Bulletin of Chinese Academy of Sciences

Volume 35 | Issue 1 Article 9

January 2020

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## Abstract

More than half of the cities in the Yellow River Basin are resource-based cities. The coordinated development of such cities in ecology and industry is of great significance to promote high-quality development in the Yellow River Basin. This study takes environmental regulation and industrial enterprise data as samples, uses panel threshold model, entropy method, and other methods to classify resource-based cities in the Yellow River Basin based on resource endowment differentiation, analyzes resource endowment, environmental regulation, and industrial pathways to create multi-element interaction, the role relationship, scientific summary of the impact of environmental regulations on the creation of industrial pathways under high-, middle-, and low-level resource endowments, and then put forward high-quality development recommendations for resource-based cities under different levels of resource endowment. The results show that the level of urban environmental regulation in the Yellow River Basin increased significantly from 2003 to 2016, and the gap between regions continued to shrink, generally showing a gradual increase in the upstream, middle, and lower reaches. The resource-based (non-resource) industry in the resource-based cities of the Yellow River Basin from 2003 to 2013, the level of path creation has improved significantly but the regional differences are significant. Under different resource endowment conditions, the impact of environmental regulations on the path creation of resource industries and non-resource industry is significantly different. Therefore, the formulation and selection of environmental policies must consider the local resource endowment conditions and the degree of dependence of economic development on the resource industry, scientifically design the environmental regulatory policy system, and give full play to the role of environmental regulation in promoting ecological protection and industrial transformation of resource-based cities in the Yellow River Basin.



## Keywords

environmental regulation; resource endowment; path creation; high-quality development



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**Citation:** LU Shuo, ZHANG Wenzhong, LI Jiaming. Influence of Environmental Regulations on Industrial Transformation of Resource-based Cities in the Yellow River Basin under Resource Endowment [J]. Bulletin of Chinese Academy of Sciences, 2020 (1): 73–85.

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**Abstract:** More than half of the cities in the Yellow River Basin are resource-based cities. The coordinated development of such cities in ecology and industry is of great significance for promoting high-quality development in the Yellow River Basin. This study takes environmental regulation and industrial enterprise data as samples, uses panel threshold model, entropy method, and other methods to classify resource-based cities in the Yellow River Basin based on resource endowment differentiation, analyzes resource endowment, environmental regulation, and industrial pathways to create multi-element interaction, the role relationship, scientific summary of the impact of environmental regulations on the creation of industrial pathways under high-, middle-, and low-level resource endowments, and then puts forward high-quality development recommendations for resource-based cities under different levels of resource endowment. The results showed that the level of urban environmental regulation in the Yellow River Basin increased significantly from 2003 to 2016, and the gap between regions continued to shrink, generally showing a gradual increase in the upper, middle, and lower reaches. For the resource-based (non-resource) industry in the resource-based cities of the Yellow River Basin from 2003 to 2013, the level of path creation has improved significantly while the regional differences were significant. Under different resource endowment conditions, the impact of environmental regulations on the path creation of resource industries and non-resource industry was significantly different. Therefore, the formulation and selection of environmental policies must consider the local resource endowment conditions and the degree of dependence of economic development on the resource industry, scientifically design the environmental regulatory policy system, and give full play to the role of environmental regulation in promoting ecological protection and industrial transformation of resource-based cities in the Yellow River Basin. **DOI:** 10.16418/j.issn.1000-3045.20200107004-en

**Keywords:** environmental regulation; resource endowment; path creation; high-quality development

"The Yellow River Basin is an important ecological barrier and an important economic zone in China. It is a key area to win the battle against poverty and plays a vital role in China's economic and social development and ecological security." [1] stressed by the General Secretary Xi Jinping at the Symposium on Ecological Protection and High-quality Development of the Yellow River Basin in September 2019. The Yellow River Basin is not only an important ecological barrier region and economic belt but also a major energy development area in China. This area harbors coal, oil, natural gas, and metal mineral resources essential for China's modern industrial development, with the coal resource output accounting for about 70% of the total in China. Since the founding of the People's Republic of China, the resource-based cities in the Yellow River Basin have supported the long-term, steady, and rapid development of national economy. At present, more than 50% of the cities in the Yellow River Basin are resource-based cities and old industrial cities with the industry dominated by the mining and processing of mineral resources, unitary and rigid industrial structure [2], and low-level comprehensive utilization of resources [3]. Meanwhile, the industrial development mode of high pollution, high energy consumption, and high emission [4,5] in these cities have seriously affected the ecological security and sustainable development of the basin. In the context of national ecological civilization and Beautiful China construction, the high-quality development of resource-based cities in the Yellow River Basin has become the focus of attention from local governments and academic circles. Therefore, it is of great significance to study the impact of environmental regulation on industrial transformation in the resource-based cities in the Yellow River Basin, which is conducive to the construction of a new mode of ecological protection and high-quality development in the basin.

Environmental regulations are formed by national or regional government to protect the environment and prohibit or restrict specific economic behaviors of the regulated [6]. The main objects of environmental regulations are enterprises or organizations. By influencing the production behaviors of enterprises, the regulations force the adjustment of industrial structure and then promote the coordinated and sustainable development of urban economic growth and environmental protection [7]. In view of the special attributes of resource-based cities, the relevant studies on environmental

**Received:** 2020-1-10
**Supported by:** Young Scientists Fund of the National Natural Science Foundation of China (41701128)

 

regulations are increasing, and those on the impact of environmental regulation on the industrial structure of resource-based cities mainly involve two aspects. (1) Innovation compensation. Environmental regulations mainly force enterprises to innovate production mode and further stimulate the innovation compensation of enterprises in resource-based cities [8]. Mohr [9] believed that environmental regulations would promote the resource-based cities to pay more attention to scientific and technological innovation input and improve production efficiency. Focusing on 12 resource-based industries, Wang & Guo [10] found that environmental regulations significantly promoted technological innovation of resource extractive industry. (2) Labor supply. Walker [11] found that environmental regulations had a lasting reverse effect on the employment rate based on the follow-up investigation of resource-based cities. Liu et al. [12] reported that the strict regulations on industrial wastewater discharge resulted in a 7% reduction in the employment of industrial sector in the resource-based cities studied. These available studies mainly focus on the impact of environmental regulation in resource-based cities, and seldom discuss the resource endowment of the cities. However, the difference of resource conditions in resource-based cities will impact the implementation of environmental regulations and the industrial transformation [13,14]. Therefore, it is of great significance to study the influence of environmental regulation on the industrial transformation of resource-based cities in the Yellow River Basin from the perspective of resource endowment.

In this study, we used the panel data of environmental governance of 61 cities in the Yellow River Basin from 2003 to 2016 to establish the comprehensive evaluation index system of environmental regulations, and used entropy method to determine the environmental regulation index. On this basis, the panel threshold model was used to analyze the relationships among resource endowment, environmental regulations, and industrial transformation of resource-based cities in the Yellow River Basin. We then summarized the impact mechanism of environmental regulations on industrial structure under high-, medium-, and low-level resource endowments, and put forward high-quality development recommendations for resource-based cities under different levels of resource endowment. The results provided theoretical support and decision-making reference for the high-quality development of resource-based cities in the Yellow River Basin.

# 1 Research methods and data

## 1.1 Research area and data source

The delimitation of the research area follows the three principles of keeping the natural Yellow River Basin as the basis, maintaining the integrity of regional administrative division units as far as possible, and considering the direct correlation between regional economic development and the Yellow River [15]. According to the availability of data, 74 cities (referring to prefecture-level cities/autonomous prefectures/leagues, the same below) in Qinghai, Gansu, Ningxia, Inner Mongolia (excluding Chifeng, Tongliao, Hulun Buir, and Xing'an), Shaanxi, Sichuan, Shanxi, Henan, and Shandong are included in the Yellow River Basin. Among these cities, 61 were included in this study. According to the National Sustainable Development Plan for Resource-based Cities (2013–2020) (hereinafter referred to as the Plan) [16], 36 out of the 61 cities were selected as resource-based cities in the Yellow River Basin (Figure 1).

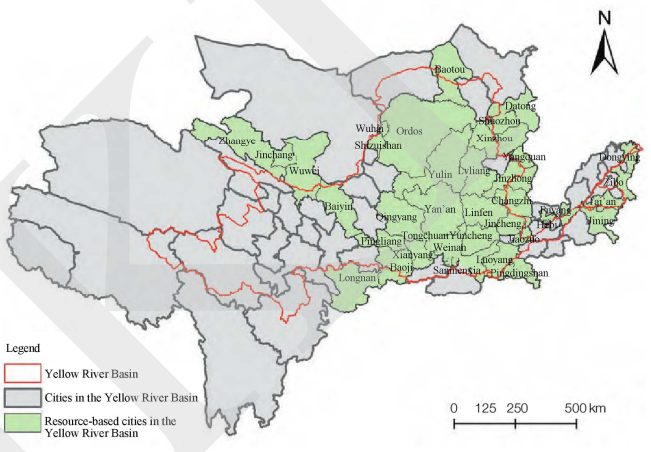


**Figure 1** Distribution of cities in the Yellow River Basin

This paper measures the resource endowment, environmental regulations, and path creation of resource (non-resource) industry in the resource-based cities in the Yellow River Basin. The basic data included the number of employees in 41 two-digit industries in the three industrial categories of extractive industry, manufacturing industry, and electricity, heat, gas, and water production and supply industry from 2003 to 2013①. The number of extractive industry employees and the environmental governance data were from China City Statistical Yearbooks (2004–2017) and the statistical yearbooks of provinces and cities.

## 1.2 Index definition

(1) Environmental regulation (*ER*). In this study, three methods were used to measure environmental regulation. (1) The single index method uses a single index to represent the intensity of environmental regulation. Aiken [17] used environmental legislation to represent the level of environmental regulation. (2) The comprehensive index method reflects the intensity of environmental regulation based on the indexes of regional pollutant discharge and governance. Li & Zou [18]

① The data is from China Industrial Enterprise Database (http://dbnav.lib.pku.edu.cn/node/12037). The "two-digit industry" refers to the industry in the major category in the industry classification of China's national economy.

used five indexes such as $SO_2$ removal rate and soot removal rate to construct the environmental regulation index system, and measured the intensity of regional environmental regulation based on the comprehensive index. (3) The assignment scoring method assigns the intensity of environmental regulation according to certain standards. van Beers & van den Bergh [19] constructed a scoring system of environmental regulation intensity, with a score range of 0–24 points, to quantitatively measure the intensity of environmental regulation in the study area. Since the single index method cannot comprehensively and objectively measure the intensity of regional environmental regulation and the assignment scoring method has certain subjectivity, we used the comprehensive index method to quantify the intensity of regional environmental regulation and established the environmental regulation index system including five indexes: soot removal rate, comprehensive utilization rate of general industrial solid waste, centralized treatment rate of sewage treatment plant, harmless treatment rate of household waste, and $SO_2$ removal rate. Entropy method [20] was used to calculate the intensity index of environmental regulation. The high index value indicates strong regulation of regional government on the environment.

(2) Path creation [*RV*(*UV*)]. Referring to the calculation methods of Frenken et al. [21] and Miao et al. [22], this study used entropy index method to measure the diversity of resource industry and non-resource industry, so as to represent the path creation level of resource industry and non-resource industry in resource-based cities respectively. A large value of *RV*(*UV*) indicates the high level of path creation of the industry.

(3) Resource endowment (*RE*). The development of extractive industry has the closest relationship with natural resources, which can accurately characterize the dependence of regional economy on natural resources [18]. We used the proportion of extractive industry employees in all employees to represent the resource endowment of resource-based cities.

### 1.3 Panel threshold model

We took resource endowment as the threshold variable to investigate its threshold effect on the relationship between environmental regulation and path creation of industry. Environmental regulation is the explanatory variable and path creation level of resource (non-resource) industry is the explained variable. The threshold effect between them was empirically tested. The panel threshold model proposed by Hansen [23] is mainly used to study the nonlinear relationship between explanatory variable and explained variable. Compared with the traditional method of studying threshold conditions, panel threshold model can estimate the specific threshold and test its significance. Based on the panel threshold model proposed by Hansen, the resource endowment index was divided into different sections according to the characteristics of the sample data of resource-based cities, and then the non-linear relationship between the environmental regulation level and path creation level of resource industry in different sections (represented by the proportion of extractive industry employees) was studied.

According to the estimation method of panel threshold model proposed by Hansen, any threshold variable is assigned as the initial value to the threshold to be estimated, and then the corresponding residual sum of squares is estimated by least square method. Finally, the minimum of residual square is taken as the final threshold, and the estimates of slope coefficients are obtained. The threshold effect test is mainly divided into two parts: (1) the significance test of threshold effect, (2) whether the estimate is equal to the real value. The specific test methods have been described in detail by Lian & Cheng [24] and Hansen [23].

## 2 Empirical results

### 2.1 Spatial pattern and evolution characteristics of environmental regulation and path creation

#### 2.1.1 Environmental regulation

In general, the intensity of environmental regulation of cities in the Yellow River Basin increased year by year from 2003 to 2016, and the regional difference was narrowing (Figure 2). The average environmental regulation intensity of 61 cities in the Yellow River Basin was only 0.21 in 2003 and increased to 0.43 in 2016. In terms of regions, the lower reaches had higher environmental regulation intensity than the upper and middle reaches. In 2003, the average environmental regulation intensity of the lower reaches was 0.30, which was significantly higher than that of the middle reaches (0.17) and the upper reaches (0.20); in the upper reaches, the environmental regulation intensity was higher than 0.30 in five cities including Yinchuan, Baiyin, and Jinchang; in the middle reaches, only Pingdingshan and Sanmenxia had the environmental regulation intensity higher than 0.30; in the lower reaches, the environmental regulation intensity was higher than 0.30 in eight cities including Jining, Dongying, and Dezhou. In 2016, the environmental regulation intensity of cities in the lower reaches was still the highest (0.48), while the gap with that in the middle and upper reaches was narrowing. The environmental regulation intensity of cities in the middle reaches has increased by nearly two times to 0.44, and that in the upper reached to 0.38. The environmental regulation intensity of cities in the Yellow River Basin presented an increasing trend from 2003 to 2016, particularly in the middle reaches, which further confirms that the cities in the middle reaches have achieved remarkable results in the control of industrial pollutant discharge. In terms of city type, the environmental regulation intensity of resource-based cities was lower than that of non resource-based cities from 2003 to 2016, and the gap was narrowing. The mean and median of environmental regulation intensity of resource-based cities were lower than those

 

of non-resource-based cities, which implied that the resource dependence affected the formulation of regional environmental regulation policies to a certain extent. The average environmental regulation intensity of resource-based cities was 0.21 in 2003 and increased to 0.42 in 2016. Meanwhile, the gap with non-resource-based cities was narrowing. The average gap in environmental regulation intensity between resource-based cities and non-resource-based cities was 0.019 in 2003 and declined to 0.008 in 2016. This reflects that environmental regulation in resource-based cities has been intensified significantly from 2003 to 2016, and the control of pollutant discharge in resource-based cities by regional governments gradually strengthened.

### 2.1.2 Path creation

(1) The path creation level of resource industry of resource-based cities in the Yellow River Basin showed significant regional difference. Specifically, the path creation of resource-based cities in the middle reaches performed better. The path creation level of resource industry of resource-based cities in the upper and lower reaches was relatively low while has been significantly improved from 2003 to 2013. In 2003, the cities with high resource industry diversity were mostly located in the middle reaches, mainly in Shanxi, southern Shaanxi, and northwestern Henan. These cities have good resource endowment and have extended the industrial chain on the basis of existing resources, realizing the path creation based on resource endowment advantage. In 2013, the diversity of resource industry of resource-based cities in the upper and lower reaches increased significantly compared with that in the middle reaches. Specifically, the diversity in Gansu, Shaanxi (except Tongchuan), and Shandong increased to over 1.2, while that in Changzhi, Lvliang, Yuncheng, Yangquan, and Datong of Shanxi showed different degrees of decline (Figure 3a and 3b). The main reason is that the five cities in Shanxi are rich in resources, and the industrial development is prone to the dilemma of path locking, which hinders the path creation of industry.

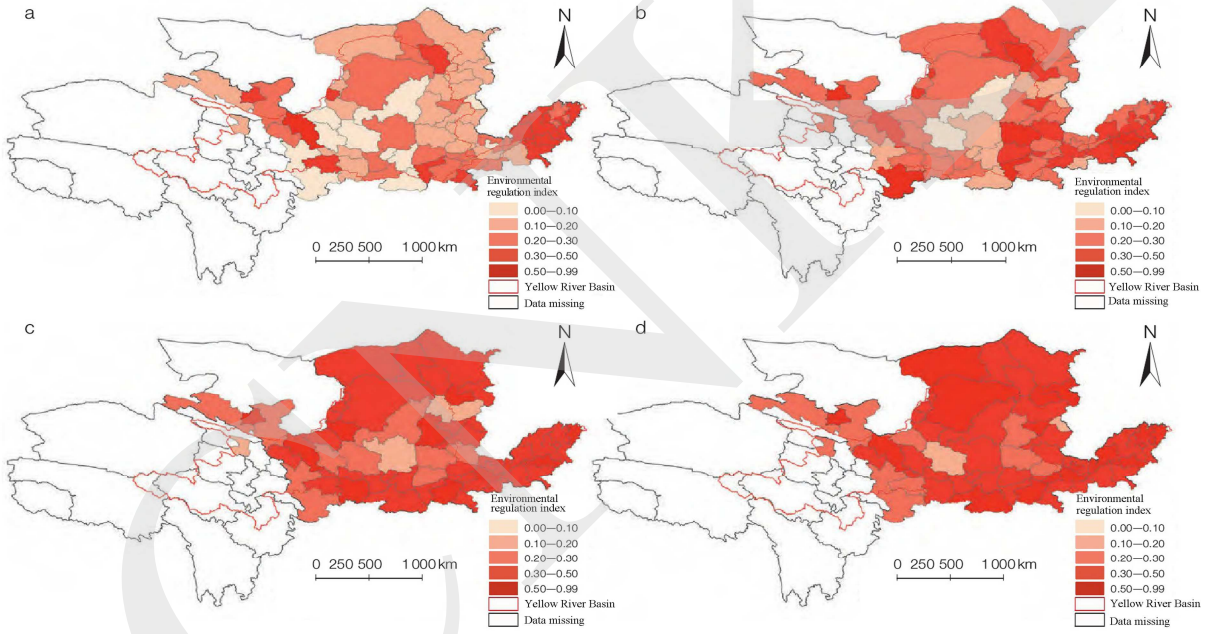


**Figure 2** Spatial and temporal evolution pattern of environmental regulation intensity of cities in the Yellow River Basin

(a) 2003; (b) 2007; (c) 2012; (d) 2016.

**Table 1** Test results of threshold effect

| Industry | Thresholds | *F* value | *P* value | 10% critical value | 5% critical value | 1% critical value |
|---|---|---|---|---|---|---|
| Resource industry | Single | 21.111** | 0.010 | 23.351 | 16.883 | 13.038 |
| | Double | 140.201*** | 0.000 | −6.893 | −12.442 | −15.708 |
| | Triple | 0.000 | 0.037 | 0.000 | 0.000 | 0.000 |
| Non-resource industry | Single | 31.974*** | 0.000 | 18.396 | 14.648 | 13.022 |
| | Double | 72.970** | 0.010 | −6.088 | −10.654 | −14.050 |
| | Triple | 0.000 | 0.040 | 0.000 | 0.000 | 0.000 |

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

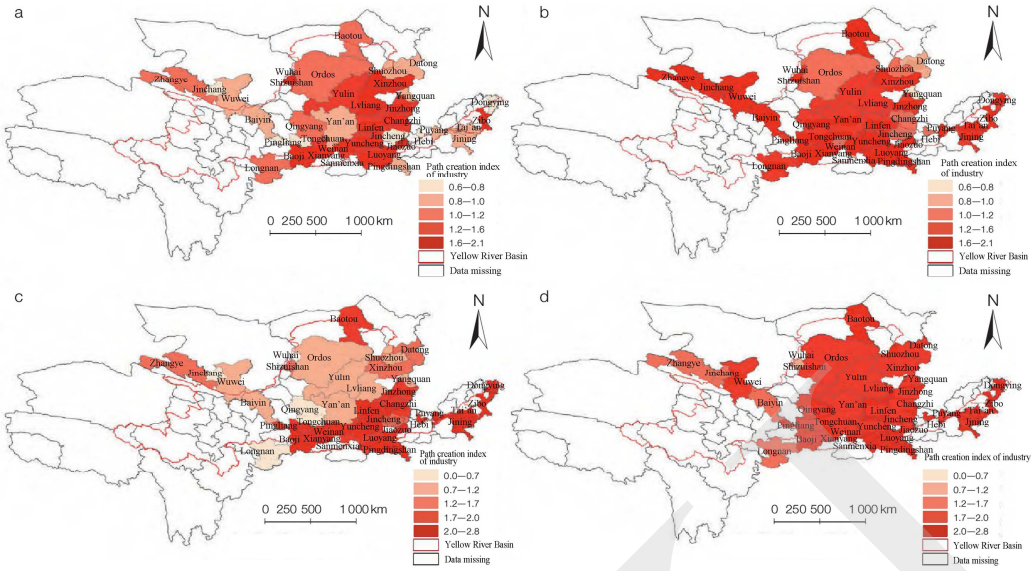


**Figure 3** Spatial pattern of path creation capacity of resource-based cities in the Yellow River Basin in 2003 and 2013

(a) Path creation of resource industry in 2003; (b) Path creation of resource industry in 2013; (c) Path creation of non-resource industry in 2003; (d) Path creation of non-resource industry in 2013.

**Table 2** Threshold estimation value and confidence interval

| Industry | Threshold | Estimate | 95% confidence interval |
|---|---|---|---|
| Resource industry | $\gamma_1$ | 0.118 | [0.094,0.119] |
| | $\gamma_2$ | 0.305 | [0.296,0.335] |
| Non-resource industry | $\gamma_3$ | 0.151 | [0.151,0.163] |

(2) The path creation of non-resource industry of resource-based cities in the Yellow River Basin has been significantly improved. The overall diversity of non-resource industry in the resource-based cities increased significantly, with the average value rising from 1.69 in 2003 to 2.17 in 2013. The regional gap has been narrowing. Except for Dongying, Zibo, Shizuishan, and Zhangye, other cities maintained an upward trend of path creation (Figure 3c and 3d). The resource-based cities in the lower and middle reaches (such as southern Shaanxi, southern Shanxi and western Henan) showed good path creation, while the path creation level of non-resource industry of resource-based cities in the upper reaches, northern Shaanxi, and northern Shanxi was still low. In 2003, except that in Baotou, the diversity of non-resource industry of resource-based cities in Inner Mongolia, Gansu, northern Shaanxi, and northern Shanxi did not exceed 1.7.

## 2.2 Influence mechanism of environmental regulation intensity on industrial path creation

### 2.2.1 Threshold effect of environmental regulation on path creation

In order to explore the non-linear relationship between environmental regulation intensity and the path creation level of resource industry in resource-based cities in different development periods of resource endowment, we employed panel threshold model with resource endowment as the threshold variable to estimate the number of thresholds of environmental regulation intensity on the path creation of resource (non-resource) industry. The estimates were tested by 300 bootstrap replicates using Stata15 software to determine whether there was threshold effect of environmental regulation intensity on path creation.

When the proportion of extractive industry employees is the threshold variable, the following conclusions can be drawn (Table 1). The double threshold test of resource industry has the highest significance ($P < 0.01$), and thus there are two thresholds. The single threshold of non-resource industry has the highest significance ($P < 0.01$), and thus there is only one threshold. Table 2 shows the threshold estimation results.

The likelihood ratio function graph clearly reflects the estimation of threshold and confidence interval (Table 2). Figure 4 illustrates the likelihood ratio function of two threshold estimates of resource industry. When the threshold variable is 0.118 and 0.305, both LR values are 0, far lower than the value at 5% significance level, which verifies that 0.118 and

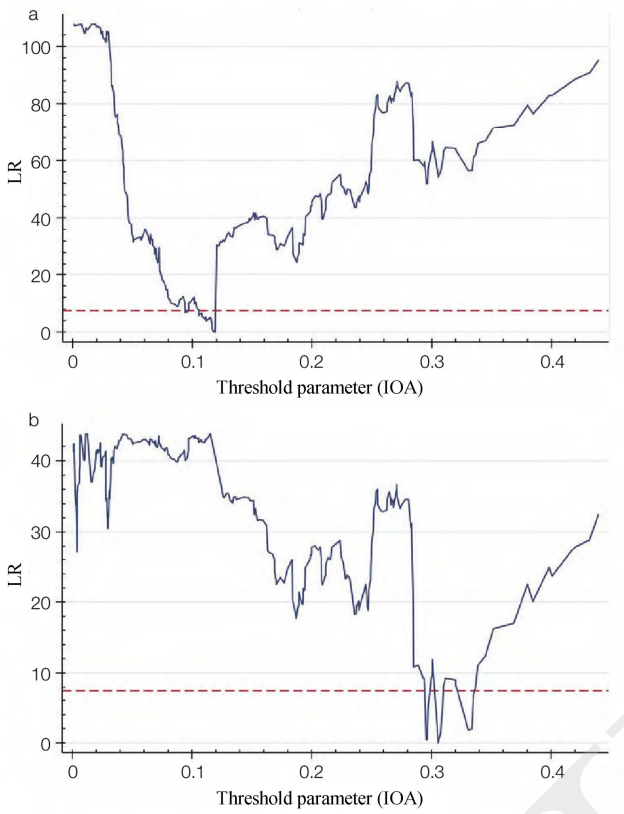


**Figure 4** Double threshold estimation of resource industry

(a) First threshold and confidence interval; (b) Second threshold and confidence interval.

0.305 are the real thresholds. Figure 5 illustrates the likelihood ratio function of one threshold estimation value of non-resource industry. When the threshold variable is 0.151, the LR is 0, far lower than the value at 5% significance level, which verifies that 0.151 is the real threshold.

When the threshold is obtained, the statistical results of threshold model of resource industry and non-resource industry are obtained respectively. The regression results of resource industry (Table 3) show that there are two obvious

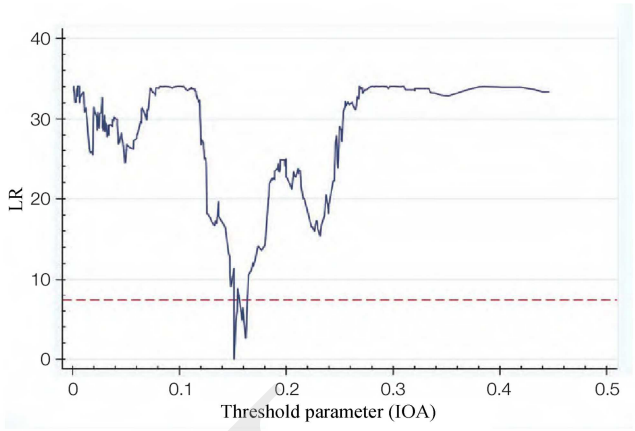


**Figure 5** Single threshold estimation of non-resource industry

thresholds (0.118 and 0.305) of environmental regulation intensity on path creation level of resource industry. When the resource endowment index is lower than 0.118, environmental regulation promotes the path creation of resource industry, as manifested by the positive correlation (correlation coefficient of 0.703) between them. When the resource endowment index is higher than 0.305, environmental regulation significantly inhibits the path creation of resource industry, as manifested by the negative correlation (correlation coefficient of −1.389) between them. When the resource endowment index is in the interval of the two thresholds, the regression coefficient fails to pass the significance test, which may be due to the insufficient sample size in this interval. However, the regression coefficient shows the trend (gradual decline from positive to negative) in line with that of the coefficient estimate.

The regression results of non-resource industry (Table 4) show that there is an obvious threshold of environmental regulation intensity on path creation level of non-resource industry. When the resource endowment index is lower than 0.151, environmental regulation promotes the path creation of non-resource industry, as manifested by the positive correlation (correlation coefficient of 0.193) between them.

**Table 3** Estimation results of double threshold model of resource industry

| Variable | Coefficient estimate | Standard error | *T* value | *P* value |
|---|---|---|---|---|
| Environmental regulation index (resource endowment < 0.118) | 0.703 | 0.071 | 9.820 | 0.000 |
| Environmental regulation index (0.118 ≤ resource endowment < 0.305) | 0.075 | 0.054 | 1.370 | 0.170 |
| Environmental regulation index (resource endowment ≥ 0.305) | −1.389 | 0.162 | − 8.560 | 0.000 |

**Table 4** Estimation results of single threshold model of non-resource industry

| Variable | Coefficient estimate | Standard error | *T* value | *P* value |
|---|---|---|---|---|
| Environmental regulation index (Resource endowment < 0.151) | 0.193 | 0.048 | 4.000 | 0.000 |
| Environmental regulation index (Resource endowment ≥ 0.151) | 0.800 | 0.113 | 7.020 | 0.000 |

When the resource endowment index is above 0.151, the positive correlation coefficient increases to 0.800, and environmental regulation significantly promotes the path creation of non-resource industry.

Based on the estimation results of threshold model, the first thresholds 0.118 of resource industry and 0.151 of non-resource industry are taken as the dividing point of low-level and middle-level resource endowment of resource industry and non-resource industry, respectively. Since there is no second threshold in the impact of environmental regulation on the diversity of non-resource industry, the dividing point of middle-level and high-level resource endowment of non-resource industry is characterized by 0.305, the second threshold of the influence of environmental regulation on the path creation of resource industry. Since the correlation coefficient has not changed, we hold that environmental regulation has the same effect on the diversity of non-resource industry in the contexts of medium-level and high-level resource endowment. With the decrease in the level of resource endowment, the promotion effect of environmental regulation on the path creation of resource industry gradually strengthens (Figure 6). The regions with high-level resource endowment vigorously develop extractive industry with the abundant natural resources, and the industry tends to be unitary and gradually generates path dependence [25]. With the increase of resource endowment, the promotion effect of environmental regulation on the path creation of non-resource industry gradually enhances, which shows that the environmental regulation can be used as an effective means to force the adjustment of industrial structure.

### 2.2.2 Impact mechanism of environmental regulation on path creation in resource-based cities with different resource endowment levels

The effect of environmental regulation on industrial structure is different due to the heterogeneity of resource endowment in resource-based cities. Resource endowment affects the implementation effect of environmental regulation policies by the comparative advantage of resource product cost. The blind increase in the intensity of environmental regulation and the unification of environmental policies will not necessarily contribute to the coordinated development of regional ecological environment and economy. The industry and regional differences of the regulated will lead to difference in the implementation effect of environmental regulations [26]. Therefore, it is necessary to clarify the impact mechanism of environmental regulation on the path creation of resource (non-resource) industry and implement differentiated environmental regulation policies for cities with different resource endowment levels.

(1) The period with low-level resource endowment is the key period for the industrial transformation of resource-based cities [27]. During this period, the resource-based cities experience the initial stage of industrial transformation, and the diversified industrial structure is initially formed. Compared

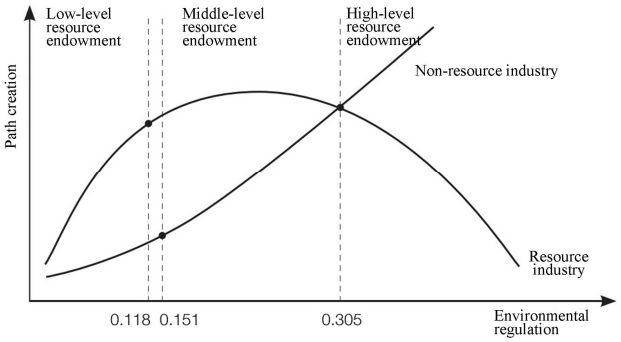


**Figure 6** Impact of environmental regulation on industrial path creation under different resource endowment levels.

0.118 and 0.305 are the thresholds of environmental regulation on resource industry, and 0.151 is the threshold of environmental regulation on non-resource industry.

with the medium-level and high-level resource endowment periods, this period has a reasonable industrial structure. The increase in environmental regulation intensity promotes the path creation of non-resource industry (Figure 7). Environmental regulation makes the environmental cost internalized by restricting the environmental performance of enterprises, which leads to the increase in product cost. In order to reduce the cost and maintain product competitiveness, enterprises are forced to transfer from resource-intensive and energy-intensive resource industry and pollution-intensive non-resource industry to technology- and knowledge-intensive non-resource industry. Environmental regulation significantly promotes the path creation of resource industry. During this period, the resources tend to be exhausted and the cost of resource exploitation is high. As a result, the profit of resource development is lower than the cost of environmental regulation, which leads to the lack of competitive advantage of primary resource products. Therefore, when the government implements strict environmental regulation and limits the emissions of Three Wastes produced by the leading industries of resource-based cities, the enterprises, to control pollution emission and pursue profit maximization, will upgrade production technology to weaken the reliance on resources, develop intensive processing, and enhance the competitiveness of products, thus promoting the diversified development of resource industry. From 2003 to 2013, the transformation of Luzhou City has achieved remarkable results, and the level of environmental regulation has increased by nearly three times, which has promoted the transformation from traditional resource industries such as mineral resources mining into a modern industrial system dominated by electronic information, biological medicine, new energy, and new material industries.

(2) The period with middle-level resource endowment is the initial period of industrial transformation of resource-based cities. The industrial center of city begins to shift from resource industry to non-resource industry. Environmental regulation can improve the path creation of non-resource industry. As the environmental regulation

becomes stricter, it is easier to drive enterprises to change production mode and promote industrial restructuring, so as to promote the path creation of non-resource industry. Meanwhile, environmental regulation promotes the path creation of resource industry. Compared with that in the period with high-level resource endowment, the comparative advantage of low cost of urban resource products gradually weakens in this period. The enhanced environmental regulation promotes enterprises to cope with the cost rise by extending the industrial chain and enhancing the added value of products, thus promoting the path creation of resource industry. From 2003 to 2013, the level of environmental regulation in Yulin City increased by 8 times, which promotes the transformation from extractive industry dominated by coal and petroleum mining into modern coal chemical industry dominated by coal to olefin and coal-to-liquids.

(3) The period with high-level resource endowment is the mature period of resource industry development. As shown in Figure 7, environmental regulation significantly promotes the path creation of non-resource industry. Since the non-resource industry in resource-based cities is the weakest in this period, environmental regulation has a significantly positive effect on the diversity of non-resource industry with a low proportion in the industrial structure. On the contrary, environmental regulation hinders the path creation of resource industry. Due to the abundant regional resource reserves and low exploitation cost of resource products [28], the profit of resource development is far higher than the cost of environmental governance. In the face of environmental regulation, most manufacturers will compensate for the increased cost of environmental regulation by increasing the output of resource products. From 2003 to 2013, the level of environmental regulation in Yangquan City increased by three times, while the diversity of resource industry decreased by 32%. Wilcoxen [29] and Gray & Shadbegian [30] reported that environmental regulation has an obvious negative effect on the development of pollution-intensive industries and manufacturing industries in the United States. According to the cost-benefit analysis, the intensification of environmental regulation will aggravate the path locking dilemma of resource industry.

## 2.3 Recommendations for high-quality development of resource-based cities with different resource endowment levels

Combined with the regression results of threshold model, the 36 resource-based cities in the Yellow River Basin are divided into three types based on the two thresholds (0.118 and 0.151) of resource industry as the standard.

(1) Thirteen resource-based cities such as Shizuishan, Jinchang, and Baotou are characterized by low-level resource endowment. These cities are mainly located in the middle and upper reaches of the Yellow River Basin, with low-level resource capability, high proportion of manufacturing and other non-resource industries, and reasonable industrial structure. The Plan issued by the State Council clearly proposes to support the alternative industries and promote the ecological governance of mines and subsidence areas in the cities with low-level resource endowment [16]. To achieve high-quality development in these cities, the effective means such as environmental regulation should be adopted to drive the industrial transformation toward high-end manufacturing industries with intensive knowledge and talents. It is essential to develop low-carbon industry and green economy, promote the ecological restoration and governance of resource-based cities, and ensure the ecological security of water source areas in the Yellow River Basin.

(2) Twenty resource-based cities such as Xinzhou, Tai'an, and Qingyang are characterized by middle-level resource endowment. This type of cities is mainly located in the middle and lower reaches of the Yellow River Basin, with the gradual decline of resource exploitation and the continuous reduction of resource reserves. These cities have passed the period of excessive dependence on resources, capital, and material investment for economic growth. The Plan proposes

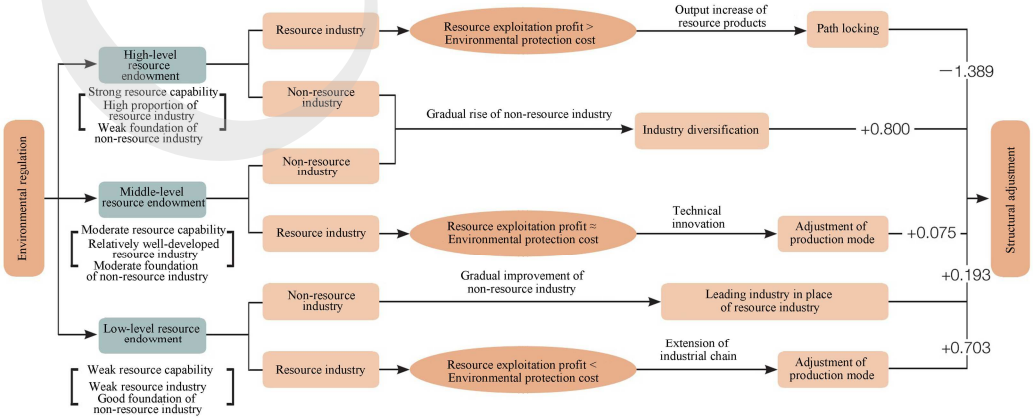


**Figure 7** Influence mechanism of environmental regulation on the industrial path creation under different resource endowment levels.

The number in the figure represents the effect coefficient of environmental planning on industrial structure, which is derived from Tables 3 and 4.

to develop strategic emerging industries and accelerate the new industrialization while improving the deep processing of resources in the resource-based cities with middle-level resource endowment [16]. In order to achieve high-quality development, the resource-based cities with middle-level resource endowment should base on the development advantages of existing resource industry, transform to technology-intensive, clean, and environment-friendly resource-based processing industry, and develop non-resource alternative industries. It is necessary to increase the intensity of environmental regulation, improve the path creation of resource industry and non-resource industry, and develop green low-carbon economy, thereby improving the quality of economic growth.

(3) Three resource-based cities, Datong, Jincheng, and Yangquan, are characterized by high-level resource endowment. These cities are mainly located in the middle reaches of the Yellow River Basin, with low proportion of urban non-resource industry, backward development of resource downstream industry, and unitary industrial structure. For resource-based cities with high-level resource endowment, the Plan proposes to improve the technical level of resource industry, extend the industrial chain, and cultivate resource intensive processing enterprises and industrial clusters [16]. In order to achieve high-quality development in the cities with high-level resource endowment, it is not enough to simply improve the intensity of environmental regulation. The key point is to implement comprehensive policies. Not only the rigid constraints should be imposed on enterprises' emission behavior, but also the measures such as financial subsidies and technological assistance should be taken for flexible regulation, so as to improve the technological innovation ability of enterprises and reduce production costs. Meanwhile, it is necessary to transform the extensive economic growth mode characterized by high-intensity exploitation and consumption of resources, extend the industrial chain, cultivate leading enterprises and industrial clusters of resource deep processing, and foster the transformation of resource industry from simplification to diversification. At the same time, the restoration and governance of mine geological environment and ecological system should be emphasized to ensure the ecological security of the basin and the water use safety of the lower reaches.

## 3 Conclusions and discussion

(1) From 2003 to 2016, the intensity of environmental regulation of cities in the Yellow River Basin has increased year by year and the gap between regions gradually narrowed. The intensity of environmental regulation was the lowest in the upper reaches, moderate in the middle reaches, and the highest in the lower reaches. The environmental regulation intensity of resource-based cities was lower than that of non-resource-based cities from 2003 to 2016, and the gap was narrowing.

(2) From 2003 to 2013, the path creation level of resource (non-resource) industry of resource-based cities in the Yellow River Basin has improved significantly, while the regional gap was significant. The path creation of resource industry in the middle reaches was better than that in the upper and lower reaches, while the latter has improved significantly from 2003 to 2013. The path creation of non-resource industry was good in the lower reaches, southern Shaanxi, southern Shanxi, and western Henan, while poor in the upper reaches, northern Shaanxi, and northern Shanxi.

(3) Under different resource endowment levels, the impact of environmental regulation on resource industry and non-resource industry was significantly different. (1) The relationship between environmental regulation and path creation of resource industry presented an inverted "U" shape. In the context of low-level resource endowment, the enhancement in environmental regulation improved the path creation of resource industry. In the context of middle-level resource endowment, environmental regulation was conducive to the path creation of resource industry, while the effect was weak. In the context of high-level resource endowment, the enhancement in environmental regulation hindered the path creation of resource industry. (2) Environmental regulation had a positive effect on the path creation of non-resource industry. In the context of low-level resource endowment, the enhancement in environmental regulation was beneficial to the path creation of non-resource industry. In the contexts of medium-level and high-level resource endowment, environmental regulation was conducive to the diversification of non-resource industry, and the effect was strong.

(4) The key to exerting the effect of environmental regulation on industrial restructuring is to adjust measures to local conditions and adopt comprehensive measures. Combined with the local resource endowment conditions and the dependence of economic development on resources, differentiated environmental regulation measures should be designed to give full play to the role of environmental regulation in the upgrading of industrial structure of resource-based cities in the Yellow River Basin.

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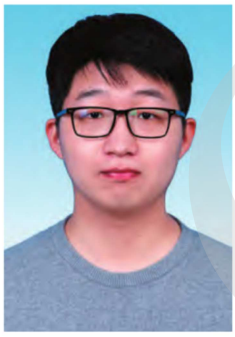

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