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Research on the Coupling and Coordination between Industrial Structure and Logistics Competitiveness

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ABSTRACT. *On the basis of discussing the interaction mechanism of industrial structure optimization and logistics competitiveness, the coupling and coordination degree model is constructed to analyze the coupling coordination degree and spatio-temporal differentiation characteristics of the "industrial structure -logistics competitiveness" system.The results show that: From the perspective of time series evolution, the system is in a high level of coupling stage for a long time, and the coupling interaction effect between industrial structure adjustment and logistics development is obvious. The overall coordination level of the system is not high, showing the trend of evolution from the stage of being on the verge of maladjustment to the highly coordinated stage. From the perspective of spatial differentiation, the coupling coordination degree of the systems is characterized by clustering. There are some spatial differences in the coupling coordination degree of the systems in different provinces in China. At present, most of the two systems in China are in a barely coordinated type. In the key period we should pay more attention to improve the coupling and coordination degree of the system.*

KEYWORDS: *industrial structure, logistics competitiveness, coupling and coordination degree, spatio-temporal differentiation.*

1. Introduction

The upgrading of industrial structure is an inevitable requirement of economic development, and the logistics industry is an important aspect of economic adjustment, there is a close relationship between them. The logistics industry started later in China, because of its own characteristics, there are many structural contradictions like "many, small, scattered and weak".In recent years, the infrastructure, operation efficiency, operation level and technological innovation of China's logistics industry have been greatly improved. The logistics industry has become the "third profit growth point", but there is a big gap compared with developed countries, and the comprehensive competitiveness of logistics industry needs to be further improved.The optimization and upgrading of industrial structure has become one of the important engines driving economic growth. China's economy steps into the "new normal" phase, the development of modern economy is not only reflected in the sustained growth of economic aggregate, but also in the transformation and upgrading of industrial structure, which requires China to speed up the pace of industrial structure adjustment [1] .

The adjustment and optimization of China's industrial structure needs more competitive logistics services. Therefore, it is necessary to analyze the relationship between the optimization and adjustment of China's industrial structure and the promotion of the comprehensive competitiveness of logistics. By deepening the understanding of the coupling and coordination of the "industrial structure-logistics competitiveness" system, we hope to improve logistics competitiveness under the premise of the optimization and adjustment of the industrial structure, and give full play to the role of logistics industry in promoting the optimization of industrial structure. Finally, we hope to promote the sustained and healthy development of China's economy.

On the research of relationship between industrial structure and logistics development, many scholars in the world have carried out relatively rich research results. According to the new economic geography theory, transportation is an important factor affecting the spatial agglomeration of enterprises. The larger the regional market capacity is, the more favorable it is to attract enterprises to gather in the region.Krugman (1991) pointed out that the development of transportation can effectively serve the social development, produce industrial correlation effect, and then promote the optimization and upgrading of industrial structure and economic development [2]. Pires (2006) discussed that the development of logistics can drive industrial agglomeration, reduce transportation costs and generate economies of scale [3]. Japan Transportation Policy Research Association has conducted relevant research on the impact of industrial structure changes on logistics system and transportation network planning In fact, there is a close interaction between logistics development and industrial structure optimization. On the one hand, the optimization of industrial structure promotes the comprehensive competitiveness of logistics.Song Sasa (2017) used panel data from 2004 to 2013 in China to study the impact of industrial structure upgrading on logistics industry agglomeration[4].On the other hand, the promotion of comprehensive competitiveness of logistics drives the optimization and adjustment of industrial structure. Luan Mengmeng (2016) studied the impact of logistics industry agglomeration on industrial structure by gradual regression, and reached the conclusion that logistics industry agglomeration can promote the upgrading of industrial structure [5].

To sum up, the relevant literatures have shown that there is a close relationship between the industrial structure and the comprehensive competitiveness of logistics. Scholars have carried out a relatively rich research on the relationship between the industrial structure and the development of logistics, But fewer literature quantitative research from the perspective of coupling and coordination, and seen them as interacting systems.Therefore, this paper uses the coupling coordination degree model to investigate the relationship between the optimization of industrial structure and the comprehensive competitiveness of logistics, and at the same time, quantitatively analyzes the coupling coordination degree and time-space

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differentiation characteristics of the "industrial structure -Logistics competitiveness" system.

2. Interaction Mechanism

The optimization of industrial structure and the promotion of logistics competitiveness are the symbiotics of mutual integration and common development. There is no optimal industrial structure, only when the industrial structure and logistics competitiveness are mutually adapted, they reach the optimal state. From the perspective of the relationship between the "industrial structure-logistics competitiveness" system, on the one hand, the logistics industry itself is a part of the tertiary industry, and the improvement of logistics competitiveness can increase the proportion of the tertiary industry, and then promote the development of the secondary industry, further promote the optimization of industrial structure. The improvement of logistics competitiveness promotes the continuous change of labor division and market scale, and further promotes economic development [11], thereby improving industrial quality and promoting industrial structure optimization. On the other hand, the upgrading process of industrial structure is often accompanied by the industrial adjustment and optimization. The evolution of industrial structure affects the way of logistics services[6]. A certain industrial structure will have different logistics demands. Industrial structure upgrading can reduce logistics costs and improve the overall competitiveness of the entire logistics industry through rational allocation of essential resources.The interaction mechanism of "industrial structure-logistics competitiveness" system is shown in Figure 1.

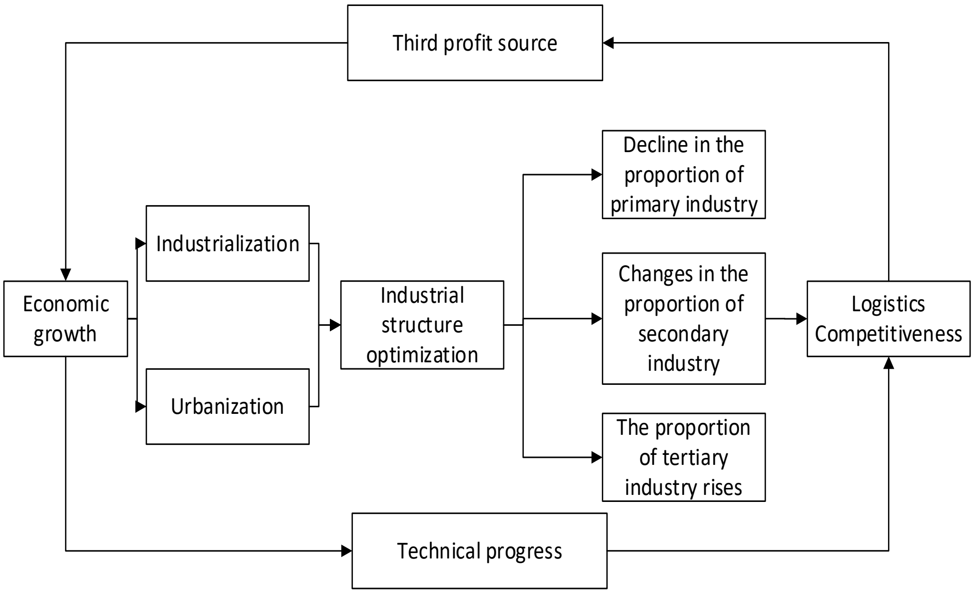

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Figure. 1 Interaction mechanism of "industrial structure-logistics competitiveness" system

The process of optimizing and upgrading of industrial structure is also the process of economic development, reflecting the quality and efficiency of economic development. Logistics industry is an important part of the tertiary industry, and also an important support of social economy. It can effectively reduce the cost of economic operation, improve the efficiency of operation and promote the upgrading of industrial structure. Different levels of industrial structure have different demands on logistics, and different stages of logistics development need to adapt to the industrial structure it serves.

3. Methodology

3.1 Measurement of industrial structure optimization level

Industrial structure is the production technology economic connection and quantity proportion relationship among industries of national economy, which happens in the process of social reproduction. Referring to the research of previous scholars [7], this paper defines that the industrial structure optimization includes two aspects: the rationalization of industrial structure and the upgrading of industrial structure.

In essence, rationalization of industrial structure is a coordination measure among industry. It refers to adjusting the uncoordinated industrial structure according to the proportion of the objective economic technology of each industry, under the condition of existing technology and resources. The process of industrial structure rationalization can promote the effective use of resources and produce good economic benefits.

This paper further improves the Theil index of Gan Chunhui (2011), and uses the reciprocal of the Theil index to measure the rationalization of industrial structure[8].

$$TH = 1/TL = 1\bigg/\sum_{i=1}^{n}\left(\frac{Y_i}{Y}\right)\ln\left(\frac{Y_i}{L_i}\bigg/\frac{Y}{L}\right) \tag{1}$$

In the formula(1), TH represents the index of industrial structure rationalization, $i = 1,2,3$, represents the first industry, the second industry and the third industry respectively; Y represents the output value; Y_i represents the output value of i industry; L represents the number of employees,. L_i represents the employees number of i industry; The higher value of the TH is, the higher rationalization level of industrial structure is.

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In essence, the upgrading of industrial structure is the promotion of industrial structure. Which refers to the relationship among industries develops from low-level stage to the high-level stage through innovation.

This paper references the index of Gan Chunhui (2011), uses the ratio of the output value between tertiary industry and secondary industry. If the index value rises, it indicates that the industrial structure is developing towards to service the economic.

$$TS = {Y_t}/{Y_s} \tag{2}$$

In the formula (2), TS represents the index of industrial structure upgrading, Y_s represents the output value of the second industry , Y_t represents the output value of the third industry. The higher value of the TS is, the higher upgrading level of industrial structure is.

3.2 Measurement of logistics competitiveness

Logistics competitiveness is a complex system. In order to evaluate logistics competitiveness comprehensively, accurately and objectively, we must establish evaluation index system from two dimensions of competitive strength and competitive potential, and follow the principles of scientific, comparability and feasibility.Among them, the competitive strength includes three aspects[9]: infrastructure, logistics scale and logistics efficiency. The competitive potential includes two aspects: economic development level and information level.

The evaluation of logistics competitiveness belongs to multi-objective comprehensive evaluation. According to the characteristics of the logistics industry, the evaluation index system of the logistics competitiveness constructed in this paper is shown in Table 1.Entropy weight-TOPSIS method is selected to analyze and evaluate logistics competitiveness[10].

Table 1 Evaluation index system of Logistics Competitiveness

	First level index	secondary level index
Logistics competitive strength	infrastructure	Transportation network density
		Civil truck ownership
	logistics scale	Freight volume
		Added value of logistics industry
		Logistics practitioners
	logistics efficiency	Added value of per capita logistics industry
		Per capita freight volume
Logistics competitive	economic development level	Per GDP
		Total import and export amount

potential		Transportation fixed assets investment
	information level	Internet penetration
		Mobile phone penetration
		Fixed broadband penetration

3.3 Coupling and coordination model

The concept of coupling comes from physics, which refers to the process that two or more systems interact with each other.As two systems of mutual influence and interaction, the "industrial structure-logistics competitiveness" system has a certain degree of interdependence, coordination and promotion between them at a certain time under the joint action of many factors.

Referring to the definition of coupling, this paper calls the dynamic relationship between the system of "industrial structure-logistics competitiveness" as coupling. Based on the data of industrial structure optimization and logistics competitiveness evaluation, the coupling coordination model is constructed as follows:

The establishment of the coupling model should first establish the efficiency function. Set X_{ij} as the j index of the i sub-system, $i = 1$ represents the industrial structure sub-system, $i = 2$ represents the logistics competitiveness sub-system. α_{ij} and β_{ij} are the maximum and minimum values of each sub-system. The calculation formula of efficiency coefficient x_{ij} is:

$$x_{ij} = \begin{cases} \left(X_{ij} - \beta_{ij}\right) / \left(\alpha_{ij} - \beta_{ij}\right), & x_{ij} \text{has positive effect} \\ \left(\alpha_{ij} - X_{ij}\right) / \left(\alpha_{ij} - \beta_{ij}\right), & x_{ij} \text{has negative effect} \end{cases} \tag{3}$$

In the formula (3), x_{ij} is the efficiency contribution value of variables X_{ij} to the system, reflecting the satisfaction degree of indicators to achieve the goal, $x_{ij} \in [0,1]$. The comprehensive contribution of each index in the subsystem to the order degree of the system is the comprehensive order parameter, which is generally realized by the method of geometric average and linear weighting. The expression of the comprehensive order parameter is as follows:

$$U_i = \sum_{j=1}^{n} \lambda_{ij} x_{ij}, \sum_{j=1}^{n} \lambda_{ij} = 1, i = 1, 2 \tag{4}$$

In the formula (4), λ_{ij} is the weight of the j index in the i sub-system. In this paper, entropy weight method is used to set the weight of order parameter.

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Based on the coupling coordination model in physics, the function expression of the system "industrial structure-logistics competitiveness" is obtained as follows:

$$C = 2\sqrt{(U_1 \times U_2)} \Big/ (U_1 + U_2) \tag{5}$$

When the characteristics of industrial structure and competitiveness of logistics feedback and adjust each other, showing coordinated and orderly development, the coupling degree of them is higher, otherwise, it is lower.

Table 2 Criteria for coupling stage

coupling stage	Low level coupling stage	Stage of confrontation	Running in stage	High level coupling stage
coupling degree	（0，0.3］	（0.3，0.5］	（0.5，0.8］	（0.8，1］

(2) coupling and coordination model

Through the quantitative measurement of the coupling coordination degree of the "industrial structure-logistics competitiveness" system, the interaction and dynamic change of the system can be described.

However, the coupling degree model is mainly used to represent the strength characteristics of the interaction between the internal elements of the system, which can not represent its coordinated development level.

In different levels of industrial structure optimization, there is the best level of logistics competitiveness coupled with it. Therefore, it is difficult to fully reflect the overall effect and coordination effect between them only based on the coupling degree. Coupling coordination degree is a combination of coupling degree and coordinated development level, which can reflect the coordination degree of "industrial structure-logistics competitiveness" system under different coupling levels.

The calculation formula of the coupling coordination degree model constructed in this paper is as follows:

$$D = \sqrt{C \times T}$$
$$T = aU_1 + bU_2 \tag{6}$$

In the formula(6), D is the coupling and coordination degree, T is the comprehensive coordination index of the two systems, which reflects the overall development level of "industrial structure -logistics competitiveness" system. a and b are the parameters to be evaluated, which respectively represent the contribution of industrial structure and Logistics competitiveness to the coupling coordination degree.In view of that both sub-systems are equally important, we take $a = b = 0.5$ in the calculation of coordination degree in this paper.

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Table 3 Criteria for coupling and coordination stage

coupling and coordination stage	On the brink of imbalance	Barely coordinated	Moderate coordination	Highly coordinated
coupling and coordination degree	（0，0.3］	（0.3，0.5］	（0.5，0.8］	（0.8，1］

4. Empirical analysis

4.1 Research area and data source

This paper takes 31 provinces of China as an example, and makes an empirical study on the coupling and coordination of "industrial structure-logistics competitiveness" system.The data used are from 2002-2017 China Statistical Yearbook, China population and Employment Statistical Yearbook, national economic and social development statistical bulletin, China's information and industrialization integration development level evaluation report.Some missing data were supplemented by interpolation.

Because China has no unified statistical caliber for logistics industry at this stage, the output value of transportation, storage and post accounts for more than 80% of the output value of logistics industry, which can roughly represent the development level of logistics industry. Therefore, in the calculation of the competitiveness of logistics, this paper uses the development of transportation, storage and post industry to replace the development of logistics industry.

4.2 Time series evolution analysis

According to the calculation method of coupling coordination degree, the comprehensive order parameters, coupling degree and coupling coordination degree of China's "industrial structure-logistics competitiveness" system in 2002-2016 are calculated. The results are shown in Table 4.

Table 4 Coupling degree and coupling coordination degree of China's "industrial structure -logistics competitiveness" system in 2002-2016

time	coupling degree	coupling stage	coupling and coordination degree	coupling and coordination stage
2001	0.6532	Running in stage	0.1640	On the brink of imbalance
2002	0.7912	Running in stage	0.2140	On the brink of imbalance
2003	0.9902	High level	0.2194	On the brink of

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		coupling stage		imbalance
2004	0.9405	High level coupling stage	0.2953	On the brink of imbalance
2005	0.8209	High level coupling stage	0.3141	Barely coordinated
2006	0.8049	High level coupling stage	0.3542	Barely coordinated
2007	0.9095	High level coupling stage	0.4669	Barely coordinated
2008	0.9017	High level coupling stage	0.5047	Moderate coordination
2009	0.9582	High level coupling stage	0.5790	Moderate coordination
2010	0.9272	High level coupling stage	0.6166	Moderate coordination
2011	0.9260	High level coupling stage	0.6782	Moderate coordination
2012	0.9542	High level coupling stage	0.7534	Moderate coordination
2013	0.9862	High level coupling stage	0.8202	Highly coordinated
2014	0.9929	High level coupling stage	0.8890	Highly coordinated
2015	0.9999	High level coupling stage	0.9533	Highly coordinated
2016	0.9998	High level coupling stage	0.9733	Highly coordinated

From the perspective of coupling degree, "Industrial structure-logistics competitiveness" system has a high coupling degree, with strong interaction between the two systems and obvious coupling interaction effect. The coupling degree with the highest value of 0.9999 in 2015 and the lowest value of 0.6532 in 2001. From 2007 to 2016, the coupling degree basically remains above 0.9.

From the perspective of coupling and coordination degree, "Industrial structure-logistics competitiveness" system is steadily improving, with the lowest value of 0.1640 in 2001 and the highest value of 0.9733 in 2016. From the near maladjustment type in 2001 to the reluctant coordination type in 2005, to the moderate coordination type in 2008, and to the high coordination type in 2013. The overall trend of coupling coordination degree is toward a higher level, and it gradually evolves from the stage of near maladjustment to the stage of high coordination.

4.3 Spatial differentiation analysis

The level of economic development in different provinces of China is not balanced, and there is a big difference between industrial structure and logistics competitiveness. The overall analysis of the coupling coordination degree of "industrial structure -logistics competitiveness" system may not be applicable to all

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provinces, and the practical significance of the study will be greatly discounted. It is necessary to study the coupling coordination degree of "industrial structure-logistics competitiveness" system from the provincial level.

Using the formula of coupling coordination degree, the coupling coordination degree of "industrial structure-logistics competitiveness" system in 2001, 2007 and 2016 was calculated. The results are shown in Table 5.

Table 5 Coupling and coordination degree in China's provinces in 2001, 2007 and 2016

province	2001	2007	2016
Beijing	0.5741	0.6654	0.6497
Tianjing	0.6129	0.5253	0.4928
Hebei	0.4439	0.4647	0.4795
Shanxi	0.3338	0.2526	0.4011
Inner Mongoria	0.3897	0.3119	0.2951
Liaoning	0.4696	0.4199	0.5488
Jilin	0.3407	0.3180	0.2664
Heilongjiang	0.2434	0.2987	0.3897
Shanghai	0.7189	0.7904	0.8166
Jiangsu	0.4604	0.5527	0.5902
Zhejiang	0.4708	0.5538	0.5819
Anhui	0.3669	0.4156	0.4057
Fujian	0.4710	0.4678	0.5031
Jiangxi	0.4331	0.3227	0.3748
Shandong	0.4880	0.4459	0.4876
Henan	0.3601	0.3101	0.3825
Hubei	0.3540	0.4386	0.3748
Hunan	0.4357	0.4095	0.3856
Guangdong	0.5533	0.5226	0.6086
Guangxi	0.4079	0.3721	0.2610
Hainan	0.3962	0.3333	0.3778
Chongqing	0.3299	0.3608	0.3634
Sichuan	0.4185	0.3981	0.4109
Guizhou	0.3020	0.3034	0.3020
Yunnan	0.3033	0.2924	0.2684
Tibet	0.0477	0.0760	0.1787
Shaanxi	0.3640	0.2602	0.2083
Gansu	0.2851	0.2821	0.3030
Qinghai	0.2083	0.1518	0.1512
Ningxia	0.2291	0.1942	0.1872
Xinjiang	0.3273	0.2688	0.3172

The results show that there are significant spatial differences in the degree of coupling coordination between the "industrial structure-logistics competitiveness" systems in different provinces of China. At present, the "industrial structure - logistics Competitiveness" system of most provinces in China is in a barely coordinated type.

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5. Conclusion

From the perspective of coupling and coordination, this paper takes the industrial structure and logistics competitiveness of 31 provinces in China as the research object, and analyzes the temporal evolution trend and spatial differentiation state of the coupling and coordination degree of "industrial structure-logistics competitiveness" system. The research results indicate that:

First, from the perspective of temporal evolution, the "industrial structure-logistics competitiveness" system has been in a high-level coupling stage for a long time. But their coordination degree is not high, and showing a trend of development from the stage of near maladjustment to the stage of high coordination.

Secondly, from the perspective of spatial differentiation, there are certain spatial differences in the coupling and coordination degree of "industrial structure-logistics competitiveness" system. As a whole, the coupling and coordination degree in different provinces in China is quite different, and the coordination level is unbalanced. The "industrial structure-logistics competitiveness" system of most provinces in China is in a barely coordinated type.

At present, it is a critical period for China's industrial restructuring and logistics transformation and upgrading, and more attention should be paid to improving the coupling and coordination of them. According to the above conclusions, China should actively promote the adjustment and optimization of the industrial structure in each province, moderately increase the proportion of the tertiary industry, strengthen technological innovation, and promote the improvement of logistics competitiveness through industrial structure upgrading. At the same time, we should give full consideration to the difference of logistics resource endowment conditions of each province in China, and choose the industrial structure suitable for the development of local logistics, in order to maximize the role of industrial structure in promoting the development of logistics industry, and create good conditions for the realization of high coupling and coordination between them.

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