Analysis on the Coupling and Coordination Degree of Transportation, Industrial Structure and Regional Economy in Guizhou

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Abstract. In order to clarify the coupling and coordination relationship and spatiotemporal evolution pattern of transportation, industrial structure, and regional economy, based on the construction of a comprehensive evaluation index system for transportation, industrial structure, and regional economy, the entropy weight method, coupling degree, and coupling coordination degree models are used to analyze the spatiotemporal characteristics of the coupling and coordination development degree of transportation, industrial structure, and regional economy in Guizhou Province. The results indicate that the coordinated development of transportation, industrial structure, and regional economy in Guizhou Province is relatively good. There has been no situation where one aspect of development is too slow and slows down the overall development. Currently, the regional economy is gradually in a dominant position, and the industrial system has become lagging behind. The transportation system is slightly slower than the regional economic system, but it is also in a relatively coordinated development state. The results of this study aim to provide theoretical basis for the formulation of policies related to transportation and economic development in Guizhou.

Keywords: Transportation · Industrial structure · Regional economy · Coupling coordination · Guizhou

1 Introduction

Transportation, industrial structure, and regional economy interact and interact with each other. The construction and development of transportation will promote economic growth, and economic growth will also generate greater demand and supply capacity for transportation infrastructure investment. At the same time, the development of transportation and economy will have an impact on industrial structure, and there is an interactive coupling relationship and interaction effect among these three factors [1, 2]. However, in different countries and regions with different stages of economic development and investment patterns, there are significant differences in the degree of coupling and coordination among the three [3–6]. Guizhou Province is located in the southwest of China. The coupling and coordinated development of transportation, industrial structure, and regional economy in Guizhou Province is directly related to the sustainable

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economic and social development of Guizhou Province, southwestern provinces, and even the whole country. The study of the coupling and coordinated development relationship among these three is of practical significance. Currently, there are many studies on the interaction between transportation, industrial structure, and regional economy, and it is generally believed that transportation can promote the transformation and upgrading of industrial structure and regional economic development [7, 8]. At the same time, industrial agglomeration can also promote regional economic growth [9, 10]. However, existing research mainly focuses on the relationship between transportation infrastructure, industrial agglomeration, and regional economic growth, lacking systematic consideration of the three within a unified framework. This article considers transportation, industrial structure, and regional economy in a system, analyzes their interrelationships, and takes Guizhou Province as an example to analyze the current development of these three factors, in order to provide relevant theoretical support for the development of Guizhou's transportation economy.

2 A Coupled Coordination Model of Transportation, Industrial Structure, and Regional Economy

2.1 Construction of Evaluation Index System

Based on a comprehensive analysis of the structure and functions of the three subsystems of transportation, industrial structure, and regional economy, combined with the regional characteristics of Guizhou Province, and following the principles of comprehensiveness, comprehensiveness, hierarchy, systematicity, and operability, a comprehensive evaluation index system for transportation, industrial structure, and regional economy is constructed. The comprehensive evaluation index system for transportation, industrial structure, and regional economy is shown in Table 1.

2.2 Preprocessing of Indicator Data

Standardization and Isotropic Processing of Data

In order to eliminate the order of magnitude differences between different indicator values, this article uses the max min power function to standardize and homogenize data that has undergone indicator form transformation and price fluctuations removal, as well as data that does not require the aforementioned two steps of preprocessing.

$$Positive: \quad x'_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j}, \ i = 1, 2, \cdots, 10 \tag{1}$$

$$Negative: \quad x'_{ij} = \frac{\max x_j - x_{ij}}{\max x_j - \min x_j}, \quad i = 1, 2, \cdots, 10 \tag{2}$$

where, x'_{ij} is the standardized value of the jth evaluation index of the i-th sample, with a standardized value range of [0,1]; x_{ij} is the original value of the jth evaluation indicator for the i-th sample; $\min x_j$ the minimum value among all samples for the jth evaluation

Table 1. A Comprehensive Evaluation Index System for Transportation, Industrial Structure, and Regional Economy

System	Primary indicators	Secondary indicators	Effect	Symbol
System of transportation	Transportation level	Railway passenger volume	Positive	x1
		Railway freight volume	Positive	x2
		Highway passenger volume	Positive	x3
		Road freight volume	Positive	x4
		Waterway passenger volume	Positive	x5
		Waterway freight volume	Positive	x6
	Transportation infrastructure construction	Railway operating mileage	Positive	x7
		Highway operating mileage	Positive	x8
		Mileage of inland waterways	Positive	x9
	Transportation capacity	Civil aviation passenger throughput	Positive	x10
Industrial restructuring	Industrial structure	Primary industry output/GDP	Negative	y1
		Secondary industry output/GDP	Positive	y2
		Tertiary industry output/GDP	Positive	y3
Regional economies	Economic scale	GDP	Positive	z1
	Economic activity	Total retail sales of goods	Positive	z2

(*continued*)

Table 1. (*continued*)

System	Primary indicators	Secondary indicators	Effect	Symbol
		Total fixed assets investment	Positive	z3
		Household Consumption Expenditure	Positive	z4

indicator; max x_j the maximum value among all samples for the jth evaluation indicator. The above formulas are also applicable to the standardization of raw data of industrial structure and regional economy.

Determination of Indicator Weight

The main steps to calculate the weights of each indicator using entropy weights are as follows.

(a) Calculate the proportion of the i-th indicator in the transportation subsystem to the t-th year indicator value $\hat{x}_i(t)$

$$\hat{x}_i(t) = x_i'(t) / \sum_{t=1991}^{2020} x_i'(t) \ \left(0 \le \hat{x}_i(t) \le 1, i = 1, 2, ..., 10\right) \tag{3}$$

(b) Calculate the information entropy value of the i-th indicator, as shown in Eq. (4).

$$e_i = -K \sum_{t=1991}^{2020} \hat{x}_i(t) \ln \hat{x}_i(t), \quad K = \frac{1}{\ln 30} \tag{4}$$

(c) The information entropy value of a certain indicator depends on the difference between its information entropy e_i and 1, and its value directly affects the size of the weight. d_i is entropy redundancy for the i-th indicator.

$$d_i = 1 - e_i \ (i = 1, 2, ..., 7) \tag{5}$$

(d) The formula for calculating the weight coefficient of the i-th indicator is as follows:

$$\omega_i = d_i / \sum_{i=1}^{10} d_i \tag{6}$$

2.3 Calculation of Order Parameters

Use the weighted arithmetic mean method to calculate the comprehensive evaluation indicators of each of the three subsystems, as shown in model (7).

$$F\left(x'\right) = \sum_{i=1}^{10} \omega_{1i} x_i'; \ G\left(y'\right) = \sum_{j=1}^{4} \omega_{2j} y_j'; \quad H\left(z'\right) = \sum_{k=1}^{3} \omega_{3k} z_k' \tag{7}$$

where, $F(x')$, $G(y')$ and $H(z')$ represent comprehensive evaluation indicators for transportation, industrial structure, and regional economic subsystems, respectively.

2.4 Coupled Model

Combining the concept of coefficient of variation in statistics and drawing on the concept of capacity coupling and capacity coupling coefficient model in physics, a coupling measurement formula between multiple systems with correlation relationships is constructed, as shown in Eq. (8).

$$C_3 = \left[\frac{3\left(F\left(x'\right)G\left(y'\right) + F\left(x'\right)H\left(z'\right) + G\left(y'\right)H\left(z'\right)\right)}{(F(x') + G(y') + H(z'))^2} \right]^{1/3} \tag{8}$$

When C_3 approaches 1, it indicates that these three subsystems have achieved a good coupling effect. The inputs and outputs of the transportation, industrial structure, and regional economy subsystems cooperate and promote each other.

2.5 Coupling Coordination Model

In order to further reflect the coordination degree of transportation, industrial structure, and regional economic interaction coupling, a coupling coordination degree model has been introduced, and its coupling coordination scheduling can effectively evaluate the coordination degree of the interaction coupling of the three subsystems.

$$\begin{cases} T = \alpha \cdot F\left(x'\right) + \beta \cdot G\left(y'\right) + \gamma \cdot H\left(z'\right) \\ U = \sqrt{T \times C_3} \end{cases} \tag{9}$$

Among them, T is the comprehensive evaluation index value of the coupling system constructed by the three subsystems of transportation, industrial structure, and regional economy. U represents the coupling co scheduling of the three subsystems, which not only reflects the degree of coupling between the three subsystems, but also reflects the comprehensive development level of the coupling system.

3 Coupling and Coordination Analysis of Transportation, Industrial Structure, and Regional Economy in Guizhou Province

3.1 Coupling Analysis

The data in this paper are from China Statistical Yearbook and Guizhou Statistical Yearbook from 1991 to 2020. According to Eqs. (1) to (8), the numerical sequence of comprehensive evaluation indicators for each of the three subsystems in Guizhou Province, namely the sequence of order parameters, can be obtained, as shown in Fig. 1. If there is $F\left(x'\right) > G\left(y'\right) > H\left(z'\right)$, it is called a coupling type dominated by the transportation industry and lagging industrial structure; If there is $F\left(x'\right) = G\left(y'\right) > H\left(z'\right)$, this is called the coupling type of lagging industrial structure; If there is $F\left(x'\right) = G\left(y'\right) = H\left(z'\right)$, it is called a balanced coupling type.

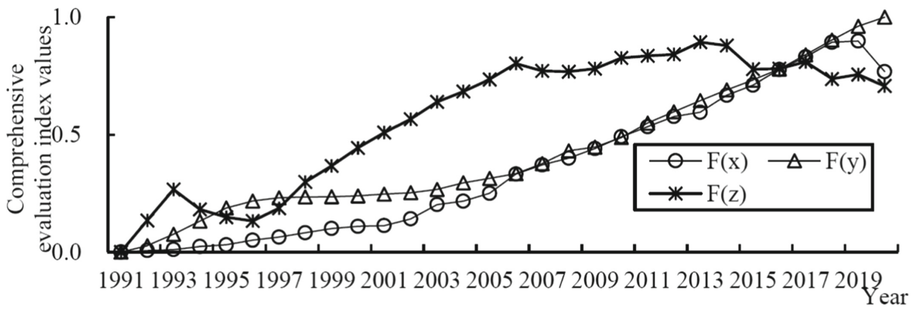

Fig. 1. Numerical trend chart of comprehensive evaluation indicators for three subsystems

It can be seen from the Fig. 1 that the overall development trend of the transportation system and regional economic system is increasing year by year, which indicates that with the construction of transport infrastructure and the increase of passenger and freight traffic, the transportation system of Guizhou is gradually improving. The regional economic system of Guizhou has also grown year by year with the increase of investment scale, GDP, and consumption level. The industrial structure of Guizhou has changed rapidly in the early stage. Due to the large transfer of the Primary sector of the economy to the second and Tertiary sector of the economy, the industrial structure of Guizhou has changed very fast in the early stage. However, after reaching a certain extent, the industrial transformation has encountered bottlenecks, and the power of industrial transformation is insufficient, showing a trend of steady stagnation, or even slow decline.

3.2 Coupling Coordination Analysis

According to Eq. (9), the coupling coordination of the three subsystems of transportation, industrial structure, and regional economy in Guizhou Province is obtained through MATLAB programming. The specific content is shown in Fig. 2.

Fig 2 reflects the coupling and co scheduling changes of transportation, industrial structure, and regional economy systems. From the figure, it can be seen that with the development of transportation, economy, and industry in Guizhou, these three subsystems have evolved from moderate imbalance at the beginning to high-quality coordination now. At present, the coupling coordination degree of the three has reached 0.907, and the coordinated development of the three is good. There has been no situation where a certain aspect of development is too slow and slows down the overall development.

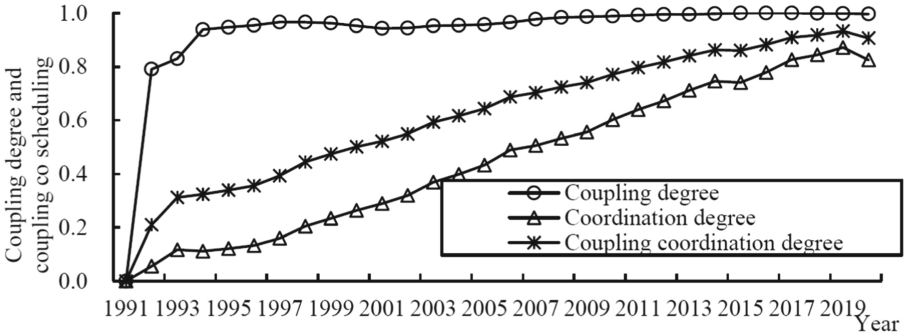

Fig. 2. Changes in coupling degree, coordination degree, and coupling coordination degree

4 Conclusion

The coupling degree and coupling co scheduling among the three subsystems of transportation, industrial structure, and regional economy were analyzed through a coupling model. Among them, the coupling degree reflects the strength of the interaction between the coupling subsystems, while the coupling co scheduling reflects the degree of coordinated development of the entire coupling system. Through model analysis, it was found that the interaction intensity of the three subsystems of transportation, industrial structure, and regional economy is extremely strong, and their coordinated development is good. There is no situation where one aspect of development is too slow and slows down the overall development. Currently, the regional economy is gradually in a dominant position, and the industrial system has become lagging behind. The transportation system is slightly slower than the regional economic system, but it is also in a relatively coordinated development state.

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