

Research on the Dynamic Interaction between Ecological Environment and High-quality Economic Development in Lianyungang City

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Abstract

As an important coastal port city in China, Lianyungang is typical and exemplary in promoting the collaborative process of ecological environment governance and high-quality economic development. Based on the time series data of Lianyungang from 2016 to 2024, this paper constructs the ecological environment index and the high-quality economic development index, and systematically reveals the dynamic interaction mechanism of the two through VAR model, Granger causality test and impulse response analysis. The study found that the impact of high-quality economic development on the ecological environment showed the characteristics of "short-term negative and long-term positive". At the initial stage, the adjustment of industrial structure may aggravate the environmental pressure, but with the application of green technology and industrial upgrading, its positive effect gradually strengthened, and finally formed a continuous promoting effect. The impact of ecological environment on economic development shows the "alternating fluctuation" effect. In the short term, ecological governance promotes economic quality and efficiency by forcing industrial transformation. In the medium term, the withdrawal of traditional production capacity may inhibit economic vitality. In the long term, sustainable economic growth is achieved by relying on the value transformation of ecological resources and the rise of green industries. The interaction between the two has significant time lag and nonlinear characteristics, indicating that policy intervention needs to take into account dynamic balance.

Keywords

Lianyungang; Ecological-environment; Economic High Quality Development; VAR Model; Dynamic Impact.

1. Introduction

Nowadays, ecological environment and high-quality economic development have become core issues of global concern, and their coordinated progress is crucial for regional sustainable development. Lianyungang City, an important city located along the coast of Jiangsu Province, boasts unique mountain and sea scenery and abundant natural resources. It has significant characteristics and enormous potential in terms of ecological environment and economic development. In recent years, Lianyungang City has actively responded to the call for national ecological civilization construction, deeply practiced the concept of "green mountains and clear waters are as valuable as mountains of gold and silver", and continuously made efforts in the field of ecological environment protection. From air pollution prevention and control to water pollution control, from soil restoration to biodiversity protection, a series of measures have achieved remarkable results, and the ecological environment has been continuously improved. At the same time, Lianyungang City is steadfastly promoting the strategy of "building the city with industry and strengthening the city with industry", continuously expanding in multiple

fields such as petrochemicals, new materials, and new energy, and showing a strong upward trend in economic development.

However, in the process of high-quality development of ecological environment and economy, Lianyungang City also faces many challenges and opportunities. How to achieve sustainable economic growth while protecting the ecological environment, and how to provide more solid support for ecological protection through economic development, have become key issues that urgently need to be explored in depth. Based on this, conducting in-depth research on the ecological environment and high-quality economic development of Lianyungang City not only helps to reveal the complex internal connections and mechanisms between the two, providing strong basis for scientific decision-making in the city, but also provides valuable reference experience for other regions in the coordinated development of ecological economy.

2. Literature Review

2.1. Research on Regional Coordination and Policy Mechanism

Scholars mainly discussed the institutional guarantee and implementation path of ecological and economic coordinated development from the perspective of regional cooperation, policy system and governance mechanism.

Houyunjin (2025) focused on the collaborative legislation of ecological environment in the Yangtze River Delta, and proposed to solve regional conflicts of interest through legislative coordination. However, the lack of legal basis and the defects of coordination mechanism are still the main obstacles, and the compensation mechanism needs to be improved to enhance the legitimacy of regional coordination [1]. Shi Xiaowan (2024) proposed that the coordination of ecological protection and high-quality economy needs to rely on green technology innovation and industrial structure optimization, emphasizing the supporting role of cross regional cooperation and social capital participation in top-level design [4]. Chen Xiao et al. (2024) took Shaanxi Province as an example to verify the long-term role of green finance in promoting high-quality economic development, but pointed out that in the short term, green finance faces cost pressure and needs to balance short-term and long-term benefits through policy guidance [5]. Liuzhixiong et al. (2024) found through the national empirical study that the ecological environment governance has regional heterogeneity for the improvement of economic quality, and suggested strengthening the governance guarantee system according to local conditions to bridge the regional differences [6]. Gong Piming (2023) built an evaluation system for high-quality economic development and found that scientific and technological innovation and green transformation are the key to breaking through the constraints of the ecological environment, and the potential of the ecological economy needs to be released through supply side reform [13].

2.2. Coupling Coordination Model and Empirical Analysis

The research in this area mainly reveals the interactive law of ecological and economic systems through quantitative models, and emphasizes the characteristics of space-time evolution and driving mechanism.

Based on the Beijing Tianjin Hebei data, Paulison and Wanyuan (2024) found that the coordination degree of ecological and economic coupling showed a pattern of "high in the center and low around". They predicted that the coordination level would continue to rise in the future, but the regional gap should be narrowed through the integration strategy [2]. Wang Qun et al. (2024) took Huangshan District as an example to build an "ecological economic" coupling model, showing that its co scheduling has risen from the primary stage to the good stage, but the industrial driving effect of ecotourism still needs to be strengthened [3]. Qian Li and Cheng Yu (2024) analyzed the spatio-temporal evolution of the Yangtze River Delta, and

pointed out that the economic growth rate far exceeded the ecological level, and it was necessary to narrow the regional gap through technological innovation [7]. Wang Yan et al. (2024) studied the digital economy and ecological coordination in the Yellow River Basin, found that the coordination degree in the lower reaches was better than that in the middle and upper reaches, and suggested optimizing the layout of digital industries to enhance synergy [9]. Zhuangweiguang and zhaoyuanyu (2023) took the tourism industry in Jiangmen as an example and found that the coordination of ecology and economy needs to improve the added value of the industry and release the consumption potential [14]. Shibaojuan and wangpingping (2023) proposed for Hebei Province that economic growth and ecological coordination need to narrow the development gap between the two systems, and promote policy optimization to achieve symbiotic development [15].

2.3. Deepening of Specific Areas and Regional Cases

Many scholars' research focuses on specific industries or geographical units to explore the path of differentiated collaboration.

Yin Wei and Ying Xiaomeng (2024) proposed that the marine economy needs to strengthen the coordination of "resources, technology and ecology", and proposed to promote offshore ecological protection and technology transformation, so as to provide reference for coastal cities [8]. Yuanchunjian (2024) built a national ecological and economic measurement system, found that the growth rate of ecological benefits was lagging behind, and called for optimization of investment and output efficiency [10]. Chenyanping et al. (2024) diagnosed the spatial balance of the Yellow River Basin and pointed out that Ningxia, Gansu and other provinces need to strengthen the coordinated management of water resources and ecology [11]. Muxiaoyang et al. (2023) analyzed the coupling of logistics, economy and ecology, revealed that the coordination degree of the East was higher than that of the west, and proposed to improve the spatial imbalance through regional linkage [12]. Guohan and huchenyuan (2022) focused on the industrial economy of the Yellow River Basin and emphasized the role of environmental regulation in promoting green development, but there were significant regional differences [16]. Huangrenquan and dongjuan (2022) studied the "economy science technology ecology" ternary system in Shaanxi Province, and pointed out that the ecological environment is the short board of high-quality development, which needs to strengthen the innovation drive [17].

The current research status shows that the research on the dynamic interaction between ecological environment and high-quality economic development has formed a multi-dimensional framework: the policy mechanism focuses on top-level design and regional cooperation, the coupling model reveals quantitative laws, and specific cases deepen the practice path. Although the existing research has made significant progress, there are still the following limitations: first, the depth of regional heterogeneity research is insufficient. Most literatures point out that there are regional differences in the coordination of ecology and economy, but there are few studies on the differentiation path of specific cities. Second, the research on dynamic mechanism is weak. The existing coupling models mostly focus on the static coordination degree, and lack of discussion on the long-term evolution law and feedback mechanism of the dynamic interaction between ecology and economy, which is difficult to reveal the long-term effect of policy intervention. According to the economic and industrial characteristics of Lianyungang, combined with the local ecological status, this paper will focus on the analysis of the dynamic interaction between the ecological environment and the high quality of the economy in Lianyungang, and explore the ecological and economic synergy mode in line with the endowment of Lianyungang.

3. Theoretical Analysis

3.1. Analysis of Driving Mechanism of Ecological Environment

The driving mechanism of ecological environment for high-quality economic development can be summarized as "three-dimensional upgrading effect". First, the upgrading effect of resource supply. The improvement of ecological benefit index directly enhances the resilience of regional economy. Ecological environment governance provides a sustainable natural resource base for economic development by restoring ecological functions and improving resource utilization efficiency. Second, the effect of industrial transformation and upgrading. Ecological environment governance forces the green transformation of traditional industries and spawns new green industries. Strict environmental protection standards urge high pollution industries to eliminate backward production capacity and turn to cleaner production; At the same time, eco-tourism, green energy and other industries rely on high-quality ecological resources to realize value-added. Third, consumption and market upgrading effect. The improvement of the ecological environment has given birth to the demand for green consumption and stimulated the expansion of the market for high-quality products and services. Consumer preferences such as eco label products and low-carbon travel force supply side reform, forming a two-way drive of "demand upgrading - industrial upgrading". At the same time, ecological advantages are transformed into regional brand value, attracting green investment and talent accumulation, and enhancing economic competitiveness.

3.2. Analysis on the Driving Mechanism of High Quality Economic Development

The driving effect of high-quality economic development on ecological environment governance can be summarized as "dual effects". First, the social environment optimization effect. High quality economic development emphasizes the synergy and symbiosis of economy, society and ecology, and promotes the formation of green production and consumption consensus in the whole society. On the one hand, the goal of economic development has shifted from single growth to comprehensive benefits, prompting enterprises to take the initiative to assume environmental responsibility, and the improvement of public ecological awareness has spawned green consumption demand, forming a virtuous cycle of "market demand supply transformation". On the other hand, high-quality oriented cultural values reshape the concept of development, provide a basis for social identity for the development of ecological environment protection, and promote capital to lean towards low-carbon fields.

Second, the strengthening effect of policy guidance. The top-level design of high-quality economic development promotes ecological governance through systematic policy tools. Tax incentives and fiscal discount policies reduce the cost of green technology transformation of enterprises and encourage the transformation of high energy consuming industries; Industrial support policies targeted to support green industries such as new energy and ecological restoration, and accelerate the low-carbon industrial structure; The risk compensation mechanism disperses the financing risks of green projects and attracts social capital to participate in ecological governance.

4. Index Construction

This paper selects nine periods of time series data of Lianyungang from 2016 to 2024. The data of some indicators are discontinuous and missing due to the change of statistical caliber. This paper carries out relevant calculation and missing value processing, and then uses entropy method to establish Lianyungang ecological environment index and Lianyungang high-quality economic development index.

4.1. Lianyungang Ecological Environment Index

Referring to the construction objectives in the implementation plan for the construction of Jiangsu ecological environment standard system (2018-2022), this paper selects three aspects of ecological environment pressure, ecological environment foundation and ecological environment governance effect to establish the ecological environment index evaluation system of Lianyungang City, and uses the entropy method to fit the ecological environment index of Lianyungang City. Details are shown in Table 1.

Table 1. Evaluation Index System of Ecological Environment in Lianyungang

Primary Indicator	Secondary Index	Tertiary Indicators	Attribute
Ecological environment index	Ecological environment pressure	Population density (person/km ²)	-
		Energy consumption per Unit of GDP (tons of standard coal/10000 yuan)	-
		Industrial wastewater discharge (10000 tons)	-
	Ecological environment foundation	Per capita public green space area (m ² /person)	+
		Cultivated land area (km ²)	+
	Governance effectiveness	Fixed comprehensive utilization rate of general industrial waste (%)	+
		Greening coverage rate of built-up area (%)	+
		Garbage harmless treatment capacity (10000 tons)	+

4.2. Lianyungang High Quality Economic Development Index

Table 2. Evaluation Index System of High Quality Economic Development in Lianyungang

Primary Indicator	Secondary Index	Tertiary Indicators	Attribute
High quality economic development index	Vitality of economic development	Per capita GDP (10000 yuan/person)	+
		General public budget revenue/gdp (%)	+
		Tertiary industry/gdp (%)	+
		Proportion of fixed asset investment in GDP (%)	+
	Driving force of scientific and technological innovation	Output value of high tech industry (10000 yuan)	+
		Proportion of R&D expenditure in GDP (%)	+
	People's quality of life	Number of doctors per 10000 people (person)	+
		Student teacher ratio	-
		General public budget expenditure per capita (yuan/person)	+
		Engel coefficient of all residents	-
	Coordination and sharing	Per capita income gap between urban and rural areas (yuan/person)	-
		Urban registered unemployment rate (%)	-
		Urbanization rate (%)	+
	Degree of Opening Up	Dependence on foreign trade (%)	+
		Total actually utilized foreign capital (10000 US dollars)	+

As shown in Table 2, according to the performance evaluation index system for high-quality development of cities divided into districts issued by Jiangsu Province and the comprehensive evaluation method for high-quality development of economic development zones in Jiangsu Province (2021 version), combined with the actual situation of Lianyungang, this paper constructs the evaluation index system for high-quality economic development of Lianyungang from five aspects: economic development vitality, scientific and technological innovation power, people's quality of life, coordination and sharing, and the degree of opening to the outside world, and uses entropy method to fit the high-quality economic development index of Lianyungang.

4.3. Model Establishment

Economic theory usually cannot provide a rigorous explanation for the dynamic interaction between variables. Vector autoregressive model regards the variables to be analyzed as endogenous variables, and each variable depends on the lag value of itself and all other variables, so it can provide a framework to analyze the simultaneity between system variables and the dynamic response of separating the impact of each variable on itself and other variables. The mathematical expression of the p-order unconstrained VAR model is as follows:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \dots + A_p y_{t-p} + b x_t + \varepsilon_t, t = 1, 2, \dots, T$$

Where y_t is a k-dimensional endogenous variable, x_t is a d-dimensional exogenous variable, p is the lag order, b is the estimated coefficient matrix, T is the number of samples, k×k dimensional matrix A_i (i=1,2,..., p) and k×d dimensional matrix b are the coefficient matrices to be estimated. ε_t is a k-dimensional disturbance vector, which can be correlated with each other at the same time, but not with its own lag value and the variable on the right of the equation.

5. Empirical Analysis

5.1. Stationary Test of Data

VAR model is built on the basis of stable data. It is a phenomenon of regression and takes logarithm for each data. After logarithmization, the nature and relationship of the data will not be changed, and the obtained data is easy to eliminate the heteroscedasticity problem, and will also make its trend linear. LnHQD is used to represent the transformed economic high-quality development index, and LnECO is used to represent the transformed ecological environment index. Here, ADF unit root method is used to test the stationarity of the above data. From table 3, it can be seen that LnHQD and LnECO show unstable characteristics at the 5% confidence level. After the first-order difference, LnHQD and LnECO show stable characteristics at the 5% confidence level, showing the first-order single integer.

Table 3. Stationary Test of Data

Variable	Inspection Type	ADF Inspection Value	t	p	Inspection Results
LnHQD	(C,T,K)	-1.467534	-3.320969	0.4971	Unstable
LnECO	(C,T,K)	-1.805464	-3.320969	0.3525	Unstable
Δ LnHQD	(C,T,K)	-4.042421	-3.403313	0.0235	Stable
Δ LnECO	(C,T,K)	-4.413529	-3.403313	0.0154	Stable

5.2. Build VAR Model

Before establishing the VAR model, the lag order of the model should be determined first. According to table 4, combined with LR test, AIC information criterion and SC criterion, select

the lag order of 2 when the standard value is the smallest. Combined with the impact of the variable schedule, the VAR model constructed in this paper is: $y_t = A_1y_{t-1} + A_2y_{t-2} + \varepsilon_t$.

Table 4. Judgment Result of Lag Order

Lag	LogL	LR	FPE	AIC	SC	HQ
1	21.11511	NA	1.20e-05*	-5.705036	-5.843863	-6.260772
2	25.72282	3.071809	1.62E-05	-5.907607*	-6.185261*	-7.019079*

5.3. Model Stability Test

After the model is built, this paper judges the stability of the VAR model through the AR root graph. From Figure 1, we can see that the reciprocal of all characteristic roots are located in the unit circle, which can show that the model built this time has good stability. On this basis, we can further carry out impulse response analysis and variance decomposition analysis.

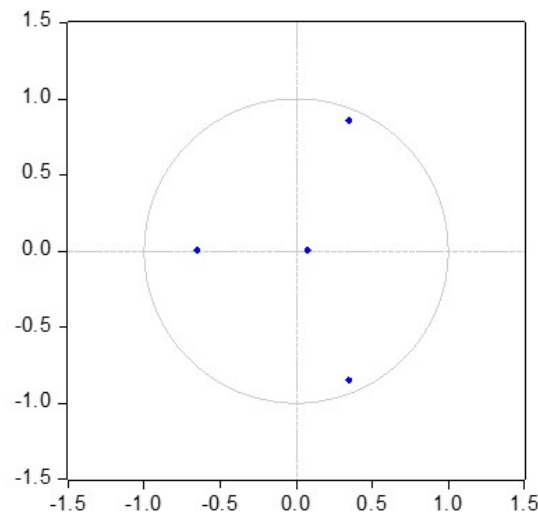


Figure 1. Inverse Roots of AR Characteristic Polynomial

5.4. Granger Test

Granger causality test can analyze the role and influence direction between two variables. The Granger causality test of Lianyungang ecological environment and high quality economic development index is shown in Table 5. Specifically, the ecological environment has a positive impact on high-quality economic development, which can promote high-quality economic development; High quality economic development can also strengthen the construction of ecological environment. Although Granger causality test reveals the interaction between these variables, it is slightly inadequate in measuring the specific degree of these effects. This paper will continue to use impulse response function to more accurately supplement the influence degree between these variables.

Table 5. Granger causality test results

Excluded	Chi-sq	Prob.	Conclusion
ΔLnHDQ does not Granger Cause ΔLnCEO	0.29487	0.08629	Correlation
ΔLnCEO does not Granger Cause ΔLnHDQ	2.451222	0.02936	Correlation

5.5. Impact of High Economic Quality on Ecological Environment



Figure 2. Response of DLNHQD to Cholesky One S.D. DLNCEO Innovation

From Figure 2, we can see the response and response path of the high-quality economic development index rate to the ecological environment index. The high-quality economic development index had no immediate impact on the eco-environmental development index at the beginning. The impact in the first phase was 0, but then there was a significant negative impact in the third phase, and returned to a positive impact in the third phase. At this time, the growth rate of the eco-environmental index increased by about 0.1 percentage point for every 1 percentage point increase in the high-quality economic development index. Since then, in the fourth and fifth periods, the economic high quality index still has a positive impact effect on the development of the ecological environment index, and after the sixth period, the impact effect of the economic high quality development index on the ecological environment index tends to be stable.

From the above analysis, it can be seen that the high-quality economic development index has almost a positive impact effect on the ecological environment index during the inspection period, and only a short-term negative impact effect appears at the beginning. The reason for this is that the concept of high-quality economic development has been put forward. Society will change the way of production and life to a certain extent, and the impact on the environment will be aggravated to a certain extent in the process of eliminating backward products; In the short term, the social production mode will be upgraded. The production level also tends to be stable, and the concept of ecological and environmental protection is deeply rooted in the hearts of the people. Therefore, high-quality economic development will have a positive impact on the ecological environment for a long time in the future.

5.6. Impact of Ecological Environment on High Quality Economic Development



Figure 3. Response of DLNCEO to Cholesky One S.D. DLNHQD Innovation

From Figure 3, we can see the response and response path of the eco-environmental index rate to the economic high quality index. At the beginning, the eco-environmental index had no immediate impact on the high-quality economic development index. The impact in the first period was 0, but then there was a significant positive impact in the second and third periods, and the maximum positive impact was reached in the third period. For every 1% increase in the eco-environmental index, the growth rate of the high-quality economic development index increased by about 1.25%. Thereafter, in the fourth and fifth periods, the eco-environmental index had a negative impact on the development of the economic high quality index, and reached the maximum in the fourth period. From the sixth to the eighth periods, the eco-environmental index had a positive impact on the economic high quality index, and then the impact gradually weakened, and weakened to zero in the tenth period, and then tended to converge stably.

From the above analysis, we can draw a conclusion that the eco-environmental index has a positive and negative impact on the high-quality development index alternately during the inspection period, the time lag of each stage is also short, and the cumulative effect in the short term is also large. The reason for this is that the proposal of the concept of ecological and environmental protection will quickly have a huge impact on the traditional production and lifestyle, prompting enterprises to eliminate backward production capacity in the short term, and people have also changed the bad lifestyle, which will drive the rapid economic growth in the short term; With the gradual completion of the updating of the mode of production in society, some backward production enterprises are eliminated, resulting in the reduction of the number of producers, which will lead to the lack of vitality of economic development in a certain period of time; But then the value brought by ecological and environmental protection was highlighted. Green enterprises and high-tech enterprises grew rapidly, making up for the lack of economic development caused by the elimination of traditional enterprises, and gradually stabilized.

6. Countermeasures and Suggestions

Based on the dynamic interaction characteristics of ecological environment and high-quality economic development, it is necessary to optimize the collaborative path from the following four aspects:

6.1. Promoting High-quality Economic Development and Continuously Strengthening the Positive Impact on the Ecological Environment

Industrial policy guidance: the government should issue more targeted industrial policies to encourage enterprises to adopt green production technologies and processes, and reduce the negative impact of the production process on the ecological environment from the source.

Green Innovation Incentives: increase investment in green technology innovation, promote the wide application of green technology in various industries, improve resource utilization efficiency, reduce energy consumption and pollutant emissions, and further consolidate and enhance the positive effect of high-quality economic development on the ecological environment.

6.2. Alleviate the Negative Impact on the Ecological Environment at the Initial Stage of High-quality Economic Development

Transitional support measures: in the process of eliminating backward production capacity, the government should formulate a reasonable transition plan to provide necessary support and help to the affected enterprises and workers.

Optimization of Environmental Supervision: strengthen environmental supervision, strictly implement environmental laws and regulations, but pay attention to flexibility in the

implementation process. For enterprises that actively seek transformation but are temporarily facing difficulties, a certain period of rectification and guidance should be given to ensure that while eliminating backward production capacity, enterprises' neglect of environmental protection and further deterioration of the ecological environment due to excessive regulation should be avoided.

6.3. Give Full Play to the Positive Role of Ecological Environment in High-quality Economic Development

Cultivation of ecological industry: cultivate and develop ecological agriculture, ecological tourism, environmental protection industry and other green ecological industries according to the advantages of ecological resources in various regions. Through policy guidance and capital investment, we will build a number of eco industrial demonstration areas with local characteristics, drive the coordinated development of related industries, and realize the benign interaction between ecological environment protection and economic growth.

Ecological brand building: encourage enterprises to establish ecological brand awareness, support enterprises to carry out green product certification and ecological logo application, and improve the ecological added value of products. Strengthen the publicity and promotion of ecological brands, improve consumers' awareness and recognition of green products, drive the development of ecological industry with market demand, and promote high-quality economic growth.

6.4. Coping with the Fluctuation of Ecological Environment Affecting Economic Development

Diversification of economic structure: all regions should actively promote the diversified development of economic structure and avoid excessive dependence on a single industry. In the process of ecological environment protection, we should develop emerging industries and service industries to make up for the lack of economic development vitality brought about by the elimination or transformation of traditional industries.

Dynamic monitoring and policy adjustment: establish a dynamic monitoring mechanism for economic and ecological environment development, and timely grasp the change trend of both. According to the monitoring results, timely adjust industrial policies and environmental protection policies to ensure that the economy can maintain stable and high-quality development while the ecological environment continues to improve.

Acknowledgments

Fund: The general project of philosophy and social sciences research in Jiangsu Universities "Research on the mutual promotion mechanism between ecological environment and high-quality economic development in Lianyungang" (Project No.: 2021SJA1766).

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