Exploring the Coordinated Development Path of Green Logistics and Regional Economy Coupling

Yuxia Guo^{*}, Pingping Wang, Zhouyu Tian

Business School of Suzhou University, Suzhou, Anhui, China *Corresponding Author.

Abstract: With the continuous development of the times, the contribution of the logistics industry to the economy is increasing year by year, and the rapid development of the logistics industry is driving rapid economic growth. Green logistics has become one of the directions for the development of the logistics industry. coordinated The development of green logistics and economy is crucial. Therefore, this article takes green logistics and regional economy in Anhui Province as the research object, and uses entropy weight method and coupling coordination model to measure and evaluate. Research shows that the coupling degree between green logistics and regional economy in Anhui Province is at a moderate level, and there is still room for improvement in coordination. Through the research in this article, suggestions are proposed for the coordinated development of green logistics and regional economy, in order to better promote the development of green logistics and regional economy in Anhui Province.

Keywords: Green Logistics; Regional Economy; Coupling Coordination; Entropy Weight Method; Coupling Degree

1. Introduction

The logistics industry has gradually become the mainstay of economic development. According to statistics, before the end of 2022, the total amount of social logistics in the country will be 347.6 trillion yuan, a year-on-year increase of 3.4%. The scale of logistics demand has reached a new height and achieved stable growth. However, with the rapid development of the logistics industry, a series of problems have also emerged, such as excessive pursuit of economic benefits while ignoring the environment, unnecessary energy consumption, waste of resources and excessive logistics production costs in the process of logistics activities, which do not conform to the concept of green development and hinder the high-quality development of the logistics industry. According to the research of previous scholars, green development is more in line with the requirements of high-quality development in the new era, and has a greater contribution to economic development. The development awareness of green logistics needs to be further strengthened in Anhui Province, and the development level of green logistics is relatively low. Therefore, it is necessary to explore the coupling and coordinated development path of green logistics and regional economy.

Green development is an important condition for green logistics to move towards circular economy [1]. Green logistics is to realize the green and healthy development of economy and society. The logistics industry needs to change its development model, improve resource utilization efficiency and environmental protection capabilities [2]. Cai (2022) analyzed the development of green logistics in the Yangtze River Delta region [3]: (2021)studied the Oi coupling and coordination relationship between green logistics and regional economy [4]; Xu and Li (2023)Research on the Coordinated Development of Green Logistics and Green Economy in the Yangtze River Economic Belt [5]; Ma and Shuang (2023) Research on the spatio-temporal evolution characteristics of the coupling coordination degree between digital trade and green logistics[6]. In addition, research on the coordinated development of logistics and regional economy includes Zhan (2019) [7], Zhang et al. (2019) [8], Wang et al. (2020) [9], Luo et al. (2020) [10], and carry out the coordinated development of regional logistics and tourism economy [11-12].

Through combing and thinking of the existing literature, it provides ideas and directions for

writing this article, but at the same time, it also found that the research on the coupling and coordinated development of green logistics and regional economy in Anhui Province is not rich enough. Therefore, this paper intends to explore the level of coordinated development of green logistics and regional economy in Anhui Province, and provide decision-making support for green logistics and regional economic development in Anhui Province, which certain practical has guiding significance.

Coordination Degree Model between Green Logistics and Regional Economy

2.1 Index System Construction and Data Source

2.1.1 Construction of Indicator System

In line with the principles of systematicness, scientificity, operability, and dynamics, and drawing on relevant research results [4-5], this paper constructs the following indicators for the two subsystems of green logistics and regional economy in Anhui Province system, see Table 1:

2. Construction of the Coupling Table 1. Green Logistics and Regional Economic Index System in Anhui Province

System	Indicator	Serial number	Polarity
Green Logistics	Logistics revenue per mu (10,000 yuan/mu)	A1	+
	Carbon emissions from the transportation industry (10,000 tons)	A2	-
	Carbon emission per unit freight volume (kg CO2/ton)	A3	-
	Labor productivity of logistics industry (yuan/person)	A4	+
	Logistics added value per mu (yuan/mu)	A5	+
Regional economy	GDP (100 million yuan)	B1	+
	Per capita disposable income of all residents (RMB/person)	B2	+
	Unemployment rate (%)	B3	-
	Total retail sales of social consumer goods (100 million yuan)	B4	+
	Total imports and exports (100 million US dollars)	B5	+
	Poverty rate (%)	B6	-

2.1.2 Data Source

The development of green logistics and regional economy needs to be reflected through a certain time dimension, and some indicators have not been updated in 2021 and beyond. Therefore, this paper selects the data of Anhui Province from 2012 to 2020 for research. Among them, the data of logistics revenue per mu and carbon emissions per unit of freight volume come from the Anhui and Provincial Economic Information Commission, the data of labor productivity and logistics added value per mu of the logistics industry come from the Anhui Provincial Bureau of Statistics, and the data of carbon emissions in the transportation industry come from Anhui Provincial Department of Transportation; The data of GDP, per capita disposable income of all residents, unemployment rate, and total import and export are from the National Data Network, and the data of poverty rate and total retail sales of social consumer goods are from the "Statistical Yearbook of Anhui Province".

Construction

2.2.1 Entropy Weight Method

The entropy weight method is used to calculate the comprehensive score of the index system, which reduces the influence of subjectivity on the decision-making results. The entropy weight method is operable, simple and intuitive. The specific steps are as follows: (1) Determine the evaluation object and establish the evaluation index system;

(2) Since the units of the original data between each indicator are inconsistent and the expression forms are also different, in order to reduce the impact of differences between data on the comprehensive assessment, it is necessary to standardize the original data. Here is the formula:

Positive indicators:

$$x_{ij} = \frac{x_j - x_{min}}{x_{max} - x_{min}} \tag{1}$$

Negative indicators:

$$x_{ij} = \frac{x_{max} - x_j}{x_{max} - x_{min}},\tag{2}$$

Of which; x_j For the first *j* Item indicator value, x_{min} For *j* The minimum value of the first indicator, x_{max} For the first *j* The maximum value of the item metric.

2.2 Research Methods and Model

358

Note: In order to ensure the scientificity and authenticity of the research, the value equal to 0 after standardization processing, this paper assigns a positive minimum amount to the value of 0, takes 0.001 as the translation amount, and incorporates it into the calculation process.

(3) Calculate the proportion j of the index value i under the first index, the proportion value is the largest, indicating that the importance of the index to the evaluation system is greater, the formula is as follows:

$$w_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (0 \le w_{ij} \le 1)$$
(3)

(4) Calculation *j* Information Entropy of the First Index*e*_{*i*}:

$$e_j = -\frac{1}{\ln m} \sum_{n=1}^m w_{ij} \ln Y_{ij} \tag{4}$$

(5) Calculate the *j* Information utility value of index d_j :

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

(6) Calculate the weight of evaluation indicators:

$$c_j = \frac{e_j}{\sum_{j=1}^n d_j} \tag{6}$$

(7) Calculate the comprehensive evaluation value, the formula is as follows:

$$Q_i = \sum_{j=1}^n c_j \, x_{ij} \tag{7}$$

 Q_i Represents th. *i* The comprehensive evaluation value of the indicators, *n*Represents the number of indicators, c_j Represents th. *j* The weight of the item indicator, *Q* The larger the value, the higher the contribution of this indicator [5].

2.2.2 Coupling Degree

Coupling degree refers to the mutual influence between multiple systems, so as to achieve coordinated development of the relationship, it reflects the degree of interdependence and mutual restraint between systems. The calculation formula is as follows:

$$C = \frac{\sqrt{U_1 * U_2}}{U_1 + U_2} \tag{8}$$

Among them, U_1 And U_2 Represents the comprehensive evaluation value of each subsystem obtained by entropy weight method; *C*Represents the coupling level, that is, the coupling degree of the system, which is usually valued as 0 < C < 1, *C* The larger the system, the closer the connection between the systems. For the classification level of the coupling degree [5], see Table 2 for details. 2.2.3 Coupling Coordination

The degree of coupling is mainly used to measure the degree of correlation between systems, but it is difficult to show the size of the comprehensive evaluation index of subsystems, so it will produce a phenomenon that the degree of coupling of subsystems is high but the level of development has not been improved [5]. Therefore, drawing on the way of previous scholars to deal with this problem, the formula is constructed as follows, so as to better analyze the degree of subsystem correlation.

Table 2. Criteria for Coupling DegreeDivision

Coupling	Coupling	Type of co	oupling			
interval	class	degree				
0~0.3	1	Low coupling p	eriod			
0.3~0.5	2	Antagonistic pe	riod			
$0.5{\sim}0.8$	3	Running-in peri	od			
0.8~1 4		High coupling period				
$T = \alpha * U_1 + \beta * U_2 \tag{9}$						
$D = \sqrt{C * T}$						

In the above formula, *T* A comprehensive measure of the level of coordinated development, α , β Is the pending level, and $\alpha + \beta = 1$. Referring to the practices of other scholars, green logistics is regarded as equally important as regional economy, so the α And β Assigned to 0.5 and 0.5.*D*In order to reflect the level of coordination between green logistics and regional economic development more intuitively, this paper discusses the coordination degree of green logistics and regional economic development *D* The values are divided as follows [5], as shown in Table 3:

Table 3. Criteria for Coordination DegreeDivision

Consistency	Coordination	Coordination degree		
interval	level	type		
$0{\sim}0.2$	1	Severe disorder		
$0.2 \sim 0.4$	2	Running-in		
		coordination		
$0.4{\sim}0.6$	3	Basic coordination		
$0.6{\sim}0.8$	4	Highly coordinated		
0.8~1 5		Extreme coordination		

3. Data Results and Analysis

3.1 Green Logistics and Comprehensive Development Level of Regional Economy

Substituting the collected index data into

formulas (1)-(7) can calculate the changes in the comprehensive level of green logistics and regional economic development in Anhui Province during the research period, as shown in Figure 1:



Figure 1. Comprehensive Level of Green Logistics and Regional Economic Development in Anhui Province from 2012 to 2020

It can be seen from Figure 1 that from 2012 to 2020, the development level of green logistics in Anhui Province has made steady progress. The annual growth rate of the comprehensive level of green logistics is 16.3%, and green logistics has developed rapidly. This is because the Anhui Provincial People's Government has introduced support and incentive measures, such as increasing investment in green logistics, improving road transportation facilities, etc., and has issued a series of policies and regulations related to the development of green logistics, such as the "Anhui Green Logistics Industry Development Plan", "Anhui Province Energy Conservation and Emission Reduction Optimized Logistics Development Plan", etc. Through the application of new technologies and methods, such as intelligent route planning and data analysis, logistics enterprises in Anhui Province have achieved innovations such as efficient utilization of resources and optimization of logistics vehicle scheduling, which have significantly improved logistics efficiency and reduced energy consumption, thus promoting the development of green logistics.

It can also be seen from Figure 1 that from 2012 to 2020, the comprehensive level of regional economy in Anhui Province has gradually increased, with an annual growth rate of 8.3%, indicating that the level of economic development in Anhui Province has steadily improved. On the one hand, in the field of manufacturing, Anhui Province promotes the optimization and upgrading of the industrial chain, focusing on technological innovation in the fields of industrial Internet,

digital manufacturing, energy conservation and emission reduction. At the same time, increase support for technology research and development and standard formulation. optimize the talent training mechanism, develop high-end manufacturing, and cultivate technology-based small and medium-sized enterprises. On the other hand, actively promote urban and rural development, invest in infrastructure construction, optimize public and strengthen environmental services, governance. In addition, service industries such as culture, technology, and tourism are also growing day by day in Anhui's economic development. Especially in recent years, the construction of Anhui urban agglomeration with Hefei as the core has further enhanced the spatial pattern and dynamic mechanism of Anhui's economic development, and further Anhui's continuous promoted new development achievements.

3.2 Coupling Coordination Degree Processing Results

According to the theoretical overview and formula of coupling and coordination degree mentioned above, the coupling and coordination degree of green logistics and regional economy in Anhui Province are calculated, and the following processing results are obtained according to Table 2 and Table 3.

According to the classification of the coupling degree and coordination degree of green logistics and regional economy in Anhui Province in Table 4, it can be concluded that the coupling degree of green logistics and regional economy in Anhui Province is between 0.48-0.50, without much fluctuation, and has been in an antagonistic period. The coordination degree of green logistics and regional economy in Anhui Province is fluctuating between 0.35-0.60, growth, developing from the running-in coordination period to the basic coordination period.

From the perspective of coordination, in 2012 and 2013, the green logistics and regional economy in Anhui Province were in a period of running-in coordination, that is, the two systems had just entered an orderly state from a disorderly state, and the level of coordination was not high, and there was still a lot of room for improvement. Tracking the index data, the added value of logistics per mu has the least

contribution to the comprehensive level of green logistics, so we should focus on how to increase the added value of logistics per mu and improve the utilization rate of logistics land. From 2014 to 2020, green logistics and regional economy in Anhui Province began to enter a period of basic coordination, and the coordination level of the two systems has improved. By 2020, the coordination level will be close to 0.6. According to the growth of coordination degree combined with the comprehensive development level of green logistics and regional economy in Anhui Province in Figure 1, it is tracked that the carbon emissions per unit of freight volume in the indicator data contribute the most to the comprehensive level of green logistics, so we should continue to pay attention to the issue of carbon emissions. The labor productivity of the logistics industry also contributes a lot to

the comprehensive level of green logistics, which shows that Anhui Province attaches great importance to improving the efficiency of logistics activities in the process of developing green logistics, improves the quality of logistics practitioners, and creates higher logistics value every year. In addition, the comprehensive level of the unemployment rate is only 0.54, which is far behind other indicators. The unemployment rate mainly reflects the quality of the economic operation. If the economic situation develops well, enterprises will expand production and jobs will increase, and the unemployment rate will increase. Therefore, in the future, we should continue to increase the number of jobs in the logistics industry, promote the employment of logistics personnel, and promote economic development.

Year	Coupling degree	Classification	Degree of coordination	Classification
2012	0.48857	Antagonistic period	0.37775	Running-in coordination
2013	0.48945	Antagonistic period	0.39241	Running-in coordination
2014	0.49426	Antagonistic period	0.40875	Basic coordination
2015	0.49957	Antagonistic period	0.43005	Basic coordination
2016	0.49891	Antagonistic period	0.45969	Basic coordination
2017	0.49841	Antagonistic period	0.48720	Basic coordination
2018	0.49868	Antagonistic period	0.52934	Basic coordination
2019	0.49836	Antagonistic period	0.55720	Basic coordination
2020	0.49881	Antagonistic period	0.59959	Basic coordination

Table 4. Coupling Coordination Processing Results

4. Countermeasures for Coordinated Development of Green Logistics and Regional Economy in Anhui Province

According to the above analysis results, in order to promote the coordinated development of green logistics and regional economy in Anhui Province, the following countermeasures are proposed:

4.1 Increase the Added Value of Logistics Per Mu and Promote the Development of Green Logistics

The average logistics added value per mu will be low from 2012 to 2020, which will have a certain impact on the coordinated development of the two. The development of logistics industry is inseparable from the construction of logistics infrastructure. Therefore, governments and enterprises at all levels must increase investment, optimize the construction of logistics infrastructure, meet logistics needs, and promote the rapid development of logistics industry. Optimize logistics processes and transportation efficiency. improve The e-commerce market has also brought new opportunities for logistics and transportation to a certain extent, and created a new platform for increasing the added value of logistics per mu. Logistics companies need to develop new logistics businesses and provide higher-end logistics services. For example, warehousing logistics not only provides basic warehousing services, but also combines value-added services such as supply chain finance and data analysis to achieve an increase in the added value of logistics per mu. Strengthen cooperation in promoting the international market, grasp the new trends in the international trade and logistics market, seize opportunities. continuously expand the international market, and increase the added value of logistics permu.

4.2 Strengthen the Construction of the Logistics Talent System to Ensure the Employment of Logistics Personnel

From 2012 to 2020, the labor productivity of the logistics industry has a small contribution to green logistics, and the labor quality of logistics employees should be improved in the future. The unemployment rate has a certain impact on the regional economic index system. It is necessary to ensure the employment of employees in the logistics industry and reduce the unemployment rate of the logistics industry, thereby promoting economic development. With the continuous advancement of national environmental protection policies, green logistics has become the focus of attention of all walks of life, and Anhui Province is also actively promoting the development of green logistics. Therefore, it is necessary to improve the construction of green logistics talent system as soon as possible to further promote the development of green logistics. Anhui Province should strengthen the setting of green logistics majors and the construction of teaching staff in higher education institutions. Green logistics development talents should have a professional theoretical foundation [13]. The Anhui Provincial Government can cooperate with enterprises to carry out vocational skills training, aiming at hot spots in the field of green logistics Issues and key technologies for training and guidance. At the same time, the government can issue relevant policies to continuously promote the technological innovation and development of green logistics, pay attention to the introduction of professionals and encourage and support green logistics innovation and entrepreneurship.

4.3 Reduce Carbon Emissions in the Logistics Industry and Achieve Green and Low-Carbon Development

The study found that the carbon emissions of the logistics industry have a greater impact on the development of green logistics, and it is necessary to reduce carbon emissions for promoting green logistics and sustainable economic development. In the process of transporting goods, vehicle exhaust emissions will produce a large amount of carbon dioxide [14]. Through the promotion of electric vehicles, the use of renewable energy such as solar energy, and the application of intelligent scheduling and other technical means, the carbon emissions of the logistics industry can be greatly reduced. To promote the "green" of logistics and implement green packaging design [14], logistics packaging can reduce carbon emissions from packaging design, packaging materials and other aspects. For example, reusable packaging, green packaging, etc. Use lower carbon emission means of transportation in all aspects of logistics, such as choosing green roads and developing fuel-saving technologies. Technological innovation is an important support for promoting the green and low-carbon development of the logistics industry. The development and application of emerging technologies such as artificial intelligence and the Internet of Things can promote the of logistics to be more development informatized, intelligent, and automated, thereby achieving the goal of low-carbon and intelligent logistics, and reducing energy consumption and carbon emissions in the logistics link.

5. Conclusion

Through the research on the coupling and coordinated development level of green logistics and regional economy in Anhui Province, this paper concludes that the coupling degree of green logistics and regional economy in Anhui Province is in an antagonistic period from 2012 to 2020, and the coordination degree fluctuates and rises. Generally speaking, it is in the basic coordination stage. There is still a lot of room for improvement in the future. The results put forward: increase the added value of logistics per mu, promote the development of green logistics, strengthen the construction of logistics talent system, ensure the employment of logistics personnel and reduce the carbon emissions of logistics industry, realize green and low-carbon development, and realize the coordinated development of green logistics and regional economy.

However, the index selection of green logistics and regional economy needs to be further improved. The study can also conduct time and space evolution analysis at the same time, and put forward better suggestions for the development path of green logistics and regional economy.

Acknowledgments

This paper is supported by 2023 Anhui Social and Science Innovation Development Research Project (NO.2023CX055); 2022 Anhui Social Science Innovation and Development Research Project (NO.2022CX062; NO.2022CX061); Suzhou University Doctoral Research Start-up Fund Project(2023BSK031). Anhui Province Higher Science Education Research Project (Philosophy Social Sciences) and (NO.2022AH040204)

References

- Zhu Fangyang, Lai Liangrong. Industrial Structure Upgrading, Technological Innovation and Green Logistics. Modern Management Science, 2022 (3): 40-50.
- [2] Jin Xin, Huang Fei. Measurement of Green Logistics Development Resilience and Analysis of Its Coupling Relationship--Taking the Yangtze River Economic Belt as an Example. Commercial Economics Research, 2023, No.865 (06): 73-77.
- [3] Cai Min. Research on Green Logistics Development in the Yangtze River Delta from the Perspective of Regional Economic Integration. Logistics Engineering and Management, 2022, 44 (07): 31-33.
- [4] Qi Meng. Research on the Coupled and Coordinated Development of Green Logistics and Regional Economy. Anhui Province: Anhui University of Science and Technology, 2021.
- [5] Xu Chaoyi, Li Lan. Research on the Coordinated Development of Green Logistics and Green Economy in the Yangtze River Economic Belt. East China Economic Management, 2023, 37 (07): 31-39.
- [6] Ma Yuping, Shuangjun. Research on the spatio-temporal evolution characteristics of the coupling coordination degree between digital trade and green logistics.

Business Economics Research, 2023, No.871 (12): 67-71.

- [7] Zhan Jing, Song Chaofang. The spatio-temporal evolution and coupling of logistics and economic growth in Hunan Province. Price Monthly, 2019, (02): 41-49.
- [8] Zhang Jianjun, Zhao Qilan, Liu Guiyan. Research on the Coupling and Interaction Mechanism between Regional Logistics Capability and Regional Economic Development. Practice and Understanding of Mathematics, 2019, 49 (12): 50-60.
- [9] Wang Kaili, Yang Kang. Research on the Coupled and Coordinated Development of Logistics and Economy in Anhui Province. Logistics Technology, 2020, 39 (10): 99-102.
- [10]Luo Jian, He Chuanlei, Zhao Lei, Xue Feng. Research on the coupling degree of regional logistics and economy based on cloud model. Journal of Transportation Engineering and Information, 2020, 18 (01): 160-167.
- [11]Zhang Weiwei. Analysis of the coordinated development of regional logistics and tourism economy in Jiangsu Province under the concept of green development. China Logistics and Procurement, 2023 (05): 58-60.
- [12]Shi Yunqing, Yu Penglin. Research on the coordinated development of regional logistics and tourism economy in Fujian Province under the background of green development. Commercial Economy, 2022 (03): 64-65 173.
- [13]Chen Zhihong. Exploring the development path of green logistics in the new stage. China Logistics and Procurement, 2023 (04): 68-69.
- [14]Xie Sixin, Xue Bingxin, Fan Shuqi. Research on the green development path and strategy of logistics enterprises in the Yangtze River Economic Belt under the digital economy. Logistics Technology, 2023, 46 (09): 104-106.