Research on the Coupling and Coordinated Development of Regional Economic Resilience and Ecological Environment Quality under the Background of "Double Carbon"

--Taking the Northeast Old Industrial Base as an Example

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Abstract. Improving the resilience of the regional economy and the quality of the ecological environment under the background of the "double carbon" goal are important elements in the transition of China's economy from high-speed development to high-quality development. Taking the old industrial base in Northeast China as an example, this paper constructs index systems of regional economic resilience and ecological environment quality. Based on the panel data of Heilongjiang, Jilin and Liaoning provinces from 2003 to 2020, the coupling coordination model was used to measure the degree of coordination between the two systems in Northeast China. The main conclusions are: First, the regional economic resilience and environmental quality have improved year by year, which reflects that the policies have been well implemented; Secondly, the coupling and coordination relationship between systems is continuously strengthened, and the process of integration in the Northeast region is constantly advancing; Finally, the degree of coordination between economic resilience and ecological environment needs to be further strengthened. Based on the above, this paper puts forward some targeted suggestions, hoping to provide ideas for promoting the coordinated development.

Keywords: Double carbon; Economic resilience; Ecological environment quality; Coupling coordination; Northeast old industrial base.

1. Introduction

The report of the 19th National Congress of the Communist Party of China pointed out that China's economy is transitioning from high-speed development to high-quality development. To comprehensively promote high-quality economic development, it is necessary to establish a strong and resilient economic system. Experience shows that in regions with poor economic resilience, external shocks may cause economic downturns; regions with strong economic recovery capabilities can adjust their economic, social and political structures to adapt to changes and ensure economic stability. Facing the changing external environment, further improvement is needed to improve regional economic resilience and achieve sustainable economic development.

At the same time, with the continuous advancement of the industrialization process, the problems of environmental pollution and energy consumption have become increasingly prominent. Global warming will pose a major threat to the world, and many countries have raised "carbon neutrality" as a national strategy. In 2020, China released the "double carbon" strategic goal, that is, to reach a peak in carbon emissions by 2030, and strive to achieve carbon neutrality by 2060. Therefore, strengthening the co-evolution of economic resilience and ecological environment quality has become an important research topic.

As the earliest and largest heavy industry base in New China, the old industrial base in Northeast China is gradually undergoing the process of China's economic system and structural reform. The extensive economic development model that relies on high investment, consumption and pollution for a long time has caused damage to the ecological environment, which not only limits the high-quality of economic development, but also affects the sustainable use of resources. In the new era, it is of great practical significance to strengthen the economic resilience, improve the environmental quality, and coordinate the development of the two systems to revitalize the old industrial base.

2. Literature review:

2.1 Measurement and evaluation of economic resilience and environmental quality

"Resilience" originated in the field of physics, and it means the ability of a system to recover and maintain after being disturbed. [1] In recent years, it has been introduced into the field of economic. Reggiani first proposed the concept of "resilience" in the field of economics and delved into how regional economic systems respond to shocks and obstacles. [2] From the perspective of measuring economic resilience, the overall research idea is mainly based on the concept or framework of economic resilience, using core variables such as economic growth rate [3], employment rate [4] and other indicators. A large number of literatures mainly use the core variable method to measure economic resilience, which is easy to implement, but ignores the marginal contribution of other variables in the economic system, and the comprehensive evaluation system is more consistent with the multiple characteristics of economic resilience [5]. Briguglio [6] first measured economic resilience by constructing a basket index system. Typical models include Zhu et al. (2021), who built an economic resilience index system through three dimensions. [7]

In the 1970s, foreign scholars have carried out research on the evaluation of ecological environment, which has become mature in the 21st century. [8] Domestic research on ecological environment mainly focuses on current situation and problems, index system construction, evaluation, environmental governance, etc. For example, Feng [9] both analyzed the current situation, characteristics and problems of rural ecological environment. Huang et al. [10] constructed the eco-environmental performance evaluation index system of Taihu Lake by constructing the PSR model. Among them, PSR(Pressure-state-Response) model is a framework system widely used to study environmental problems. [11] [12] It introduces the thinking mode of causality, which can intuitively reflect the relationship between ecosystem pressure, state and response.

2.2 Economic and environmental coupling and coordinated development

Coupling refers to the phenomenon that two or more systems are interrelated and mutually restricted to achieve coordinated development. The coupling studies in the early stage were mainly applied in the field of engineering, and then gradually introduced into the researches on social economy and resource environment. [13] [14] The current research mainly starts from various factors of economic system and environmental system, such as the economic development level, urbanization level and industrial policy in the economic system. [15] [16] The environment system is studied from the perspectives of water environment, atmosphere and land. [17] [18] In terms of research methods, many scholars have studied the coupling mechanism using methods such as coupling coordination degree model and spatial trend analysis. [19] [20].

In conclusion, the current studies on the coordination and coupling of environment and economy are mainly carried out from the perspectives of economic growth and environmental quality, social economy and ecological environment, urbanization and ecological environment, etc. Few are from the perspective of economic resilience and ecological environment. Also, most of the analysis is based on the time evolution process dimension, and few studies are conducted from the space-time coupling dimension. In addition, most of the studies are based on the national or provincial scale, and there is a lack of literatures based on regions, especially in northeast China.

In view of this, the possible contributions of this paper mainly include the following aspects: First, in terms of topic, there are few previous studies on the measurement of economic resilience and environmental quality. In this paper, the coupling coordination degree between the two systems is calculated, which is beneficial to enrich related research. Second, from the perspective of research, previous studies often ignored the old industrial base in Northeast China. The proposal of the "double carbon" goal makes the revitalization of the old industrial base in Northeast China imminent in the new era. This paper explores the spatiotemporal coupling relationship, providing a new perspective for related research. Third, this paper puts forward some pertinent suggestions, such as the adjustment of industrial and energy structures. It is necessary to further accelerate the process.

3. Theoretical analysis and empirical design

3.1 Construction of indicator system

Since both ecological environment quality and economic resilience are affected by various factors, this paper refers to Guo [19] Zhang [21] and based on the principles of data availability and unity. A comprehensive evaluation index system for measuring ecological environment quality and economic resilience was constructed, as shown in Table 1.

Table 1. Comprehensive evaluation index system

	Level	Index	Indicator nature
Economic Resilience Indicator System	Resistance	Share of education spending	+
		Urban registered unemployment rate	-
		Added value of the tertiary industry	+
		Added value of the secondary industry	-
	Resilience	GDP per capita	+
		Per capita disposable income	+
		Per capita fiscal revenue	-
	Adaptability	Engel's coefficient of urban residents	-
		Urbanization rate	+
		Labor productivity	+
	Transformational power	R&D spending intensity	+
		Science and Technology /Financial	+
		College students per 10,000 people	+
Eco-environmental Quality Index System	Pressure	Industrial exhaust emissions	-
		Industrial wastewater discharge	-
		CO_2 emissions	-
	State	Per capita park green space	+
		Per capita water resources	+
		Energy consumption intensity	-
	Response	Urban sewage treatment rate	+
		Harmless treatment rate of waste	+
		Investment in industrial pollution control	+

3.2 Entropy weight-coupling coordination model

3.2.1 Entropy weight method

"Entropy" was originally a concept in physics, and has since been widely used to express the degree of disorder in a system. The entropy value method is a relatively objective method to measure the index weight.

Standardization

In order to eliminate the influence of the difference, the positive and negative indicators are first subjected to dimensionless processing.

Positive indicators:

$$x'_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j} + 1 \tag{1}$$

Negative indicators:

$$x'_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j} + 1 \tag{2}$$

Calculate the proportion

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{m} X'_{ij}} (i = 1, 2, \dots, m; j = 1, 2, \dots, n) \tag{3}$$

Calculate the entropy value of the index

$$e_j = -\frac{1}{\ln(m)}\sum_{i=1}^{m} P_{ij}(1 = 1, 2, \ldots, m; j = 1, 2, \ldots, n) \tag{4}$$

Calculate the difference coefficient

$$\mathrm{d_j} = 1 - \mathrm{e_j} \tag{5}$$

Weight: On the basis of the above calculation, the weight value of a specific indicator can be obtained. which is:

$$W_j = \frac{d_j}{\sum_{j=1}^{n} d_j}(1 \le j \le n) \tag{6}$$

Overall score: $f_{ij} = \mathcal{W}_j x'_{ij}$; $f_i = \sum_{j=1}^{n} f_{ij}$

Coupling coordination model

Coupling

The first measured coupling model is:

$$C = \sqrt{\frac{f_1 \cdot f_2}{(f_1 + f_2)^2}} \tag{7}$$

In the formula: C represents the coupling degree, f1 represents the comprehensive score of ecological environment quality, and f2 represents the comprehensive score of regional economic resilience. f1 and f2 can be obtained based on the entropy value method.

3.2.2 Coupling coordination degree

The two indicator systems are different. This difference may be higher coupling when both systems are poor. In order to avoid the error caused by this situation, this paper refers to the existing literature research to construct a coupling coordination degree model:

$$D = \sqrt{C \times T} \tag{8}$$

$$T = \alpha f_1 + \beta f_2 \tag{9}$$

D is the coupling coordination degree of the two, α and β are the contribution shares of the two subsystems. In the perspective of co-evolution, the two systems complement and restrict each other. So, both are equally important. Each is given a weight of 0.5. T is the coordination index. Referring to the research results of Liao [23], the degree of coupling and coordination is more intuitively displayed. The specific division is shown in Table 2:

Table 2. Evaluation criteria of coupling coordination degree

D	Rank	D	Rank
0～0.09	Extremely disordered	0.50～0.59	Barely coordinated
0.10～0.19	Severely disordered	0.60～0.69	Primary coordinated
0.20～0.29	Moderately disordered	0.70～0.79	Intermediate Coordinated
0.30～0.39	Mild disordered	0.80～0.89	Well coordinated
0.40～0.49	On the verge of dysregulation	0.90～1	Quality coordinated

3.3 Data Description

Based on the availability of data, this paper mainly uses the panel data of the three northeastern provinces from 2003 to 2020 as a sample. The basic data are from The Statistical Yearbook of Jilin Province, The Statistical Yearbook of Heilongjiang Province, The Statistical Yearbook of Liaoning Province, The Statistical Yearbook of China’s Regional Economy. Some missing data were filled by the average growth rate method.

4. Results and Discussion

4.1 Analysis of Results for Economic Resilience and Environmental Quality

4.1.1 Spatial and temporal evolution of economic resilience

This paper obtains the economic resilience level of each province through the calculation of the data of the Northeast China from 2003 to 2020. The specific results are shown in Figure 1.

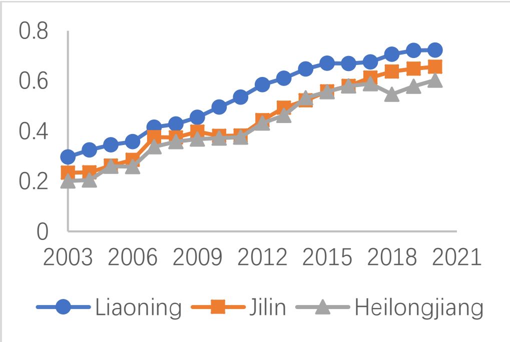

Figure 1. Economic resilience level in Northeast China from 2003 to 2020

From the perspective of time, the regional economic resilience of the three provinces showed an overall trend of rise. From 2003 to 2007, the Northeast was in the implementation stage of the revitalization policy. The Northeast kept accelerating the upgrading of the industrial structure and improving the quality of development, which made the economic resilience continuously improved. From 2007 to 2011, affected by the economic crisis, Jilin and Heilongjiang grew slowly or even declined, while Liaoning was not greatly affected. From 2011 to 2017, economic resilience increased rapidly thanks to policies brought about by the Northeast Revitalization strategy, such as large-scale infrastructure investment and the transformation of resource cities. However, since 2017, the growth of economic resilience has gradually slowed down, which is closely related to the lagging economic development and grim employment situation in recent years.

From the perspective of space, Liaoning's economic resilience level is significantly higher than that of the other two provinces. As the only coastal city in the three provinces of Northeast China, Liaoning is an important channel. The Shenyang - Dalian dual core development model is also conducive to economic development and the growth of economic resilience. However, restricted by environmental quality, industrial structure and other factors, the development has been slow in recent years. Different from the dual-core development model of Liaoning, Jilin and Heilongjiang provinces attach importance to the primacy of capital cities and adopt the single-core development model. The situation is still grim, especially in the traditional agricultural province, Heilongjiang, whose first industry accounts for larger proportion, the second industry is given priority to with heavy industry. Speeding up the promotion of economic resilience is still a long way to go.

4.1.2 Spatial and temporal evolution of ecological environmental quality level

In this paper, PSR model evaluation method was used to calculate the ecological environmental quality of the three provinces. The specific results are shown in Figure 2.

With the pollution problem in Northeast China receiving more attention, the quality of ecological environment is also constantly improved. From 2003 to 2020, the quality showed an overall growth trend, with an average value increasing from 0.35 to 0.73. Overall increase of environment index is not as large as that of economic resilience index and has certain fluctuations. There are two reasons accounting for the situation. First, the restoration of ecological quality is a long-term process. Second, in the current economic situation, environmental protection and ecological system restoration are still regarded as "costs" and "victims" of economic interests, which have not received sufficient attention from governments and enterprises. Then, the PSR subsystem of the three provinces is analyzed, as shown in the following figures.

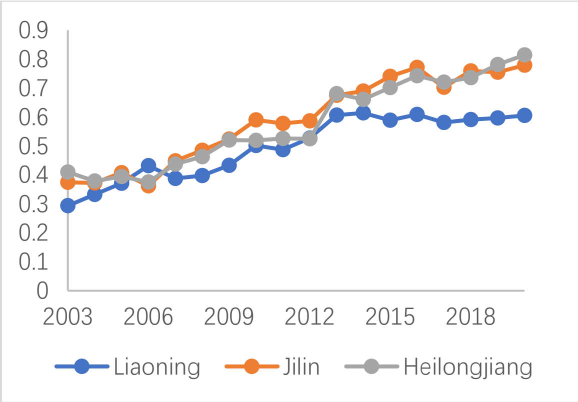

Figure 2. Eco-environmental quality in Northeast China from 2003 to 2020

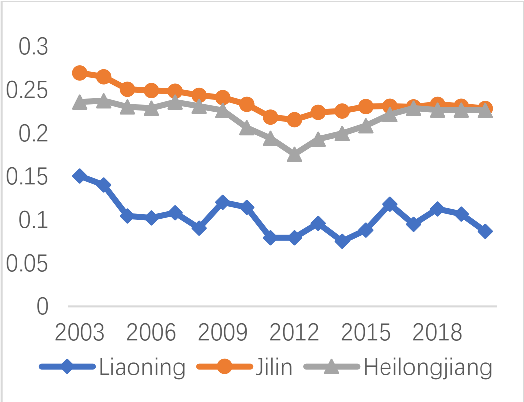

Figure 3. Pressure Subsystem Trend Chart

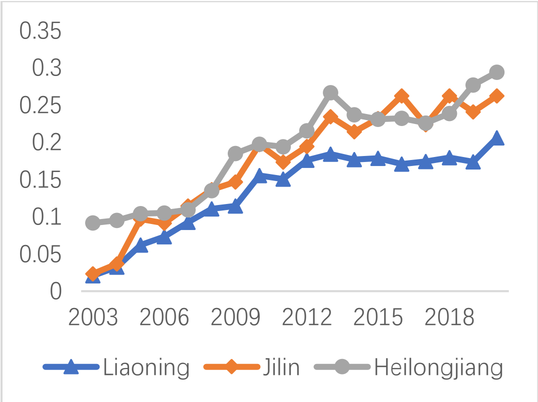

Figure 4. State Subsystem Trend Chart

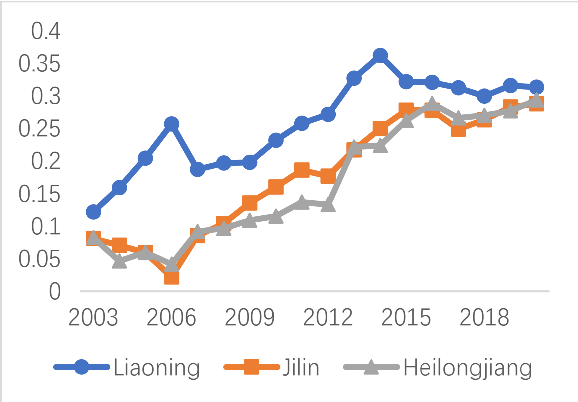

Figure 5. Response Subsystem Trend Chart

From the perspective of spatial differences in ecological environment, the comprehensive score of Liaoning Province is lower than that of the other two. As a heavy industrial province, Liaoning still faces severe challenges in structural adjustment. From the point of view of each subsystem, pressure is the least in Liaoning Province and the largest in Jilin Province. The economic development of Jilin Province is accelerating, but pollution has not improved along with the economic development. The emission of industrial "three wastes" in Liaoning is significantly lower than that in the other two provinces. Combined with the response subsystem, Liaoning government has invested a high amount of financial expenditure on environmental pollution, and has played a very good effect. In the state subsystem, Liaoning Province is in a bad state, which is closely related to the distribution of population. By 2021, about 43 million population in Liaoning province, 24 million in Jilin, and 30 million in Heilongjiang. As the population increases, all kinds of limited resources per capita level will decline, resulting in the different levels of environmental degradation. It is also the reason why index of ecological environment in recent years in Liaoning grow slowly. They also constrain economic resilience.

4.2 Analysis of spatial and temporal pattern of coupling coordination degree

Table 3. Coupling degree and coupling coordination degree

Year	Liaoning		Jilin		Heilongjiang	
	C	D	C	D	C	D
2003	0.4999	0.3841	0.4865	0.3845	0.4698	0.3788
2004	0.4999	0.4051	0.4872	0.3847	0.4771	0.3732
2005	0.4996	0.4229	0.4881	0.4042	0.4892	0.3998
2006	0.4978	0.4435	0.4964	0.4011	0.4913	0.3946
2007	0.4996	0.4480	0.4980	0.4529	0.4958	0.4381
2008	0.4996	0.4543	0.4958	0.4614	0.4959	0.4512
2009	0.4998	0.4710	0.4952	0.4774	0.4925	0.4676
2010	0.4999	0.4992	0.4881	0.4868	0.4931	0.4689
2011	0.4994	0.5053	0.4895	0.4847	0.4930	0.4713
2012	0.4993	0.5266	0.4951	0.5050	0.4976	0.4877
2013	0.4999	0.5517	0.4939	0.5373	0.4907	0.5295
2014	0.4998	0.5615	0.4951	0.5478	0.4971	0.5446
2015	0.4989	0.5603	0.4950	0.5668	0.4967	0.5591
2016	0.4994	0.5650	0.4949	0.5783	0.4962	0.5727
2017	0.4985	0.5597	0.4988	0.5730	0.4974	0.5705
2018	0.4980	0.5683	0.4981	0.5895	0.4945	0.5630
2019	0.4977	0.5725	0.4985	0.5915	0.4944	0.5797
2020	0.4980	0.5752	0.4981	0.5978	0.4944	0.5919

As can be seen from Table 3, the coupling degrees are around 0.5, close to benign coupling. At present, the whole northeast China shows a steady development trend, while the coupling coordination degree as a whole maintains a rising trend. From 2003 to 2020, the coupling coordination degree was improved from mild imbalance, to near imbalance and finally closer to primary coordination. Liaoning entered the grudging coordination stage in 2011 at the earliest, followed by Jilin in 2012, and Heilongjiang made a leap in 2013 and maintained grudging coordination from 2013 to 2020. On the whole, the economic resilience and ecological quality of the three provinces showed a good coupling and coordination relationship.

Although the coupling coordination degree is good on the whole, there are some differences among different provinces. Since the implementation of the Northeast Revitalization policy in 2003, Liaoning government has responded positively and got rid of the imbalance stage in only one year. The coupling coordination degree of Jilin has increased rapidly, surpassing Liaoning in 2015, and is now the province with the highest score among the three. Heilongjiang had a weak development momentum in the early stage, but it developed rapidly later and surpassed Liaoning in 2016. In general, the coupling coordination degree of the three provinces is similar. Jilin and Heilongjiang developed rapidly in the last five years, while Liaoning's coupling coordination degree rose slowly, indicating that industrial transformation is imminent.

5. Conclusions and Recommendations

5.1 Conclusions

The old industrial base in Northeast China is facing a period of transition. The research on the coordinated development of economic resilience and ecological environment quality is of great practical significance for the revitalization. This paper takes the data of three provinces in Northeast China from 2003 to 2020 as samples, and uses entropy weight coupling coordination model to calculate the comprehensive score and coupling coordination degree. The results show that: First, economic resilience and environmental quality have been continuously enhanced. The policies for revitalizing Northeast China and the policies for the transformation have been well implemented.

Second, the coupling and coordination relationship between two systems is increasing year by year. Although there are differences among provinces, the integration of northeast China is beneficial to the rational distribution of resources. Third, during the whole study period, the average of three provinces failed to meet the high-quality level. This shows that the reform to be further pushed forward.

5.2 Recommendations

Based on the conclusions, this paper puts forward the following suggestions: First, traditional industries will still be the main body in Northeast China for a long time. However, it is urgent to integrate IT into industries and improve production efficiency and quality. At the same time, we should strengthen cooperation with other developed cities and provinces to constantly introduce high-tech industries. Second, the long-term heavy industry foundation makes this region polluted. But on the other hand, local forests also make the place the most favorable region for carbon sink. At the same time, the "double carbon" policy will help the development of clean energy industry and promote the transformation of industrial structure, which will create a broader space for the implementation of " lucid waters and lush mountains are invaluable assets". Third, the improvement of environmental quality should not be ignored in process of improving economic resilience. Economic and environmental quality should be developed in a coordinated manner. Northeast China can strengthen green investment, develop more ecological industries to obtain economic benefits. The process that follows will be: strengthen ecological protection, minimize the damage caused by economic activities, strive to achieve balanced and stable development of the two systems, and finally achieve co-evolution.

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