	-0.4001*** (-3.01)	-0.40240*** (-3.16)	-0.4008*** (-3.05)
ERI×VGDP	0.0038*** (3.30)				
ERI×EDU		0.0275*** (3.64)			
ERI×INF			0.6161*** (3.35)		
ERI×FDI				-0.0011 (-1.15)	
ERI×GOV					0.4097*** (4.17)
VGDP	0.0034 (1.18)	0.0035 (1.19)	0.0048 (1.53)	0.0037 (1.29)	0.0035 (1.20)
EDU	-0.0117 (-0.14)	-0.0118 (-0.14)	-0.0186 (-0.22)	-0.0188 (-0.21)	-0.0156 (-0.18)
INF	0.2974*** (9.99)	0.2880*** (9.59)	0.3106*** (10.43)	0.3003*** (10.06)	0.3095*** (10.36)
FDI	0.0110 (0.52)	0.0093 (0.43)	0.0223 (1.04)	0.0173 (0.81)	0.0221 (0.77)
GOV	0.2338*** (8.53)	0.2014*** (7.44)	0.2114*** (7.70)	0.2223*** (8.28)	0.2170*** (8.05)
constant	3.3230*** (11.40)	3.3232*** (11.27)	3.5898*** (6.04)	3.4600*** (11.79)	3.5607*** (12.04)
Agj-R ²	0.6359	0.6362	0.6362	0.6364	0.6358
LogL	-5343.1320	-5342.0999	-5342.0262	-5343.0942	-5343.8580
Samples	3990	3990	3990	3990	3990

Note: indicates significance at 10%, 5% and 1%, respectively are T statistic

both global and local dimensions. It also verified, through a DSPM, the direct and indirect effects of the influence of regional environmental regulation on industrial structure upgrading. Among Chinese cities, there was significant spatial autocorrelation with regards to industrial structure upgrading and regional environmental regulation. The results of the DSPM showed that a region can promote industrial structure upgrading by strengthening the environmental regulations of the region, albeit, cognizant of the fact that the strengthening of environmental regulations in other regions could impede a particular region's industrial structure upgrading. Not only does infrastructure construction and government intervention significantly promote industrial structure upgrading, but regional environmental regulations can also effectively improve the negative impact of economic development, human capital, and foreign direct investment on industrial structure upgrading.

The study recommends the implementation of differentiated regional environmental regulation policies should be matched with the local industrial structure. Each region should take into consideration the local economic development and industrial structure situation to set regional environmental regulation policy. Give full play to environmental regulation on the industrial structure, based on environmental carrying capacity.

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