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Spatial-Temporal Heterogeneity and Decoupling Mechanism of Resource Curse, Environmental Regulation and Resource Industry Transformation in Post-Development Areas: Evidence from Inner Mongolia, China

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Abstract: Resource curse and environmental regulation are the key bottlenecks that hinder the sustainable development of the resource industry. A reasonable assessment of the decoupling relationship between resource supply, environment regulation and resource industry transformation is helpful to promote the decision-making of industrial restructuring in post-development regions. Taking Inner Mongolia Autonomous Region of China as the research object, panel data related to resources, environment and industry from 2010 to 2021 are selected to evaluate the spatial and temporal evolution of regional resource supply security, environmental regulatory pressure and resource industry transformation efficiency, measure the decoupling index among the factors, and use geographic detector technology to identify the constraints affecting factor decoupling. The results show the following: (1) the resource curse effect of Inner Mongolia is not significant, and some resource industries have prominent advantages; (2) the security of resource supply and the transformation efficiency of the resource industry show overall upward trend, the pressure of environmental regulation is basically balanced, and the development level of factors in resource-endowed regions and central cities is relatively high; (3) the spatial and temporal evolution of the decoupling relationship between resource supply, environmental regulation and resource industry transformation is uncertain, and the resilience of regional economic and social governance is poor; (4) resource endowment and resource industry advantages are the key that restricts the decoupling of factors, and the cumulative effect of ecological governance is likely to lead to the randomness of the decoupling of environmental regulation and resource industry transformation. In addition, this study suggests that the post-development areas should pay attention to the classification of resource industry relief, trans-regional economic and social collaborative governance and special resources exploitation.

Keywords: resource curse; environmental regulation; resource industry transformation; decoupling relationship; post-development area; Inner Mongolia

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1. Introduction

1.1. Global Post-Development Areas Governance

Sustainable development in post-development areas is a global initiative. The support of developed countries represented by the United States, Europe, Japan, South Korea, etc. to the post-development areas is mainly reflected in the introduction of resources and industries. Because the resource development intensity of these countries is relatively low, they often use international competitive strategies to obtain low-price resources and develop distinctive industries in the post-development areas [1–4]. Developing countries represented by China and India face relatively serious governance problems in post-development regions, which need to bear a greater pressure of transformation, and they have to balance the development of traditional industries and the introduction of new industries [5,6]. The Middle East, Africa and other countries have prominent advantages in oil, gas and mineral resources, and these countries need to give full play to the advantages of the resource industry to drive regional development, but it leads to the backwardness of economic development in resource-poor areas [7]. Therefore, the post-development regional governance strategies formulated by countries with different levels of development are not the same, but solving the problem of sustainable development of resource-based cities is a mainstream problem faced by all countries [8].

Promoting the transformation of the resource industry is an important means for the sustainable development of global resource-based cities, the core of which is to break the double constraints of resource reserves and environmental regulations [9,10]. In recent years, to reduce the risk of industrial factor supply caused by resource dependence, China's resource-based cities have continuously promoted the industrial transformation strategy on the basis of adhering to the principle of green development and stabilized the sustainable development goal of regional economy by expanding resource supply channels, upgrading resource industry technology, extending industrial chain and replacing emerging industries [11–13]. Up to now, under the dual influence of policy guidance and market regulation, 23 resource-based cities in China have completed reshaping their industrial structure and basically got rid of resource dependence and environmental constraints. In addition, there are still 239 regions in China with resource-based industries as the core growth poles, which are facing significant pressure on resources and the environment, and some post-development regions show a typical Dutch disease phenomenon [14]. Therefore, realizing the complete decoupling of the resource curse, environmental regulation and resource industry transformation is the key link to solving the sustainable development of resource-based cities.

1.2. Spatial-Temporal Heterogeneity and Decoupling Mechanism of Resource Curse, Environmental Regulation and Resource Industry Transformation

The existing studies on the decoupling relationship between resources, environment and industry mainly focus on the interaction effect among factors, regional heterogeneity of the decoupling relationship, the decoupling mechanism analysis and strategic response. The decoupling relationship between carbon emission, energy consumption, water resources utilization, ecological environment and economic growth is a current research focus [15,16]. From the perspective of the correlation study between the consumption of natural resource products and regional economic development, scholars hope to classify the stages of regional economic development by judging the decoupling relationship between factor consumption and the regional economy and believe that the strong decoupling effect is mainly distributed in regions with a high economic transformation degree [17–19]. In terms of pollution factor emissions, the complete decoupling of carbon emissions and economic growth is regarded as an important link in the transformation from late industrialization to the stage of common prosperity, and traditional high-pollution and energy-consuming industries achieve the goal of "carbon neutrality" and "carbon peak" through technological transformation [20,21]. In addition, from the view of macroeconomic analysis, the measurement of the decoupling relationship has begun to extend to other fields, and the decoupling relationship between tourism, transportation industry development, urbanization, regional poverty and economic growth has been paid attention by scholars [22–25]. It can be seen that the core of decoupling relationship research is to evaluate the degree of separation between different elements. The existing research includes multiple studies on factor decoupling around the core issues of economic and social development, laying a rich theoretical research foundation for the micro-analysis of the decoupling effect.

Analyzing the decoupling relationship between different factors and economic development is the basis of evaluating regional industrial transformation and formulating sustainable development strategy [26,27]. It is generally believed that the decoupling effect is mainly divided into strong decoupling, weak decoupling and negative decoupling [28–30]. Strong decoupling can be regarded as the fact that there is no correlation effect among the factors, which means that the destruction of the means of production and the environment has no impact on the sustainable development of the regional economy, and the regional economy has basically completed the goal of economic transformation [31,32]. Weak decoupling is mainly reflected in the process of economic and social governance of developing countries. That is, the economic pattern is transformed through factor replacement, industrial upgrading and governance capacity improvement, and the dependence of economic and social development on different factors is weakened, while some typical regions still need the support of resource products [33–35]. Negative decoupling indicates that the regional economic and social development is in the middle or late stage of industrialization, and the industrial pattern with the resource industry as the core occupies a dominant position, in which industrial development requires sustainable resource product guarantee, and it constantly causes damage to the ecological environment, requiring large ecological governance costs [36,37]. The three stages of decoupling effect require different response strategies, among which weak decoupling and negative decoupling are the main difficulties China faces; particularly, the high degree of resource dependence and environmental damage of core industries in some later developed regions seriously restricts China's overall goal of high-quality development [38]. In addition to resource development channel expansion, technological innovation drive, industrial chain extension and industrial substitution and other means to resolve the bottleneck risk of economic transformation, some scholars believe that it is also necessary to pay attention to the dynamic change trend of the international situation and market regulation and formulate flexible transformation ideas and coping strategies [39,40].

The research on regional heterogeneity of the decoupling effect is an important extension of the analysis of the decoupling relationship between factors. Besides the differences in the decoupling relationship between different factors such as resources, environment and economic growth in temporal and spatial dimensions, the decoupling relationship between different regions also has significant regional heterogeneity [41,42]. By means of technological innovation and management model innovation, developed countries have basically realized the complete decoupling of resource products and economic growth, and the inhibiting effect of environmental pollution on economic development has also been reduced [43]. In view of the fact that developing countries have not fully realized economic transformation, some industries and regions have a greater dependence on resource products, especially in the industrial sectors involved in national economic security. With the continuous expansion of the depth of environmental governance, although the pressure of environmental regulation is gradually reduced, it still restricts the efficiency of regional sustainable development [44–46]. Most low-income countries belong to resource-rich regions, and resource-based industries play a significant role in driving regional economic growth; it is difficult to achieve complete decoupling of resource dependence, environmental regulation and economic growth by effective means in the short term [47–49]. The regional differences in the decoupling relationship between factors within China are also prominent. The phenomena of resource dependence and environmental regulation, represented by resource-based cities, have not been eradicated. Scholars analyze the progress of China's economic transformation by studying the decoupling relationship between factors in different regions and industries [50,51]. However, the existing research on the regional heterogeneity of decoupling effect is relatively macro, and there is no systematic research on ethnic areas, post-development areas, resource-based cities and other special regions.

1.3. Innovation

According to the literature review, there are some differences in the governance strategies of post-development regions in the world, but a basic consensus has been reached on the transformation of resource-based cities as a sustainable development goal of post-development regions. At present, the main problem is the lack of systematic analysis of typical cases in post-development areas, including research innovation in methods, models and path selection. Meanwhile, achievements have conducted diversified studies on the decoupling effect of economic growth with different factors and regions, mainly focusing on resource supply, energy consumption, pollution emission, etc. There is little research on the correlation between the resource curse, environmental regulation and single type of industrial transformation in special regions; the inherent contradictions between economic growth dependence and resource and environmental policy regulation are ignored by most studies.

Although research on resource curses, environmental regulation, and resource industry transformation has accumulated some results, this study looks at the specific situation of a more recently developed region, in particular, the Inner Mongolia Autonomous Region of China, and through in-depth analysis of the unique socio-economic and environmental characteristics of the region, the findings have the characteristics of the study category. Therefore, in our research, the post-development regions that are the key weaknesses of China's economic and social governance are chosen as the main research perspective to evaluate the spatial-temporal evolution of the resource curse, environmental regulation and transformation efficiency of resource-based industries in specific regions, measure the decoupling relationship between resources, the environment and industries, and comprehensively reveal the evolution of decoupling effect among factors in China's post-development regions. Additionally, the impact mechanism of the decoupling relationship between resources, the environment and industry on the transformation of resource industry is also analyzed so as to explore the sustainable development model of China's post-developed regions.

2. Materials and Methods

2.1. General Research Design

To analyze the decoupling relationship between the resource curse, environmental regulation and resource industry transformation in the post-development regions, in this research, a five-step method is designed for the study of the decoupling effect of special regions, and Inner Mongolia, a representative post-development region in China, is selected as an empirical analysis case. The specific process is as follows: firstly, the status quo of the superiority degree of resource products and the resource industry in the region is analyzed; secondly, by selecting the relevant indicators of resource supply security, environmental regulatory pressure and resource industry transformation efficiency, different system evaluation systems and models are constructed, and the spatial-temporal dynamic evolution process of each system is measured; thirdly, based on the above evaluation results, the Tapio decoupling index model is used to analyze the decoupling relationship between resource-industry and environment-industry system; then, the factor detection module function of the geographic detector model is adopted to identify the key factors affecting the decoupling of resource supply, environmental regulation and resource industry transformation; finally, scenario analysis is carried out on the calculation results, and a cooperative governance idea of resource, environment and industry is proposed (Figure 1).

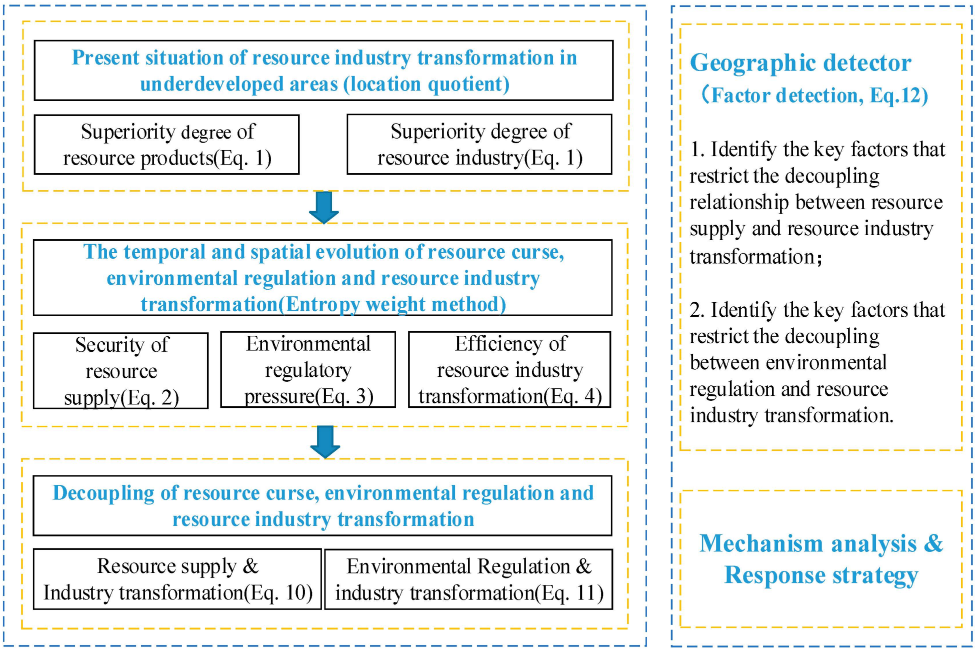

Figure 1. Research flow chart.

2.2. Model and Approach

2.2.1. Measurement of Resource Products and Industrial Superiority

Resource products and industrial superiority are important indicators to reflect the transformation degree of resource industry. The method of location quotient can be used to measure the regional superiority of resource products and resource industries [52]. Location quotient is a commonly used spatial analysis method to judge the factor advantage of the resource production industry, that is, to judge the degree of advantage of a certain factor in a specific region by the ratio of the share of the total amount of a certain factor in a specific region to the proportion of regional output value. The main accounting methods are as follows:

$$RA_j = \frac{R_j / \sum\limits_i R_{ij}}{\sum\limits_j G_j / \sum\limits_i \sum\limits_j G_{ij}} - 1 \tag{1}$$

In Equation (1), RA_j is the advantage ratio of the resource product or the resource industry; i refers to a specific region; j refers to the resource products or resource industries; R_j refers to the output of resource products or the output value of resource industries in the corresponding region; $\sum\limits_i R_{ij}$ represents the total output value of the resource product or the resource industry j in the study area; $\sum\limits_j G_j$ represents GDP of the specific region in current year; $\sum\limits_i \sum\limits_j G_{ij}$ represents GDP of the study area in current year.

The degree of advantage is divided according to the measured result of the advantage ratio, and the division standard is shown in Table 1. When the advantage ratio is greater than or equal to 1, a significant advantage is presented, which indicates that the basis of the resource product or resource industry consumption in the resource area can radiate to support consumption in other regions. When the advantage ratio is less than zero, an unstable advantage or disadvantage is presented, indicating that a large amount of resources need to be transferred to other regions to support the consumption of regional resource products or resource industries.

Table 1. Criteria for mineral reserve superiority classification.

Advantage Ratio Range	Advantage or Disadvantage Level
$RA_j \geq 1$	significant advantage
$0.2 \leq RA_j < 1$	general advantage
$0 \leq RA_j < 0.2$	unstable advantage
$-0.2 \leq RA_j < 0$	unstable disadvantage
$RA_j < -0.2$	disadvantage

2.2.2. Assessment of Resource Supply, Environmental Regulation and Industrial Transformation Efficiency

Index System

Resource supply risk, environmental regulation pressure and industrial transformation efficiency are important first-level indicators to reflect the resource curse, environmental regulation and resource industry transformation, respectively. Based on these indicators, this paper explores the internal characteristics of the resource industry, combines them with the basic status quo of economic and social development in China's later developed regions, and further selects 20 index factors, which are based on the indicators of resource industry and supplemented by objective environmental indicators, to construct an evaluation system of resource supply, environmental regulation and resource industry transformation development level (Figure 2). X_1,X_2, . . ., X_{20} indicates each indicator factor separately in the following sections.

Evaluation Model and Method

(1) Evaluation model

In order to reasonably measure the spatial-temporal evolution level of resource supply, environmental regulation and industrial transformation in the selected research area, it is necessary to construct a quantitative measurement model of each dimension.

Resource supply system is shown in Equation (2).

$$RS = \alpha_1 ES + \alpha_2 RP + \alpha_3 SS \tag{2}$$

In Equation (2), RS represents the resource supply risk; ES refers to the security of energy supply; RP refers to the resource supply potential; SS refers to the secure supply of mineral resources; α_1, α_2 and α_3 are the weights of each indicator, respectively.

Environmental regulatory is shown in Equation (3).

$$ER = \beta_1 GE + \beta_2 PD \tag{3}$$

In Equation (3), ER represents the environmental regulatory pressure; GE refers to the governance effect; PD refers to the pollution discharge; β_1 and β_2 are the weights of corresponding indicator.

Resource industrial transformation is shown in Equation (4).

$$IT = \gamma_1 II + \gamma_2 ID \tag{4}$$

In Equation (4), IT represents the efficiency of industrial transformation; II refers to the industrial input; ID refers to the industrial dominance; γ_1 and γ_2 are the weights of corresponding indicator.

(2) Evaluation method

a. Entropy weight method

Indicators of different dimensions need to be reasonably weighted. To comprehensively evaluate the disturbance effect of each index on different systems, the entropy weight method is selected to objectively assign weights to each index in this paper.

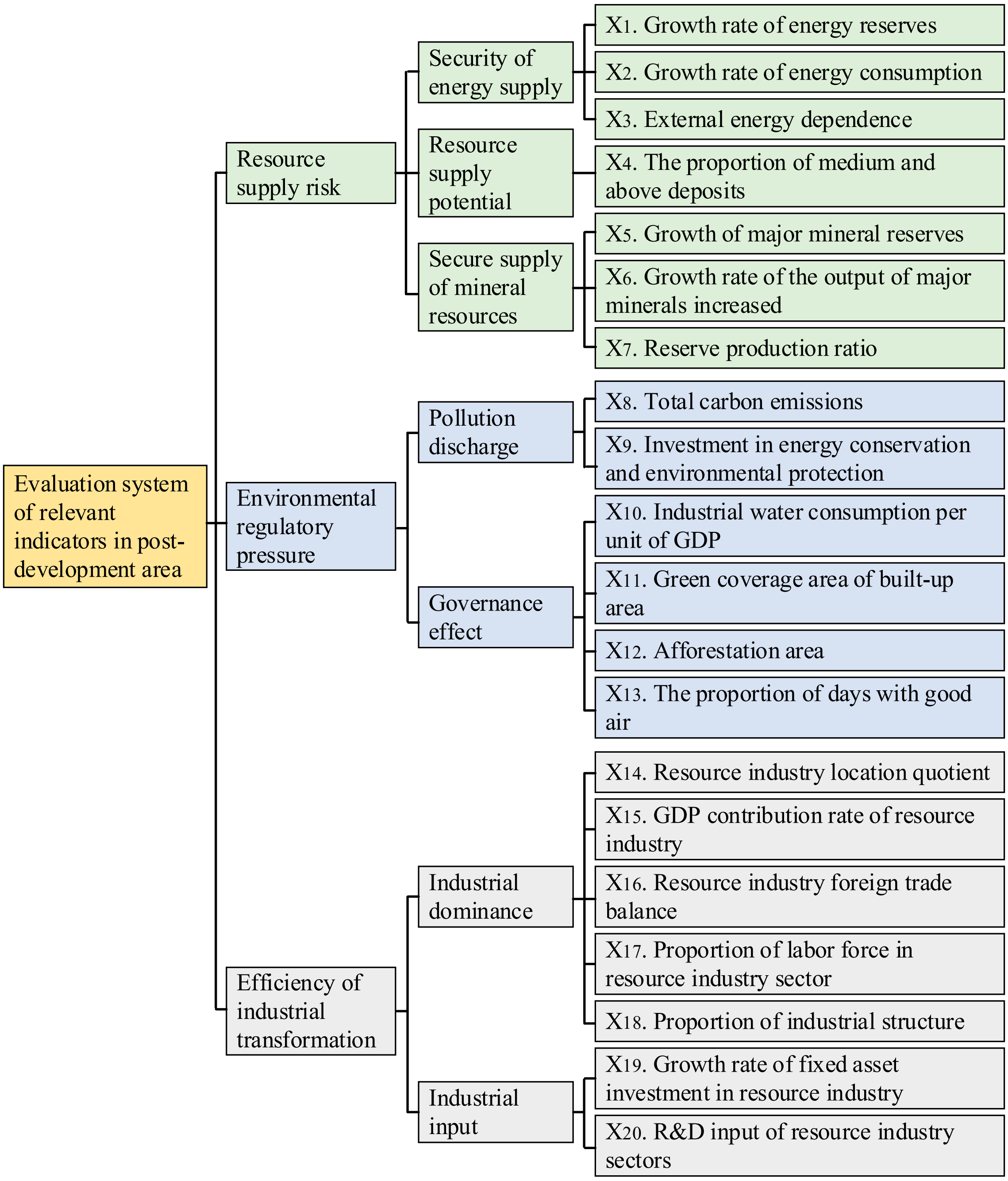

Figure 2. Evaluation system for resource supply risk, environmental regulatory pressure and industrial transformation efficiency.

First, it is necessary to standardize the data according to the attribute of the indicator. When the entropy weight method is used to determine the weight of sub-division indicators of subsystems, there are differences in the action direction of indicators in each dimension, which is different from the standardized processing of principal component analysis data. Here, positive or negative indicators are selected to standardize the data.

Positive indicators are as follows:

$$Y_{ij} = \frac{X_{ij} - Min(X_j)}{Max(X_j) - Min(X_j)}(i = 1, \ldots, m; j = 1, \ldots, n) \quad (5)$$

The negative indicators are as follows:

$$Y_{ij} = \frac{Max(X_j) - X_{ij}}{Max(X_j) - Min(X_j)}(i = 1, \ldots, m; j = 1, \ldots, n) \tag{6}$$

Suppose there are m cities, n indicators and X_{ij} represents the original value of the indicator j for the city i. $Max(X_j)$ and $Min(X_j)$, respectively, represent the maximum and minimum values of indicator j in all cities; Y_{ij} represents the value of index j of city i after dimensionless standardization, and the larger the Y_{ij}, the greater the contribution to the target value ($Y_{ij} \in [0,1]$).

Then, the indicator weight should be determined. The proportion of the index value of object i under index j is shown in Equation (7).

$$p_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{m} Y_{ij}} \tag{7}$$

The information entropy of index j is shown in Equation (8).

$$e_j = -\frac{1}{Inm}\sum_{i=1}^{m} p_{ij} Inp_{ij} \tag{8}$$

Finally, the weight of indicator j is determined as shown in Equation (9).

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \tag{9}$$

In the above formulas, $i = 1, \ldots, m;\ j = 1, \ldots, n$.

b. Measurement of decoupling index

Decoupling is a correlation phenomenon of economic factors corresponding to coupling, which comes from the category of physics and mainly reflects the interrelation between two or more economic factors. The elastic coefficient proposed by Tapio is a relatively mainstream method for estimating the decoupling index at present. It introduces incremental data to dynamically represent decoupling, thus avoiding the impact of base period selection.

$$DI_{RS} = \frac{(RS_t - RS_{t-1})/RS_{t-1}}{(IT_t - IT_{t-1})/IT_{t-1}} = \frac{\Delta RS}{\Delta IT} \tag{10}$$

$$DI_{ER} = \frac{(ER_t - ER_{t-1})/ER_{t-1}}{(IT_t - IT_{t-1})/IT_{t-1}} = \frac{\Delta ER}{\Delta IT} \tag{11}$$

In Equations (10) and (11), DI_{RS} and DI_{ER} represent the decoupling index of resource supply, environmental regulation and resource industry transformation, respectively; RS_t and RS_{t-1} refer to the resource supply risk of each area in the year t and the year $t-1$; ER_t and ER_{t-1} refer to the environmental regulatory pressure of each area in the year t and the year $t-1$; IT_t and IT_{t-1} refer to the efficiency of industrial transformation of each area in the year t and the year $t-1$; ΔRS, ΔER and ΔIT are the average annual growth rates of each system, respectively.

It should be noted that the relevant data used here are calculated by Equations (2)–(4). In general, the measurement results divide the decoupling types into 8 categories with the critical values of 0, 0.8 and 1.2, as shown in Table 2. In order to explore the decoupling relationship between resource supply, environmental regulation and resource industry transformation, this paper frames the decoupling type based on the actual development situation of resource-based cities (Table 2).

Table 2. Determination of decoupling state between resource supply and resource industry transformation.

Decoupling State	ΔRS(or ΔER)	ΔIT	Implication	Overall State
strong decoupling $(-\infty, 0)$	<0	>0	While resource industrial transformation accelerates, the intensity of resource supply (or environmental regulation) decreases.	ideal
weak decoupling $[0, 0.8)$	>0	>0	Resource industrial transformation and resource supply (or environmental regulation) accelerate simultaneously, but the former is faster than the latter.	ideal
recessive decoupling $(1.2, +\infty)$	<0	<0	Resource industrial transformation and resource supply (or environmental regulation) slow down simultaneously, but the former is slower than the latter.	relatively ideal
extended connection $[0.8, 1.2)$	>0	>0	Resource industrial transformation and resource supply (or environmental regulation) accelerate simultaneously, and the growth rate of both is balanced.	ordinary
recessive decoupling $[0.8, 1.2)$	<0	<0	The transformation of resource industry and resource supply (or environmental regulation) slow down simultaneously, and the two rates are balanced.	ordinary
strong negative decoupling $(-\infty, 0)$	>0	<0	While the transformation of resource industry slows down, the supply of resources (or environmental regulation) increases, and the two show an inverse growth trend.	unsatisfactory
weak negative decoupling $[0, 0.8)$	<0	<0	Resource industrial transformation and resource supply (or environmental regulation) slow down simultaneously, but the former is faster than the latter.	unsatisfactory
expansionary negative decoupling $(1.2, +\infty)$	>0	>0	Resource industrial transformation and resource supply (or environmental regulation) accelerate simultaneously, but the former is slower than the latter.	unsatisfactory

c. Geographic detector

In order to further explore the key factors affecting the decoupling of resource supply, environmental regulation and resource industry transformation, the factor detection module of the geographical detector model is selected to explore the impact factors and explanatory power of the decoupling system of resource supply, environmental regulation and resource industry transformation. The calculation formula is as follows:

$$q = 1 - \frac{1}{N\sigma^2}\sum_{i=1}^{n} N_i \sigma i^2 \tag{12}$$

where q represents the explanatory power of influence factor; N_i and N are the number of units in factor layer i and the whole region, respectively; σi^2 and σ^2 are the variances of factor layer i and the whole region, respectively. The value range of q is [0, 1]. The larger the value of q, the stronger the explanatory power of the independent variable to the dependent variable; otherwise, the weaker the explanatory power.

2.3. Data Sources

The data used in this study are composed of panel data related to resource supply, environmental regulation and resource industry transformation in the Inner Mongolia Autonomous Region of China from 2010 to 2021. These data are mainly gathered from the World Bank, China City Statistical Yearbook, Inner Mongolia Statistical Yearbook, Inner Mongolia Mineral Resources Statistical Bulletin, Inner Mongolia Ecological and Environmental Protection Bulletin, China Emission Accounts and Datasets and internal reports of relevant departments. In addition, some missing data are supplemented by a data fitting method.

3. Results

3.1. Selection of the Research Area

The Inner Mongolia Autonomous Region is located in the northern border of China. As the provincial administrative region with the widest longitude range in China, it is about 2400 km long from east to west, of which the total area ranks third in the country. The Inner Mongolia Autonomous Region is the province that owns the largest number of new discovered minerals in China. Most of the 168 discovered minerals can be discovered there. The reserves of key strategic mineral resources such as coal, rare earth and iron ore in Inner Mongolia rank among the top in China, forming a complete resource industry chain. Here, Equation (1) is adopted to measure the dominance of the two dimensions. From the perspective of resource reserve superiority, coal, natural gas, iron ore, chromium ore, copper, tin, molybdenum ore, gold, cobalt ore, rare earth, fluorite, crystalline graphite and other strategic key minerals have significant comparative advantages, but shale gas, coal bed gas, bauxite, lithium, zirconium ore and potash and other resources are relatively poor. In the point of advantages of resource industry sectors, the coal mining and washing industry, metal mining and processing industry, non-ferrous metal smelting and rolling industry in Inner Mongolia have prominent advantages nationwide, while other resource industry sectors have no obvious comparative advantages and even have disadvantages (Figure 3). It should be noted that as an ecological barrier in northern China, Inner Mongolia not only needs to control the environmental damage caused by the development of the resource industry but also faces a large ecological resistance risk, and its environmental regulation pressure is more severe than that of other regions. In addition, the resource-based cities under the jurisdiction of Inner Mongolia rank among the top in China, but its GDP is in the middle and lower level of the country, which indicates that Inner Mongolia is a typical region that suffers from the “Dutch disease”. Therefore, taking the Inner Mongolia Autonomous Region as an empirical case, by testing the decoupling effect of resource curse, environmental regulation and resource industry transformation in this region and, then, identifying the inhibiting factors of economic governance in this region, it has important reference significance for the decision-making of resource industry transformation in the post-development region.

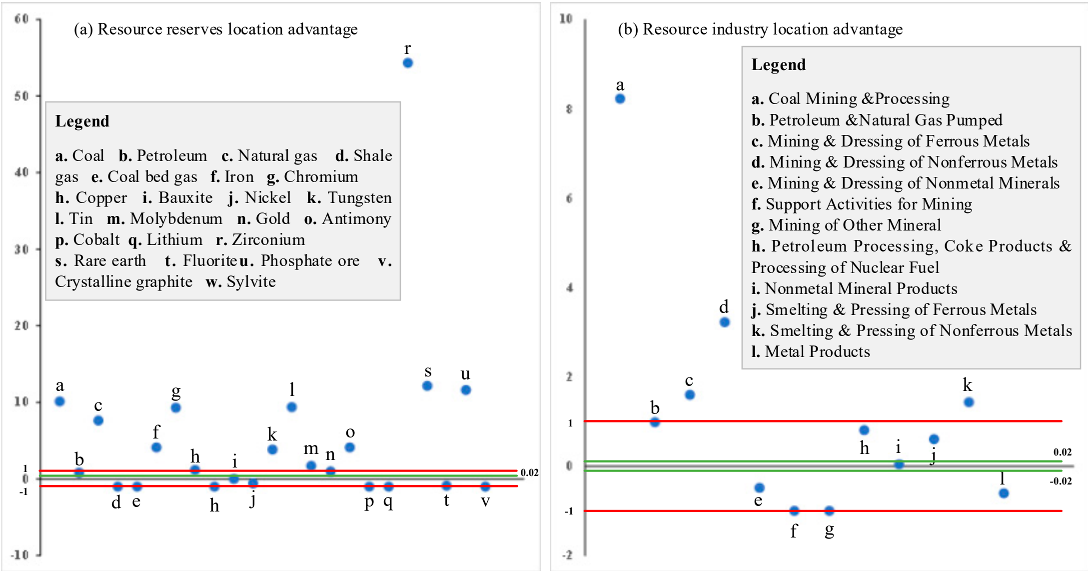

Figure 3. Superiority degree calculation of resource reserves and resource industry based on location quotient method. (**a**) Resources reserves location advantage; (**b**) Resource industry location advantage, the red line represents plus or minus 1 and the green line represents plus or minus 0.02.

3.2. The Spatial-Temporal Evolution Assessment of Resource Supply, Environmental Regulation and Resource Industry Transformation

In this paper, panel data related to resource supply, environmental regulation and resource industry transformation in the Inner Mongolia region of China from 2010 to 2021 are collected. The evaluation model is derived from Equations (2)–(4), and the spatial-temporal differentiation of factors in the Inner Mongolia region and its 12 cities is comprehensively weighted by the entropy weight method (Equations (5)–(9)). Due to the randomness of the changes in the temporal dimensions of each factor, Jenks is adopted to investigate the spatial heterogeneity of 12 cities in Inner Mongolia; the development level of the factors is divided into three levels (high, middle and low), and the time profiles are selected as 2010, 2011 and 2021.

It is found that there is obvious temporal heterogeneity of resource supply security, environmental regulation pressure and resource industry transformation level in Inner Mongolia (Figure 4). From the perspective of resource supply security, due to the continuous strengthening of resource exploration in recent years, Inner Mongolia's resource supply security shows an overall upward trend from 2010 to 2021 with only a short-term downward trend in some years. From the perspective of environmental regulation pressure, affected by environmental policies, the level of resource regulation pressure is relatively high in 2015 and 2018 and relatively balanced in other years. From the perspective of the efficiency of industrial transformation, after experiencing the "golden decade" of resource exploration and development industry, Inner Mongolia's resource industry began to shrink gradually after 2011, and the transformation efficiency of resource industry continued to improve.

The spatial heterogeneity of resource supply security, environmental regulatory pressure and resource industry transformation efficiency is more significant in Inner Mongolia (Figure 5). Through a detailed study of the spatial distribution characteristics of the development level of above three factors in 2010, 2011 and 2021, it is found that the dynamic change trend of resource supply, environmental regulation and resource industry transformation degree in 12 cities in Inner Mongolia is obvious. Since 2010 is still the golden period of resource exploration and development in China, the resource supply security level of Ordos, Ulanqab, Xilin Gol and Hulun Buir and other advantageous resource endowment regions is relatively high. However, due to the synchronous progress of resource development and resource industry development, except Baotou, Chifeng and Tongliao and other traditional ecological barrier cities, such areas are also facing high environmental regulatory pressure. At the same time, some regions have begun to promote industrial upgrading by relying on resource industries and economic first-mover advantages, making the resource endowment advantage regions and central cities represented by Baotou and Ordos show a higher efficiency of resource industry transformation. By 2016, China had formulated a number of environmental protection and resource industry development policies, resulting in the gradual contraction of the resource exploration and development industry; in addition to Ordos, Ulanqab, Xilin Gol and Hulun Buir, the security level of resource supply in Alxa League, Xilin Gol, Hinggan League and Tongliao has been improved. Similarly, macro-policy changes have driven environmental governance in Inner Mongolia to achieve results, and the environmental regulatory pressure tends to stabilize or even decline in most regions. Additionally, except for Ordos and Baotou, the transformation efficiency of the resource industry in Bayan Nur, Wuhai and most cities in eastern Inner Mongolia has gradually improved, and the resource industry has stepped into contraction. By 2021, due to the decreasing of resource reserves and the stabilization of environmental policies, the development of the resource industry in Inner Mongolia is being transformed from a painful period to a stable development stage. Apart from Ordos, Ulanqab, Hinggan and other traditional coal-dominated resource endowment advantage areas, the security level of resource supply in other cities has declined sharply and is at a relative disadvantage. Compared with 2010, the traditional environmental regulation pressure level was higher, and the environmental regulation pressure is spreading to the western region of Inner Mongolia. The transformation efficiency of the resource industry is relatively stable; the efficiency in resource endowment advantageous regions and central cities is still high while insignificant fluctuation appears in some cities.

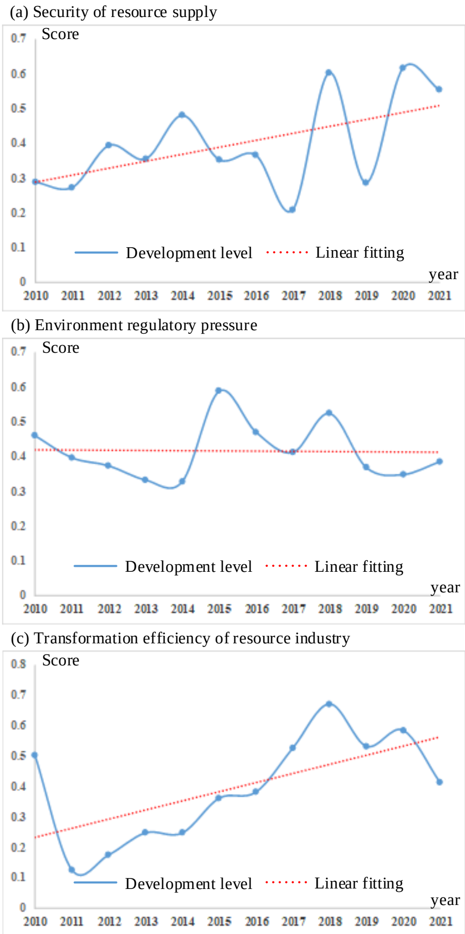

Figure 4. Overall evolution trends of resource supply, environmental regulation and resource industry transformation level. (**a**) Security of resource; (**b**) Environmental regulation pressure; (**c**) Transformation efficiency of resource industry.

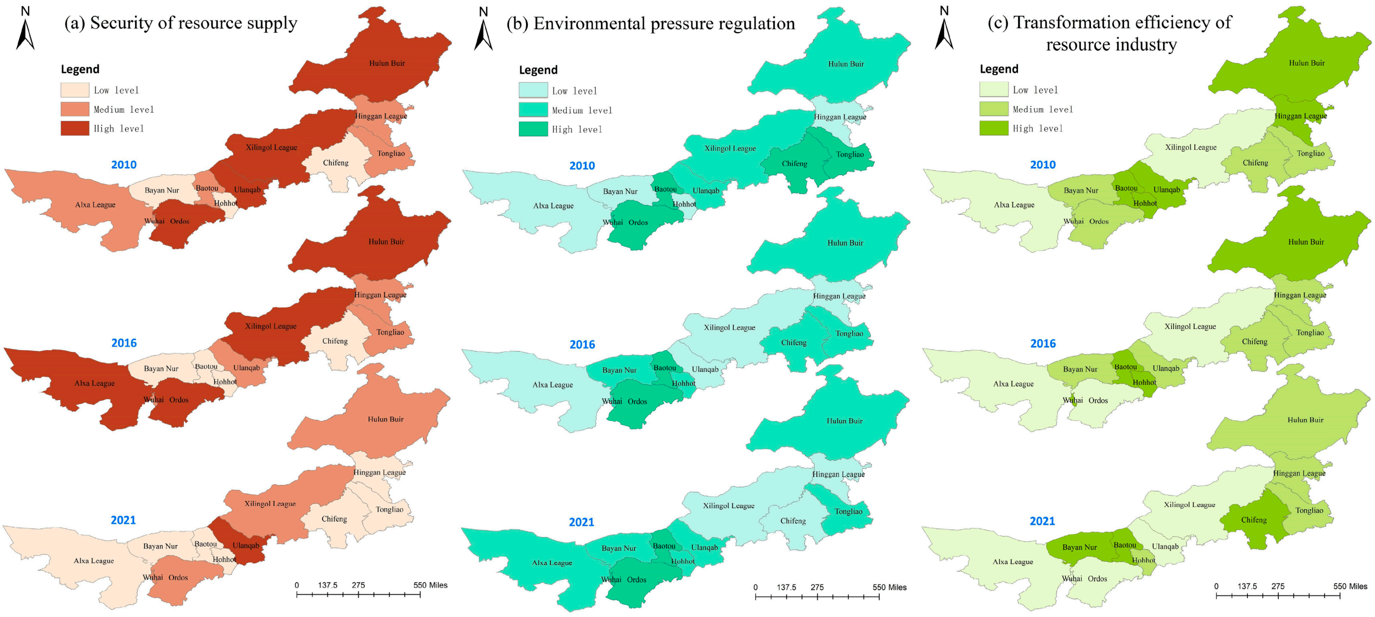

Figure 5. Spatial distribution of resource supply, environmental regulation and resource industry transformation level. (**a**) Security of resource supply; (**b**) Environmental pressure regulation; (**c**) Transformation efficiency of resource industry.

3.3. Analysis of the Decoupling Relationship between Resource Supply, Environmental Regulation and Resource Industry Transformation

The evaluation of the spatial and temporal evolution trend of factors can reflect the changes in a single dimension. To reveal the dual interaction between resource supply, environmental regulation and resource industry transformation, it is also necessary to carry out a quantitative analysis of the decoupling between the factors. With the above assessment results as the data source, the decoupling relationship between resource supply, environmental regulation and resource industry transformation is analyzed based on the Tapio decoupling model (Equations (10) and (11)). Since eight different decoupling types are divided in Table 2, only the decoupling states among different elements in different years are judged in the calculation process for the sake of more intuitive subsequent analysis. Meanwhile, the decoupling index measurement requires the examination of two continuous time bases. To ensure the consistency of data dimensions, the research phase is selected from 2011 to 2021, and the spatial heterogeneity of the decoupling relationship is investigated by taking 2011, 2016 and 2021 as the time profiles.

Overall, from 2011 to 2021, the dynamic change trend of the decoupling relationship between resource supply, environmental regulation and resource industry transformation in Inner Mongolia is obvious, showing great uncertainty. From the view of the classification of decoupling relationship state, except for 2011 and 2021, the decoupling relationship between factors is in an unsatisfactory state; the decoupling relationships in most years are above average level; a few years presents a single unsatisfactory state; and the decoupling relationship between environmental regulation and resource industry transformation is generally superior to the decoupling relationship between resource supply and resource industry transformation (Figure 6). This indicates that the decoupling relationship between resource supply, environmental regulation and resource industry transformation in Inner Mongolia is greatly affected by objective environment and policy changes, and the decoupling relationship between elements is unstable. As a typical resource-based post-development region in China, Inner Mongolia's economic development relies on resource endowment and resource industry to a high degree. At the same time, Inner Mongolia is facing the dual pressure of environmental governance and environmental risk prevention in the north. As a result, it cannot get rid of the barriers to economic governance caused by resource, environment and industrial structure in the short term.

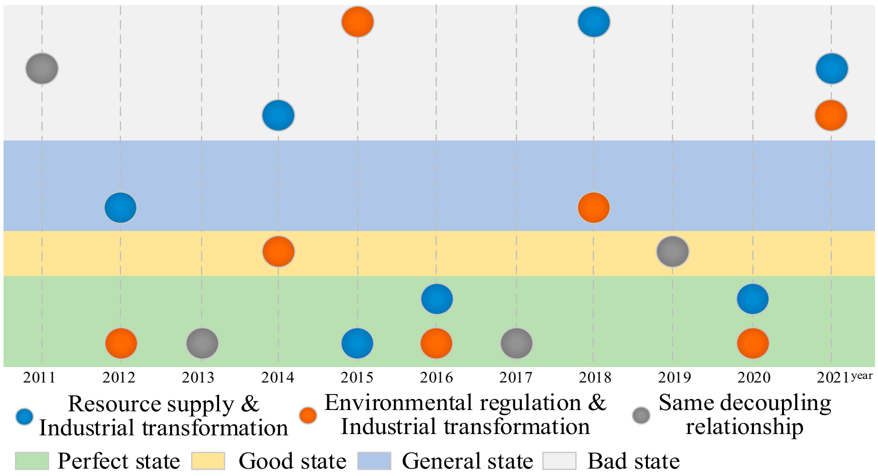

Figure 6. The decoupling relationship between resource supply, environmental regulation and resource industry transformation in Inner Mongolia from 2011 to 2021.

In addition, this study identifies the spatial heterogeneity of the decoupling relationship between different types of alliance city elements from the following aspects: firstly, the decoupling index of 12 cities in Inner Mongolia in 2011, 2016 and 2021 is measured; next, basing on the decoupling state classification, the natural breakpoint method (Jenks) is used to cluster the decoupling relationship between resource supply, environmental regulation and resource industry transformation of each city; then, the dual distribution structure of resource supply and resource industry transformation, environmental regulation and resource industry transformation is analyzed; finally, the spatial-temporal differentiation of the decoupling relationship between the elements is judged (Figures 7 and 8).

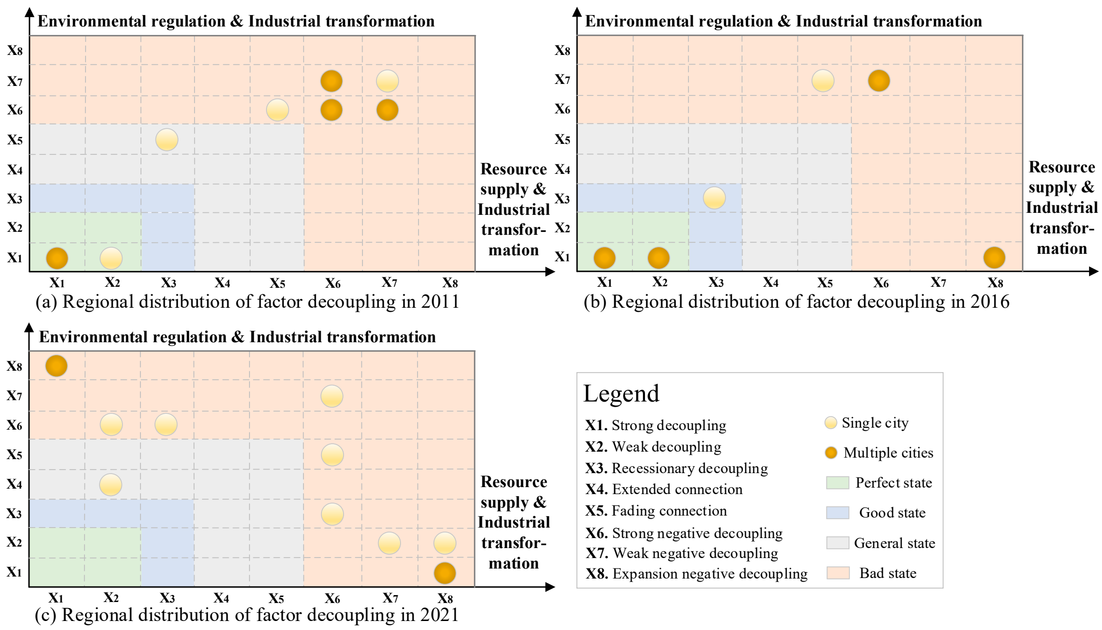

Figure 7. Cluster scatter diagram of the decoupling relationship between resource supply, environmental regulation and resource industry transformation in each city. (**a**) Regional distribution of factor decoupling in 2011; (**b**) Regional distribution of factor decoupling in 2016; (**c**) Regional distribution of factor in 2021.

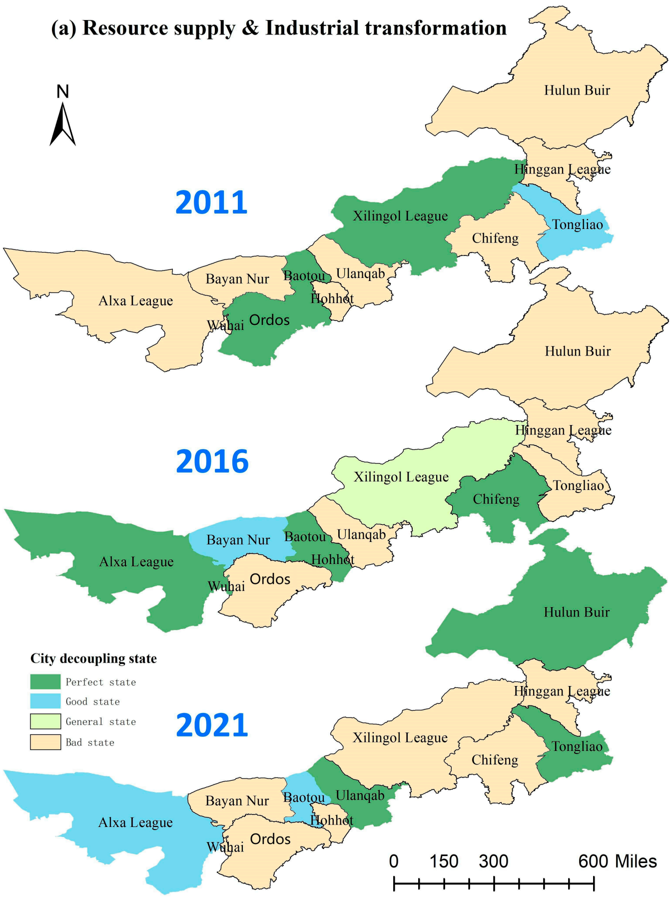

Figure 8. Spatial distribution of decoupling effect between resource supply, environmental regulation and resource industry transformation. (**a**) Resource supply & Industrial transformation; (**b**) Environmental regulation & Industrial transformation.

In 2011, the decoupling relationship between the factors of eight cities is not ideal, that is, at least one of the decoupling relationship between resource supply and resource industry transformation, environmental regulation and resource industry transformation is not ideal; the decoupling relationship in the rest of the cities is in a state of above average decoupling. The decoupling relationship between resource supply, environmental regulation and resource industry transformation in the 12 cities is similar. From the perspective of spatial distribution characteristics, the decoupling state of factors in Ordos, Baotou, Xilin Gol and Tongliao is relatively better, and the decoupling degree in central regions is higher than that in western and eastern regions. It shows that in the golden age of resource exploration and development industry, the decoupling effect of resource supply, environmental regulation and resource industry transformation is not yet common; most regions need to rely on resources and their derivative industries to promote regional economic growth and are less affected by environmental regulation. In 2016, the spatial heterogeneity of the decoupling relationship between resource supply, environmental regulation and resource industry transformation in Inner Mongolia is more significant than that in 2011. Due to the influence of environmental policies on the decoupling relationship between factors in the earlier stage, the decoupling between environmental regulation and resource industry transformation is ideal in eight cities, and the spatial distribution of the decoupling relationship between resource supply and resource industry transformation is relatively discrete. The decoupling state between traditional resource endowment advantageous areas and central cities is still well; the decoupling trend between resource supply and resource industry transformation is obvious in Chifeng and some western cities; and most western and eastern cities are gradually realizing the decoupling between environment and resource industry transformation. It shows that after the loss of policy dividends, strict environmental regulations and industrial policies restrict the development advantages of the resource industry but also make the overall regional industry gradually get rid of the impact of resource and environmental constraints. In 2021, the distribution of decoupling relationships among factors in Inner Mongolia is more random; the overall decoupling level has declined compared with 2016; and there is a coupling development trend between resource supply, environmental regulation and resource industry transformation in some cities. Among them, Hohhot, Bayannur, Chifeng and Xilin Gol are in an ideal state of decoupling between resource supply and resource industry transformation; Ulanqab, Tongliao and Hulun Buir are in an ideal state of decoupling between environmental regulation and resource industry transformation; other cities are below the average level of decoupling. It should be noted that due to the critical period of global COVID-19 prevention and control in 2021, the pattern of international energy consumption underwent great changes; Inner Mongolia, as the core production area of coal resources in China, experienced abnormal growth because of the objective situation change; except for some cities with advantages in resources and environment, the resource supply and resource industry in other regions experienced a brief coupling development, and environmental regulation and resource industry development advanced simultaneously.

3.4. Factor Identification and Mechanism Analysis

3.4.1. Factor Identification

Factor recognition is an effective tool to detect the interaction between factors. In order to analyze the mechanism of the decoupling relationship between resource supply, environmental regulation and resource industry transformation, the decoupling index is selected as the dependent variable and 20 index factors as the independent variables, the factor detection module of the geographical detector is used to identify the decoupling relationship among factors in Inner Mongolia. The calculation results according to Equation (12) are shown in Table 3. It is found that the explanatory power q-value of the GDP contribution rate of the resource industry and the proportion of the structure of the secondary and tertiary industries for the decoupling relationship between resource supply, environmental regulation and resource industry transformation are both greater than 0.83, and the p-value is in the confidence interval (0,0.1), which indicates that the corresponding indicators can reflect 90% of the actual situation, and the factor detection results are reliable. From Table 3, it can be seen that the contribution rate of resource industry GDP and the proportion of secondary and tertiary industry structure have a higher impact on the decoupling relationship between resource supply and resource industry transformation than environmental regulation and resource industry transformation, and the internal impact of the two indicators is relatively balanced. In the index system of resource supply security, the growth rate of energy reserves has a higher impact on resource supply and resource industry transformation. In addition, there is no environmental regulation index factor has a significant restriction effect on the decoupling relationship between environmental regulation and resource industry transformation, indicating that the explanatory role of the environmental regulation index factor is not significant.

Table 3. Factor explanatory power of the decoupling relationship between resource supply, environmental regulation and resource industry transformation.

Resource Supply and Resource Industry Transformation			**Environmental Regulation and Resource Industry Transformation**		
Index	q statistic	p value	Index	q statistic	p value
X_{14}	0.195	0.824	X_{14}	0.411	0.523
X_{15}	0.999	0	X_{15}	0.831	0.107
X_{16}	0.467	0.509	X_{16}	0.612	0.303
X_{17}	0.464	0.512	X_{17}	0.388	0.614

Table 3. *Cont.*

Index	q statistic	p value	Index	q statistic	p value
X_{18}	0.997	0	X_{18}	0.838	0.097
X_{19}	0.14	0.893	X_{19}	0.115	0.928
X_{20}	0.469	0.506	X_{20}	0.352	0.661
X_1	1	0	X_8	0.03	0.994
X_2	0.11	0.929	X_9	0.326	0.654
X_3	0.199	0.817	X_{10}	0.682	0.243
X_4	0.285	0.71	X_{11}	0.085	0.96
X_5	0.119	0.919	X_{12}	0.138	0.903
X_6	0.465	0.512	X_{13}	0.266	0.746
X_7	0.283	0.711			

X_1, X_2, ..., X_{13} represent the index factors of resource supply risk, environmental regulatory pressure and industrial transformation efficiency in Figure 2.

3.4.2. Mechanism Analysis

Different index factors have different mechanisms for the decoupling relationship between resource supply, environmental regulation and resource industry transformation, it is necessary to analyze them in combination with the attributes of index factors and the basic characteristics of regional economic and social development. Based on the results of factor identification, the mechanism of action among the factors is analyzed, and the interaction between resource supply, environmental regulation and resource industry transformation in Inner Mongolia is revealed.

First of all, the contribution rate to GDP of the resource industry, reflecting the marginal effect change in output of the resource industry sector, is an important indicator reflecting the value of the resource industry sector. It inhibits the decoupling relationship between resource supply, environmental regulation and resource industry transformation, indicating that the traditional advantages of the resource industry in Inner Mongolia still exist. The resource industry is not only the key factor driving the change in resource supply security, but also the core object of environmental governance in this region. The resource industry occupies an important share in the whole region, indicating its supporting effect on regional economic growth is still strong. As an objective environmental auxiliary index, the proportion of secondary and tertiary industrial structure actually reveals the change in Inner Mongolia's industrial pattern from the level of industrial structure. This index has an impact on the decoupling relationship between factors, which once again verifies that the development of the secondary industry led by the resource industry restricts the decoupling between resource supply, environmental regulation and resource industry transformation. At the same time, the strong explanatory power of secondary and tertiary industrial structure ratio index indicates that the resource industry transformation in Inner Mongolia is not complete yet, and the continuity ability of the tertiary industries such as ICT, tourism and service industry is not sufficient.

Secondly, the growth rate of energy reserves is the only index in the resource supply index system that has an impact on the decoupling relationship between resource supply and resource industry transformation, indicating that in addition to the contribution of the resource industry sector, energy reserves are the core factor affecting the decoupling of factors. Through the investigation of the energy and resource endowment status in Inner Mongolia, it is found that the coal reserves, production and location advantages of the region are obvious. The high export effect of coal resources and its products leads to its driving effect on the resource industry chain and, thus, leads to the decoupling inhibition of resource supply and resource industry transformation. Under the dual influence of resource endowment advantage and external resource dependence, the inhibition effect of energy reserves in Inner Mongolia on the decoupling of resource supply and resource industry transformation will exist for a long time, and the more prominent the advantage of resource endowment is, the stronger the inhibition effect is.

Finally, in the evaluation index system constructed by this research, there is no index factor that has a significant inhibitory effect on the decoupling relationship between environmental regulation and resource industry transformation in Inner Mongolia yet. According to the results of environmental regulatory pressure with temporal and spatial evolution evaluation, the dynamic change degree of environmental regulatory pressure in different years is relatively high, and the environmental regulatory pressure in different regions is also different. It indicates that environmental regulatory indicators are uncertain, and the emphasis of implementing China's environmental governance policies in different years and regions is different, resulting in the randomness of its impact on the decoupling relationship between environmental regulation and resource industry transformation. In addition, as Inner Mongolia is an ecological barrier in northern China, it faces greater ecological governance pressure than other regions. Because of this, when analyzing the influence mechanism of this index on the decoupling relationship between elements, it is difficult to avoid the influence of endogenous problems on the test results.

4. Discussion

This paper takes the Inner Mongolia Autonomous Region of China as an empirical case to analyze the spatial-temporal heterogeneity and decoupling relationship of the resource curse, environmental regulation and resource industry transformation in post-development areas. These econometric analysis results show the actual situation of economic and social development in the post-development area and bring some valuable enlightenment.

(1) According to Figure 3, in addition to mineral resources such as shale gas, coalbed methane and potassium salt, the occurrence conditions of strategic key minerals in this region are good, and the comparative advantages of the coal mining and washing industry, metal ore mining and processing industry, non-ferrous metal smelting and rolling industry are prominent. In view of the factors that determine the benefit intensity of the resource curse mainly include resource endowment and resource industry superiority, it shows that the effect of the resource curse is not significant in Inner Mongolia.

In general, the decoupling of resources, environment and industry is the goal of high-quality development, but the post-development areas need to be treated differently according to the actual situation. The development of characteristic industries in such areas not only supports the economic and social development of the territory, but also plays an important role in the guarantee of resource products in external regions. Therefore, our point of view is not to completely abandon the advantageous industries, but to speed up the transformation and upgrading of traditional industries, and develop alternative industries in stages.

(2) From 2010 to 2021, the security level of resource supply and the transformation efficiency of resource industry in Inner Mongolia basically show an upward trend, and the overall level of environmental regulation pressure is balanced; the spatial distribution of resource supply security, environmental regulation pressure and resource industry transformation efficiency is relatively discrete; resource-endowed regions and central cities have relatively high levels of resource supply security and obvious advantages in resource industry transformation, but at the same time face more severe environmental regulatory pressure.

As can be seen from the spatial-temporal evolution trend of factors, resource exploration and development strategies lead to dynamic changes in resource supply security, and industrial structure adjustment also causes the adjustment of contribution intensity of dominant industries. However, the resources and industrial advantages of the post-development areas are still prominent. At the same time, the interference effect of policy factors should also be paid attention to, for example, the cumulative effect of ecological barrier function and resource industry pollution control in the north has led to increased environmental regulation pressure in some areas. Therefore, the government should put forward differentiated decision-making paths under different resource endowments, industrial patterns and specific policy conditions to solve the impact of abnormal disturbances on sustainable development goals.

(3) There is great uncertainty in the decoupling effect of resource supply, environmental regulation and resource industry transformation in Inner Mongolia. From 2011 to 2021, the decoupling relationship among the 12 cities and leagues in Inner Mongolia shows a trend of first improvement and then deterioration. Regions with high levels of resource supply, resource industry transformation and economic development have better decoupling status among factors, but resource dependence, consumption pattern and policy environment lead to abnormal changes in the decoupling relationship. The GDP contribution rate of the resource industry and the structural proportion of secondary and tertiary industries are the key restraining factors affecting the decoupling of resource supply, environmental regulation and resource industry transformation.

The decoupling relationship among factors is affected by the temporal and spatial evolution of resource supply, environmental regulation and resource industry transformation. It is found that for the post-development area, under the condition of good resource reserves, outstanding industrial advantages and no significant environmental regulatory pressure, the three factors will show a synergistic promotion phenomenon to the regional economy. However, with the increase of resource consumption, industrial optimization and environmental governance intensity, the coupling development degree of this region is relatively poor. Due to the initial completion of economic structural adjustment in some areas, the decoupling state between the factors is better. In addition, to achieve a complete decoupling of factors, local governments should focus on the gradual mitigation of resource industries. Therefore, we believe that although the transformation and upgrading of post-development areas will go through a difficult period, it is conducive to long-term development, and such areas should persist in exploring feasible transformation paths.

5. Conclusions

This paper chooses Inner Mongolia as a representative to study, which can reflect the experience and practice of transition governance in China's post-developing regions and can also bring beneficial theoretical and practical reference for the sustainable development of post-developing regions in the world.

On the one hand, by constructing a scientific evaluation model of the spatial-temporal evolution trend of factors, this paper uses location quotient, comprehensive empowerment evaluation, decoupling measurement and factor detection to accurately identify the problems of resource curse, environmental regulation and resource industry transformation in Inner Mongolia and explores and proposes feasible solutions. At the theoretical level, this study makes up for the shortcomings of previous studies in the selection of methods and mechanism analysis, which can provide innovative ideas for scholars interested in the study of sustainable development in post-development regions around the world.

On the other hand, in view of the problems existing in Inner Mongolia, we propose to grasp the supporting role of advantageous industries on the regional economy in stages, on the basis of promoting the transformation of traditional industries, and formulate differentiated decision-making strategies according to different policy requirements. Of course, the region also needs to adapt to economic problems brought about by transformation and upgrading. As Inner Mongolia is a typical post-development region in the world, it is general in terms of resource endowment, environmental regulation and industrial pattern. This study believes that for the vast majority of post-development areas, it is necessary to seize the advantages of regional characteristic resources and accelerate the optimization and upgrading of traditional industries on the basis of ensuring the normal operation of the national economy. It is important to pay attention to inter-regional cooperation in resource sharing, mutual assistance of talents, flow of factors and interoperability of decisions and adopt a transformation path in line with regional realities to enhance economic resilience.

Finally, this paper is concerned that most post-development regions are ethnic minorities or border areas of a certain country. For example, Inner Mongolia is a gathering region of Mongol nationality and also a northern border region in China. When implementing the sustainable development strategy in such areas, they should not harm the macro interests of the country by seeking short-term and partial economic growth and can seek to break the situation from multiple dimensions such as resources, industry, culture, geography and landform. On the basis of the stable development of the resource industry, the post-development regions should work together to promote the formation of new regional growth poles in emerging industries such as culture, tourism and digital economy, so as to nurture the upgrading of traditional industries and achieve comprehensive and high-quality development.

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