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Research Article

Analyzing the Coupling Degree of Coordinated Development between Ecological Environment and Regional Economy in Underdeveloped Areas

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Accelerating economic development necessitates the rapid consumption of more ecological environmental resources. Excessive consumption of ecological environmental resources will seriously damage the overall coordination between the ecological environment and the local economy. We examine the objective issues of regional economic development and environmental protection in the three eastern provinces. Local governments should prioritize the degree of interdependence between regional economic development and the ecological environment. A healthy development strategy includes managing and improving the regional environment while also ensuring the orderly and stable development of the local economy. The grey correlation analysis model is based on the coupling relationship analysis and uses the underdeveloped Northeast Economic Zone as the study goal. So, this study proposes that the regional economic circle of three northeastern provinces be the main topic of a quantitative analysis of the coupling relationship and influencing factors of the coordinated development of the ecological environment and regional economy from 2013 to 2020. Inferred from the perspective of spatial coupling relationships is the calculation of the coupling degree model based on the grey correlation degree. Specifically, Harbin (0.661), Changchun (0.650), Jixi (0.615), and Liaoyuan (0.629) fall into the antagonistic type and low-level coupling type categories. The degree of coupling between Northeast China's economic development and the natural environment significantly decreased from 2015 to 2018 from the perspective of the time series coupling relationship. The changing trend of coupling degree makes it abundantly clear that the problems with the ecological environment's constraints in the underdeveloped areas of the three northeastern provinces have not been fundamentally resolved. If no action is taken rapidly, the ecological environment will continue to deteriorate because environmental problems do not improve significantly in a short time.

1. Introduction

The country's rapid economic growth has hampered Chinese economic growth, resulting in serious environmental issues. The tourist market has expanded as people's living conditions have improved, rising from 0.49 trillion in 2003 to 5.40 trillion yuan in 2017. The natural atmosphere, which also serves as the primary safeguard for the local economy, greatly influences the excellence of a tourist site [1–3]. The natural atmosphere influences both the travel experience and the tourism expansion rate. Furthermore, changes in the natural environment, particularly those caused by climate change, harm tourism growth. Economic and tourism growth has both positive and negative environmental effects [4, 5]. While guiding or hastening the development of the ecological atmosphere's integrity, tourism and economic development will have a significant negative impact on the environment [6]. A major issue that must be addressed and managed is how to actively develop the local economy and tourism while maintaining a balance with the natural environment.

Traditional urbanization lacks the ability to achieve sustainable growth due to its obsession with large-scale expansion and disregard for quality development. China has

developed a new urbanization strategy based on this that balances quantity and quality. Emerging urbanization has significant implications for the population, geography, economy, society, and new urbanization's intricate relationship with the environment [7, 8]. According to the population urbanization perspective, when non-agricultural residents move to cities and towns, their housing needs and way of life change. This situation puts a strain on resources as well as the environment. The extended development model was the cornerstone of the economic development strategy, and early economic urbanization had a significant negative impact on the environment [9, 10]. Economic urbanization, on the other hand, will lead to more spending on ecological and environmental conservation. As a result of social urbanization, infrastructure and public services have frequently increased, but population growth has placed a strain on the environment. Social urbanization, on the other hand, has grown in importance alongside the concepts of long-term growth and environmental protection. Spatial urbanization might very well cause increased air and sound pollution due to increased traffic, in addition to increasing demand for land resources as cities grow. The negative environmental effects predominated in the early stages of new-type urbanization. However, abundant natural resources and a beautiful environment may provide a solid foundation for increased urbanization [11, 12].

Industrialization is the development of supplementary industries, which dominate economic growth in the late and middle stages. China's economy is now heavily reliant on industries that generate and utilize a significant amount of energy. China's increasing industrialization and urbanization, as well as the promotion of these trends, have had a negative influence on the environment and limited the country's economic growth. Shi et al. analyzed and investigated coordination using geographically and temporally weighted regression (GTWR). In China's 17 tropical and subtropical zones, there is spatiotemporal heterogeneity between economic growth and the natural environment. The biological environment, as well as economic growth, exhibits significant spatiotemporal diversity. More regions were identified as experiencing economic lag. The ecological lag type predominates in developed eastern regions, whereas the economic interval type predominates in central and western regions. Economic growth and the biological environment have agglomeration effects and favorable spatial links. Economic growth and environmental protection are increasingly interacting [13]. Fan et al. examined the coupled, synchronized growth scenario in each of China's 31 major cities. The research results describe the cities as having a privileged ecological environment which is in class 10, while the social economy is in class 5. We also discussed some of the major issues concerning development coordination. The best examples of synchronization can be found in Beijing, Hangzhou, and other cities, which demonstrate how vibrant social economies and reliable environmental protection can coexist. In terms of connected, coordinated growth, Lhasa and Yinchuan rank near the lowest of the cities studied. They must promote social and economic growth that is coordinated and appropriate for the specific ecological environment [14]. Fang et al. properly evaluated the current situation in the urbanized Shandong Peninsula by utilizing data from national statistics from 2008 to 2017. The findings show that raising the CCD level of an urban environment is necessary to ensure sustainable urbanization. Despite progress in coupling and coordination across the board, roughly half of the cities on the Shandong Peninsula remain in transitional or uneven growth phases. This regional growth disparity can be observed using the fundamental geographic pattern, which demonstrates that coastal cities have significantly higher coupling and coordination than inland cities [15]. Excessive resource use and pollution, which are primarily brought on by increased urban development, are also contributing to an increase in environmental stress. Countermeasures for performance improvement in various cities were taken into account. The gradual installation of high-quality infrastructure, enhancing urban appeal, raising resource efficiency, and making the best use of technology for treatment and recycling are a few of these.

All countries' economic development levels have significantly improved as a result of the growth of globalization in the economy, and both the size of the population and the scale of production have significantly increased. However, countries have also demonstrated significant ecological damage during the development process, which hinders social and economic development [16, 17]. The ecological environment is not only a critical foundation for human survival and development but also a powerful force in promoting regional economic development. Therefore, we can only promote sustainable and synchronized growth of both the regional economy and the ecological environment by fully coordinating both [18]. Eastern China's economic development is relatively slow in comparison to other regions due to industrialization. Northeast China's urbanization processes are relatively backward, and local enterprises face numerous development problems and flaws. Inadequate technical and management levels, for example, result in a lack of full coordination between regional economic and environmental development [19]. Therefore, focusing on the research and analysis of the degree of coupling coordination between the regional economy and the ecological environment can effectively predict the region's future economic development.

The innovations of this paper are as follows:

(i) This paper performs an empirical analysis of some cities in Northeast China and compares the dynamic change characteristics of this region using the coupling coordination degree model and the regression analysis model.

(ii) The paper investigates the coordinated development trend index L, develops a fitting equation between the ecological system and the economic system, and conducts a quantitative analysis of the coordinated development degree from 2013 to 2020.

(iii) Using MAPGIS software, the distribution characteristics and spatial differences of the coordinated development level of the ecological environment and economic growth in Northeast China are more intuitively displayed.

(iv) The interaction factors of the two systems are determined using grey correlation analysis. The essential problems of ecological constraints in the underdeveloped areas of the three northeastern provinces are highlighted.

The following is the overall structure of this paper. Section 2 shows the related work. An overview of regional economic development and the ecological environment in underdeveloped areas is described in detail in Section 3. Section 4 consists of constructing a coupling model for the coordinated development of the ecological environment and regional economy. Section 5 provides the results and analysis. Section 6 provides a conclusion of the work.

2. Related Work

The growth limit theory is based on the notion that the environment has a significant impact on economic growth and that a mismatch between the environment and the resources available will severely impede long-term economic advancement. Foreign countries began to study the relationships between the environment and economy since 1950s, the results show that the procedure of economic development will cause a series of environmental problems and even a serious threat to sustainable development. Keynes' economic development concept is also being used in the current research process [20, 21]. In 1966, the idea of a circular economy was first proposed. So, after that, the connection between economic growth and environmental development in 213 countries was researched and examined between 1970 and 2008, leading to the following findings. Environmental pressure and economic growth are strongly connected [22]. This paper investigates and discusses the environmental implications of economic growth. This is accomplished by developing an ecological environment optimization model and conducting a thorough investigation into the issue of ecological environment maintenance. Therefore, the economic environment has a larger optimal maintenance window than the ecological environment [23, 24]. The empirical analysis is used by domestic and international experts and scholars to investigate the beneficial relationships between them in the ecological environment. The study's effects on regional economic development are urbanization and development in China's ecological environment. We discovered that the degree of coupling between the regional economy and the ecological environment is influenced by a variety of factors that vary greatly [25]. Relevant experts and scholars assessed and analyzed the degree of economic development coupling. The environment in five different provinces in Northwest China was evaluated and analyzed, and the relationship between the two was demonstrated [26]. The grey correlation analysis method is used in this paper to select relevant data from Henan Province from 2008 to 2020. In Henan Province, we investigate the key factors influencing the relationship between the regional economy and the ecological environment. Consumers build correlation and coupling degree models of the regional economy and ecological environment, as well as their roles. We examine the relationship between the regional economy and the ecological environment in Henan Province from various perspectives, primarily from time and space [27].

3. An Overview of Regional Economic Development and the Ecological Environment in Underdeveloped Areas

3.1. An Overview of the Study Area. Northeast China refers to the region comprised of three northeast provinces, Liaoning Province, Jilin Province, and Heilongjiang Province, as depicted in Figure 1. It also includes the five eastern league cities of the Inner Mongolia Autonomous Region: Chifeng City, Xing'an League, Tong Liao City, Xilin Gol League, and Hulunbuir City [28]. The three northeastern provinces chosen for this study are in the heart of Northeast Asia. They not only are important agricultural bases in China but also have relatively strong industrial development. As a result, the study of these three provinces is extremely representative.

During the process of analyzing Northeast China's economic development, the issues and flaws in its economy are condensed and summarized in the following aspects. First, even though Northeast China's national economy is expanding more rapidly than the rest of China, its rate of development is still comparatively slow. Second, the ecological environment of Northeast China is under greater stress due to the region's economic development, which is heavily dependent on local environmental resources [29].

3.2. Analysis of Economic Development in Underdeveloped Areas (Three Northeastern Provinces). The economy of Northeast China has shown the momentum of rapid development after China's improvement and opening up. The change in GDP in Northeast China is shown in Figure 2. The GDP in Northeast China changed the most from 2013 to 2020, with a total GDP of 5091.932 billion yuan. In 2020, the economic development of Liaoning was the most prominent in the three northeastern provinces, with a GDP of 2490.95 billion yuan, followed by Heilongjiang and Jilin.

As a result of the industrial structure's adjustment, the tertiary industry has grown to play a significant role in Northeast China's economic structure. While the primary industry accounts for the smallest portion of the economic structure, the secondary industry is second only to the tertiary industry in terms of economic contribution. Figure 3 shows that the proportion of the three major industries in the three northeast Chinese provinces remains consistent in 2020. It is primarily due to the consistency of the three northeast Chinese provinces' cultural backgrounds and resource distribution [30]. In

Figure 1: Study area map of Northeast China.

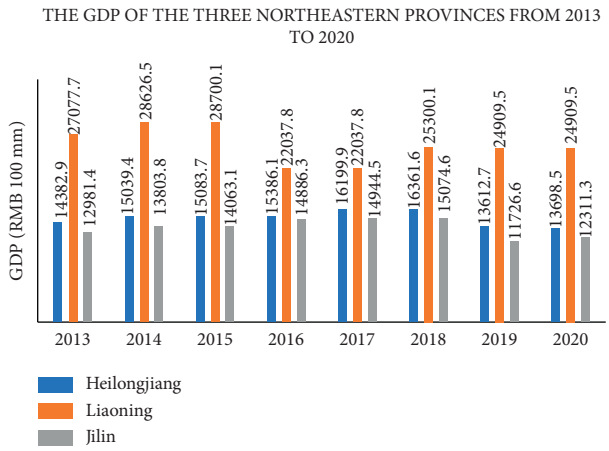

Figure 2: Statistics of regional gross national product of the three northeastern provinces.

comparison to Heilongjiang Province, the proportion of secondary industry in Liaoning Province and Jilin Province is relatively high, indicating that these two provinces have a higher level of industrialization.

3.3. Analysis of Ecological Environment in Underdeveloped Areas (Three Northeastern Provinces). In the procedure of economic development, Northeast China has experienced many years of large-scale development, which has had a negative influence on the ecological environment. Therefore, the ecological environment problems in Northeast China are becoming more and more serious [31]. Figure 4 depicts an investigation into industrial SO_2 and smoke emissions in Northeast China. The air quality problem in Northeast China in 2020 is severe, and industrial SO_2 and industrial smoke emissions are rising. Industrial waste proportions are relatively high, particularly in terms of industrial SO_2 and manufacturing smoke emissions. They account for a relatively high proportion and are the primary causes of the destruction of the regional ecological environment.

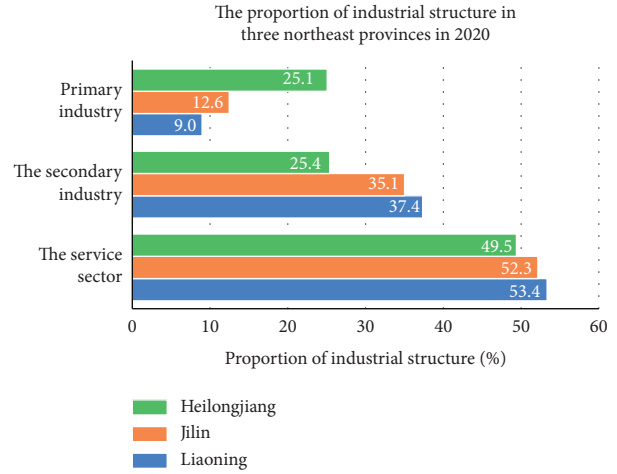

Figure 3: Industrial structure of provinces in Northeast China.

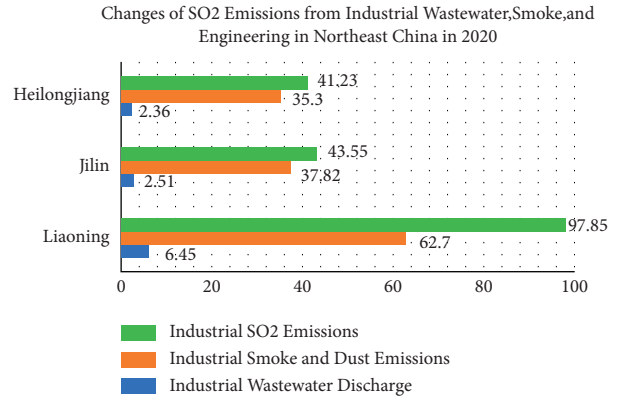

Figure 4: Changes in industrial wastewater, soot, and SO_2 emissions from projects in Northeast China.

According to an analysis of industrial SO_2, industrial soot, and industrial wastewater emissions in the aforementioned provinces, Liaoning Province is the most affected. In Heilongjiang and Jilin provinces, industrial SO_2, industrial soot, and industrial waste emissions are relatively low. Because Liaoning Province's iron and steel industries are so advanced, pollution, waste gases, and wastewater emissions are high. There is currently no effective treatment for toxic gases discharged by the iron and steel industry, which is also the primary cause of Liaoning Province's significant over-standard emissions of industrial SO_2, industrial dust, and industrial wastewater. If this industrial pollution is not effectively treated, it will endanger Northeast China's ecological environment [32].

4. Constructing a Coupling Model for the Coordinated Development of the Ecological Environment and Regional Economy

4.1. Construction of System Coupling Model Based on Grey Correlation. Grey correlation analysis is also referred to as grey correlation degree. This quantitative method of analyzing influencing system factors is primarily based on the

similarity and development trend of two system factors [33, 34]. Regression analysis, correlation analysis, quantitative description, and grey correlation analysis of all influencing factors in the system can more accurately replicate the system's differences and complete the identification of main factors [35]. The model's basic steps are as follows.

Step 1. Determine analysis sequence.

The two sets of analysis sequences in this paper are the economic development sequence group and the ecological environment sequence group, which are X_i and Y_i, respectively.

Step 2. Dimensionless sequence variables.

In the analysis of grey correlation degree, it is generally necessary to deal with the dimensionless data. This paper adopts the averaging method:

$$\begin{aligned} X' &= \left(X_i - X_{min}()\left(X_{max\,x} - X_{min}()\right)\right), \\ Y' &= \left(Y_j - Y_{min}()\left(Y_{max\,x} - Y_{min}()\right)\right). \end{aligned} \tag{1}$$

Step 3. Calculate the correlation coefficient.

Whether the coupling degree and correlation degree can be calculated usually depends on the solution result of the correlation coefficient. The two behavior sequences in the system have the correlation characteristics shown in the following formula (grey correlation theory), which can be described as

$$\xi_{ij}(t) = \frac{\min\limits_i \min\limits_j \left|X_i'(t) - Y_j'(t)\right| + \rho \max\limits_i \max\limits_j \left|X_i'(t) - Y_j'(t)\right|}{\left|X_i'(t) - Y_j'(t)\right| + \rho \max\limits_i \max\limits_j \left|X_i'(t) - Y_j'(t)\right|}, \tag{2}$$

where $\xi_{ij}(t)$ represents the correlation coefficient at time t, $X_i'(t))$ and $Y_j'(t)$ are the standardized values of the i^{th} economic development and the j^{th} ecological environment indicators of cities in Northeast China at time t, respectively, and ρ represents the resolution coefficient $\rho = 0.5$.

Step 4. Calculate the degree of correlation and coupling.

Calculate the correlation coefficient's average value based on the sample size of k. In other words, it is possible to obtain a correlation matrix (index sequence) and the level of interaction between the ecological environments. The resulting matrix can show the complexity of the coupling between the two factors and economic development.

$$r_{ij} = \frac{1}{k} \sum_{j=1}^{k} \xi_{ij}(t), \tag{3}$$

where k represents the number of samples, and the ecological environment and economic development coefficient of the sample area studied in the paper are also represented by k. In the coupling process of ecological environment and economic development, various factors that have no obvious influence can be reflected by comparing the r_{ij} value of different parameters and the sequence of data values.

Step 5. Coupling model based on correlation degree.

Based on the correlation matrix, the average value is calculated by row or column, respectively, and the correlation model of system coupling can be obtained:

$$\begin{aligned} d_i &= \frac{1}{l} \sum_{j=1}^{1} r_{ij} (i = 1, 2 \ldots m, j = 1, 2, \ldots, l), \\ d_j &= \frac{1}{m} \sum_{j=1}^{m} r_{ij} (i = 1, 2 \ldots m, j = 1, 2, \ldots, l). \end{aligned} \tag{4}$$

The number of eco-environmental system indicators is l in formulas (3) and (4). The number of indicators of the economic development scheme is m. The average value of the correlation degree of the i^{th} index between the eco-environmental system and the economic development system is d_i, which reflects the size of the coupling of the eco-environmental system affected by it. The regular degree of the correlation degree of the j^{th} index of the economic development scheme and ecological environment system is d_j, which reflects the size of the coupling of the economic development system affected by it.

Using space and time as entry points and based on the relevant degree of coupling, this paper provides quantitative analysis and judgment on the coordination of environmental schemes and economic development. An overall assessment of the coupling strength of the two systems in Northeast China's economic development and ecological environment is required. The following is the specific solution equation:

$$C(t) = \frac{1}{m \times l} \sum_{i=1}^{m} \sum_{j=1}^{I} \xi_{ij}(t), \tag{5}$$

where $C(t)$ is the coupling degree and m and l represent the index number of economic development and ecological environment system, respectively.

4.2. Description of Evaluation Index. The regional economic system and ecological environmental system are relatively complex. So, it is necessary to select reasonable and effective evaluation indicators in the process of studying the impact relationship between these two systems. Table 1 depicts the evaluation index system developed in this paper.

The data selected in this paper are mainly from the statistical yearbook of China from 2013 to 2020 in the three northeastern provinces.

5. Results and Analysis

5.1. Analysis Results of Main Factors. It is based on original data, a distinctive sequence, a grey correlation analysis method, and a variety of economic development parameters. The research unit disregards the original cities as provincial boundaries in the three eastern provinces. Table 2 shows the results of calculating the correlation matrix of the coupling impact of the ecological environment and economic development for the three eastern provinces in 2020.

The most visible indicators of economic development are an increase in GDP per capita and an improvement in the overall state of the economy. The characteristics of the country's industrial structure are visible due to the sample area's historical status as China's industrial core. The main indicator of regional economic growth in the industrial sector is an increase in the value of industrial output. The coupling of the ecological environment leads to economic development. The ecological environment and economic level subsystems have the strongest correlations, with a correlation coefficient between them of up to 0.695.

The ecological environment will have a significant impact on economic development. The correlation coefficient of 0.706 between the economic development system (X) and the ecological environment pressure subsystem results in the first position (Y2). That is, the factors that have the greatest impact on the sample area's economic development are the use of water and soil resources, the discharge of pollutants, and so on. The economic development system and sulfur dioxide emissions (y4) have a coupling degree of 0.705. The economic development system and industrial smoke emissions (y5) have a coupling degree of 0.697. The degree of coupling between the economic development system and industrial wastewater emissions (y6) is 0.715, which is quite high.

5.2. Spatiotemporal Analysis of the Coupling Relationship between Regional Economy and Ecological Environment

5.2.1. Result Analysis of Spatial Coupling Relationship. For starters, regionality refers to both spatial and temporal development patterns. Second, the interaction of their elements is based on the ecological environment and economic development's coupling degree values, as well as the classification conclusion of the coupling mechanism in the sample area. From high to low, the coupling stages can be classified into four types: high-level coordination, running in type, antagonistic in type, and low-level coupling type. Using nine representative cities from the three eastern provinces as the specific analysis object, the system's reference parameter is determined as urban GDP. The coupling and coordination relationships between various regions are then described, with specific data shown in Table 3.

(1)Coordinated Type. Dalian is a coastal city with a superior geographical location. It is the external window of Liaoning, which is even the sample area. It is in the first group of economic development in the three northeast provinces, with a coupling degree of 0.676. In 2020, the GDP of Dalian reached 703.04 billion yuan.

(2) Running in Type. Shenyang, the capital city of Liaoning Province, is a running city in a coupling area. In 2020, the coupling degree of Shenyang's ecological environment and economic development was 0.621. The population pressure was large, which restricted the city's environmental coordination and economic development to a certain extent.

(3) Antagonistic Type. The economic development level of such areas has diversified characteristics, and many reasons have led to the formation of the most obvious degree of coupling between environmental and economic development in this area. In terms of talent and labor attraction, Harbin (0.661), the capital of Heilongjiang Province, and Changchun (0.650), the capital of Jilin Province, have relatively prominent regional advantages and faster economic development. However, due to excessive population and the occupation of too many environmental resources, environmental dependence does not decrease but increases. This gradually highlights the ecological environment's negative feedback impact on economic development and the urbanization process. Compared with the two, it has the highest coupling degree.

(4) Low-Level Coupling Type. Jixi's ecological environment and economic development were 0.615 and 0.629 in 2020, respectively, because of the lack of leading industries and a low level of regional environment and economic development. The environmental impact is significantly less than the pressure it can withstand, and the issue of environmental protection has not even been considered, so there is no obvious degree of coupling.

5.2.2. Result Analysis of Time Series Coupling Relationship. Time series analysis can reflect the periodic fluctuation characteristics of the degree of coupling between the ecological environment and economic development in nine cities in the sample area. The "m" time series analysis of the coupling degree from 2013 to 2020 is shown in Figure 5. The figure depicts the fluctuation characteristics of the degree of coupling between the ecological environment and economic development in this region.

The analysis and calculation results show that 0.659 and 0.711 are the value ranges of the sample area's coupling degree from 2013 to 2020, and the fluctuation range is large, indicating two problems. First, in the sample area, there is a

Table 1: Regional economic ecological environment evaluation indicators.

System layer	Element layer	Index layer
Regional economic system	Economic level	GDP (x_1)
		Per capita GDP (x_2)
		Per capita gross non-agricultural output value (x_3)
	Economic structure	The proportion of primary industry in GDP (x_4)
		GDP percentage for tertiary industry (x_5)
		The value of total industrial output as a percentage of the combined value of industrial and agricultural output (x_6)
Eco-environmental benefits	Ecological environment level	Greening coverage rate of built-up area (y_1)
		Area of cultivated land per capita (y_2)
		Per capita public green space area (y_3)
	Ecological environment pressure	Industrial SO_2 emission (y_4)
		Industrial smoke emission (y_5)
		Industrial wastewater discharge (y_6)
	Ecological environment protection	Centralized sewage treatment rate (y_7)
		Rate of total utilization of industrial solid waste (y_8)
		Removal of industrial smoke (dust) (y_9)

Table 2: Coupling correlation data statistics on regional economic development and the ecologic environment.

System	Index	Economic level			Economic structure			Mean value	
		x_1	x_2	x_3	x_4	x_5	x_6		
Ecological environment level (Y_1)	y_1	0.551	0.566	0.538	0.721	0.747	0.730	0.642	
	y_2	0.701	0.685	0.698	0.845	0.589	0.516	0.672	**0.657**
	y_3	0.520	0.836	0.778	0.732	0.601	0.501	0.657	
Ecological environment pressure (Y_2)	y_4	0.767	0.763	0.771	0.651	0.690	0.588	0.705	
	y_5	0.753	0.792	0.754	0.684	0.641	0.555	0.697	**0.706**
	y_6	0.856	0.833	0.858	0.691	0.562	0.488	0.715	
Ecological environment protection (Y_3)	y_7	0.595	0.618	0.599	0.555	0.670	0.732	0.628	
	y_8	0.561	0.545	0.550	0.613	0.645	0.668	0.597	**0.638**
	y_9	0.730	0.801	0.746	0.655	0.649	0.573	0.692	
Mean value		0.670	0.715	0.699	0.683	0.644	0.595	0.667	
			0.695				**0.640**		

Table 3: Statistics of coupling degree types of some cities in Northeast China (2020).

Area		Coupling degree	Urban GDP (100 million yuan)	Classification of types
Liaoning Province	Shenyang	0.621	6571.6	Running in type
	Dalian	0.676	7030.4	Coordination type
	Anshan	0.642	1738.8	Running in type
Jilin Province	Changchun	0.650	6638.0	Antagonistic type
	Jilin	0.663	1452.6	Antagonistic type
	Liaoyuan	0.629	429.9	Low-level coupling type
Heilongjiang Province	Harbin	0.661	5183.8	Antagonistic type
	Qiqihar	0.656	1200.4	Antagonistic type
	Jixi	0.615	572.4	Low-level coupling type

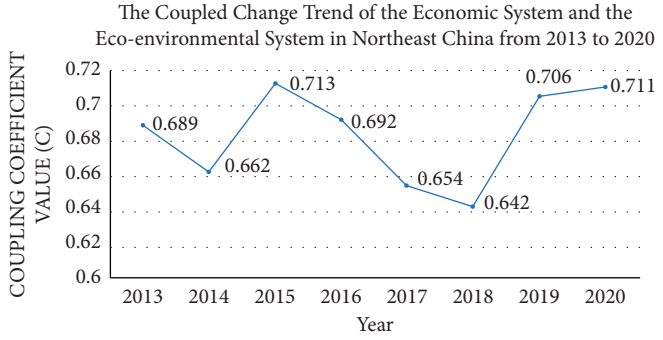

Figure 5: From 2013 to 2020, the coupling change trend of the economic system and the ecological environmental system in Northeast China.

strong coupling between the ecological environment system and the economic development system, which are closely related. Second, the degree of action, focus, and intensity of the coupling between the local ecological environment and economic development are dynamic rather than static.

6. Conclusions

The coupling degree of the ecological environment and economic development in the sample area in 2020 is 0.711, indicating a medium correlation degree. According to the grey correlation analysis method, the main constraints on economic development are the emission of three wastes and the restriction of water and soil resources. The overall level of the economy and people's living standards in Northeast China reflect the stress of economic development on the ecological environment. The spatial distribution is determined by economic development and environmental interaction, and Northeast China is primarily antagonistic and low-level in terms of spatial coupling relationships. The main representative cities are Shenyang (0.621), Anshan (0.642), Liaoyuan (0.629), and Jixi (0.615), and comparative analysis reveals that the overall coupling degree of cities in Liaoning Province is higher. Compared to the other two provinces, Jilin and Heilongjiang have a significantly higher percentage of cities with a high coupling degree. A time series analysis shows that the coupling degree curve has changed from 0.713 in 2015 to 0.642 in 2018, indicating that this is the second stage. The degree of coupling between economic development and the environmental state fluctuated significantly after declining in 2018 and beginning to rise in that year. The changing characteristics of the coupling degree curve are expected to drive the next five years. In this region, the degree of coupling between economic development and the ecological environment will increase and will be antagonistic in the short term. At the same time, the ecological environment will have a significant constraining effect on economic development.

Data Availability

The data used to support the findings of this study are available on reasonable request from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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