

## Article

# A Study on the Coupling and Coordination between Logistics Industry and Economy in the Background of High-Quality Development

Bo-Rui Yan \*, Qian-Li Dong, Qian Li , Fahim UI Amin and Jia-Ni Wu

School of Economics and Management, Chang'an University, Xi'an 710064, China; dongql@chd.edu.cn (Q.-L.D.); laplace0911@163.com (Q.L.); fahimulamin@gmail.com (F.U.A.); jianiwu@chd.edu.cn (J.-N.W.)

\* Correspondence: moran624@163.com

**Abstract:** China's economy has stepped up from the high-speed growth stage to the high-quality development stage. With the high-quality development of the economy, the logistics industry is bound to move towards high-quality development. By establishing the index system of high-quality economic development and logistics, this work has measured their high-quality development level and analyzed their coupling coordination degree by using the coupling coordination model. The results show that there are great regional differences in high-quality economic development, high-quality logistics development and their coupling coordination degree in China. In the areas with high-quality economic development, the logistics industry is not necessarily high quality, and the coupling coordination degree between the logistics industry and high-quality economic development is generally not high. The main reason for this is that the coordination between the logistics industry and high-quality economic development is poor. While vigorously improving the high-quality level of the logistics industry, it should strengthen the high-quality connection between the logistics industry and the economy, so as to form a situation of mutual promotion and common development.

**Keywords:** logistics industry; high-quality economy; coupling coordination degree; super-SBM model; Ma index



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## 1. Introduction

After more than 40 years of medium and high-speed growth, China's economy has achieved remarkable results, and the level of industrial and agricultural productivity has been greatly improved. However, China's early economic development has mostly relied on the drive of traditional factors and investment pull, with extensive development as the main factor. In 2015, the Fifth Plenum of the 18th Central Committee of the Communist Party of China clearly proposed the "Five" development concepts of innovation, coordination, green, openness and sharing. In 2017, general secretary Xi Jinping clearly pointed out in the 19th National Congress of the Communist Party of China: "China's economy has shifted from high-speed growth stage to high-quality development stage". The outbreak and spread of COVID-19 across the world in 2020 aggravated the adjustment of the world economic structure and intensified international competition. To speed up the construction of a double circulation pattern, the key is to deepen the reform of China's current market scale and production system, optimize the market allocation, open up all links of the supply chain, and promote the optimization, upgrading and docking of industries.

The linear economic model of the industrial revolution has brought negative impact on the environment and resources, and the concept of high-quality economic development includes the concept of sustainable economic development and improving environmental pressure, although the current research on high-quality development is dominated by Chinese scholars, it coincides with the concept of global sustainable development. Sustainability has emerged as an important term in the logistics industry, hence pressurizing

the entire sector to reconsider their existing practices to be more environmentally, socially and economically responsible [1]. In the context of logistics, the understanding of sustainability is limited [2], and the concept of high-quality development further improves the connotation of sustainability of the logistics industry. Industry 4.0 has become one of the main forces to build a social, economic and technological environment after 2010 [3]. Some scholars have proposed Logistics 4.0 [4], which also shows that the logistics industry will put more emphasis on all-round management and more efficient and comprehensive services. With the requirements of China's high-quality economic development, the logistics industry will move towards high-quality development, and the service of the logistics industry makes it impossible to achieve high-quality development in isolation, which involves all enterprises upstream and downstream of the supply chain, macro-regional and even international logistics activities, as well as fields such as industry, agriculture, social production and consumption. How to guide the industrial upgrading and development to meet the requirements of high-quality development through the coupling and coordinated development of the logistics industry and economy and the linkage between the logistics industry and other industries is a problem worthy of consideration.

Starting with the connotation of high-quality development, this paper establishes the measurement index system of the high-quality development of the logistics industry and economy and the measurement model of their coupling and coordinated development. The remainder of it is organized as follows. The second section reviews the relevant research in the literature, the third section introduces the variable selection and solutions, the fourth section introduces and discusses the results, and the fifth part is the conclusion and puts forward the future research directions.

## 2. Literature Review

### 2.1. High-Quality Development of Economy

The research group of the provincial and ministerial level cadre training class of the Central Party School believed that the quality of economic development in a broad sense is the result of the increase in a country's or a region's economic aggregate, the improvement of economic efficiency, the optimization of economic structure, the continuity of economic development and the sharing of economic development achievements. In a narrow sense, it is the degree to which products and services meet the needs of residents. This view represents the opinions of other scholars and is the consensus of academic circles on the quality of economic development. At present, it is generally accepted that high-quality economic development should include innovation, coordination, openness, green and sharing. This view can more comprehensively describe the connotation of high-quality economic development and provide more comprehensive guidance for the measurement of high-quality economic development level.

On the measurement of high-quality economic development level, from the perspective of spatial scope, it can be divided into four categories. One is to measure and compare the high-quality economy of each country [5–7], the second is to focus on measuring the high-quality development of China's economy as a whole [8,9], the third is to measure the high-quality development of provinces [10–12], the last is to measure the high-quality economic development of an economic region [13].

From the perspective of the index system, the worldwide index system emphasizes international comparability. Although it is based on the basis of five development concepts—innovation, coordination, green, openness and sharing [5,6]—there is no unified opinion on the specific content of the index system. There are four types of measurement systems focusing on the high-quality development level of domestic and even regional economies: one is to take total factor productivity as the main index to measure the level of high-quality economic development [14], the second is the index system established on the basis of five development concepts or related concepts, such as innovation, coordination, green, openness and sharing [15], the third is the index system established from the kinetic energy, structure and results of economic growth [16], and the fourth is the index established

from the two dimensions of economic growth fundamentals and social results [17,18]. Some other index systems were established by integrating some aspects of the above categories [19]. Due to the small number and the lack of a unified view, it will not be repeated here one by one. Among them, the index system established according to the five development concepts of the second type is the most, but a unified opinion has not been formed. First, the secondary indexes contained in the primary indexes are different, and the specific measurement indexes are different. In terms of the number of measurement indexes alone, there are only 10 [20], and some as many as 50 [21].

## 2.2. High-Quality Development of Logistics Industry

The high-quality development of logistics is an integral part of the high-quality development of the economy. Wang [22] first proposed the concept of high-quality development, but it involves industrial agglomeration and regional high-quality development, not the high-quality development of logistics. The real research on the high-quality development of logistics is the two pieces of literature that appeared in 2017. Since then, the number of research results has increased significantly. Generally speaking, the research span for the high-quality development of the logistics industry is relatively short. Since the 19th National Congress of the Communist Party of China proposed the research and judgment that China's economy has entered the stage of high-quality development, it has attracted extensive attention in the fields of academia and industry. The research results have increased significantly in the past two years, but the total amount of research results is still small, so it is still necessary to strengthen the research [23].

There are a few judgments and interpretations on the connotation of high-quality logistics development in China, but there is no clear concept of it and there is no consensus on the concept and connotation of it. Chen [24] believed that the connotation of high-quality logistics development must include four aspects: low cost, high efficiency, high service level and green development. Zhu et al. [25] proposed that under the background of digital technology, the connotation of high-quality logistics development includes six dimensions: time dimension, space dimension, direction dimension, wisdom dimension, integration dimension and ecological dimension. From the perspective of integrated field theory, Dong and Yan [26] proposed the whole process of the high-quality development of the logistics industry, including network chain development strategy, target design, synthetic field element, network chain maturity and network chain structure governance, including logistics chain and supply chain. Xiao [27] believed that the high-quality development of logistics includes two meanings: first, the development quality of the logistics industry is high, and second, the logistics industry can meet the economic development and people's needs with high quality.

To summarize, logistics high-quality development includes at least two meanings. First, the logistics industry has high development quality, which is reflected in high logistics benefits, high service level, strong endogenous power, sound industry, green environmental protection, etc., with the characteristics of "innovation, coordination, green, openness and sharing". Second, the logistics industry can serve the social economy and people's lives, strongly support the national economic development and meet the people's growing need for a better life.

The high-quality development of logistics and the quality of logistics development are different concepts. The former is not simply used to improve the quality of logistics development; it is a new stage and model of logistics development. On the whole, there are a few interpretations of logistics high-quality development in China, but the understanding of the connotation of logistics high-quality development is not comprehensive and profound, there is no unified opinion on the concept, and there is no clear judgment on the concept and connotation of it, which needs to be further studied [23].

As for the evaluation system of high-quality logistics development, some studies have considered the internal and external environment of the logistics industry for evaluation. For example, the index system established by Mu [28] included the economic environment

of the logistics industry, the scale level of the logistics industry, the input level of the logistics industry, the output effect of the logistics industry, etc. The index system established by Cheng [29] included economic development level, logistics demand, logistics industry scale, informatization level and infrastructure construction. Li [30] believed that the development quality of the logistics industry can be measured from three aspects: development efficiency, development structure and development environment. Li [31] and others established evaluation indexes including low-carbon logistics environment, low-carbon logistics strength, low-carbon logistics potential and low-carbon logistics level from a low-carbon perspective.

It is more evaluated from the perspective of input-output. For example, Cao [32] and others believed that relevant indexes include input (capital input of the logistics industry and labor input of the logistics industry) and output (scale of the logistics industry and quality of the logistics industry). The index system established by Lu [33] included input (labor and capital) and output (added value and goods turnover). In the index system established by Li [34], input includes capital input (fixed asset investment in logistics industry), labor input (employees in logistics industry), and energy input (energy consumption in logistics industry); output includes expected output (output value of the logistics industry) and unexpected output (CO<sub>2</sub> emission in logistics industry).

The corresponding analysis method is data envelopment analysis (DEA). The traditional DEA models include the CCR model [35] and BCC model [36]; the former is an efficiency model based on the constant return to scale (CRS) and the latter is an efficiency model based on the variable return to scale (VRS). The difference between the two assumptions is that the BCC model has a convex constraint to consider the difference of returns to scale. It was first applied to the efficiency evaluation of logistics enterprises [37], and then many scholars studied the research on the efficiency of the logistics industry in the derivative model of DEA (such as DEA-PCA, EBM-DEA, Fuzzy DEA, DEA-TOPSIS-LP, DEA-Malmquist model, etc.) [38,39]. DEA models can be divided into two categories, one is the general expected output model, the other is the model containing unexpected output, and the Super-SBM model considering unexpected output is more applied. It is mainly because in the actual social production, when people's physical needs are solved, it will also produce various side effects, such as wastewater, waste residue, waste gas and other pollutants. This unexpected output is what people want to avoid as much as possible, so the unexpected output model has gradually attracted the attention of relevant scholars.

### 2.3. Logistics Industry and Economy

The research on the relationship between the logistics industry and the economy has a long history. For example, Danuta [40] found that the inventory of logistics links can appropriately reflect the changes of regional economic development in the economic transition period. The research of many scholars has also shown that regional economy and logistics will affect each other and has shown a positive correlation [41].

At present, there are three main views on the relationship between logistics and the economy. First, it is believed that the economy drives the growth of logistics. Chen [42] and others believed that regional economic development is the reason for the growth of regional logistics. Zhang [43] used relevant theories to conclude that economic development promotes the development of logistics, and the development of logistics changes the growth mode of the regional economy. Li [44] and others found that rapid economic development vigorously promotes the development of logistics, but the role of modern logistics in promoting economic development is not significant in the primary stage. Taylor [45] pointed out that the growth of world trade means an increase in the demand for logistics services to provide goods. Ma [46] used the spatial Dobbin panel model to analyze the role of resource endowment and industrial structure in promoting the total factor productivity of the logistics industry. Based on the theory of system dynamics. Yang [47] and others analyzed the fact that the regional logistics industry is affected by factors such as regional industrial structure and regional residents' consumption level. Llanto et al. [48] studied

the impact of ASEAN economic integration on the structure, behavior and performance of the logistics industry. Langvinienė et al. [49] analyzed the change and direction of the Lithuanian transport service industry under the background of European economic growth.

The second view is that logistics drive rapid economic growth. Pedersen [50] pointed out that logistics plays an important role in economic development. The research of Sánchez et al. [51] and Zaman et al. [52] found that different logistics performance levels have different effects on economic development. Zhou [53] used a logistic model to analyze the regional economic growth brought by the development of the regional logistics industry. Peng [54] proposed that the overall contribution of logistics capacity to economic growth is large. Fan [55] and others proved the positive spillover effect of logistics node facilities on economic growth based on the panel data of Haixi coastal port cities. Mateo-Mantecon [56] and others analyzed the impact of ports on the economy. The research results of Lee et al. [57] showed that port development is a means of promoting economic growth, trade and employment in South Africa. Sezer [58] and others believed that the logistics industry has made a great macro contribution to the national economy by creating employment opportunities, national income and foreign capital inflow. Tang et al. [59] analyzed the impact of international logistics performance on economic growth. Through elasticity analysis. Cui [60] and others found that the logistics industry has a significant positive significance in promoting GDP growth. Arya et al. [61] found that an efficient logistics system is the determinant of sustainable economic growth. The research of Saidi et al. [62] showed that transport and logistics infrastructure does contribute to the “attraction” of foreign direct investment and sustainable economic growth.

The third view is that logistics and economy are interdependent, coordinated and promoted to each other. For example, Shin et al. [63] believed that there are many direct and indirect links between the logistics sector, economic growth and development. Xu [64] analyzed the significant correlation between the regional economy and regional logistics. Reza [65] used Indonesian data to analyze the two-way impact between logistics and economy, and Kuzu et al. [66] analyzed the two-way relationship between logistics and economy using Turkish data. Liu [67] and others verified the two-way interactive relationship between regional logistics and regional economy by using the Granger causality test. Liang et al. [68] analyzed the interactive relationship between regional economy and regional logistics and constructed a dynamic coupling model between them. Kong [69] and others used the grey system theory to analyze the correlation and coordination between modern logistics and rural economic development. Hanif et al. [70] analyzed the interaction between logistics and regions by using the VAR model. Song [71] constructed a coordination evaluation model between China’s regional logistics industry and economic development based on the entropy method and composite system model. With the development of logistics and the economy, we need to pay attention to the indicators of sustainable development, such as ecological benefits [61]. How to balance the sustainability of logistics, economy and the environment needs to be further studied.

The research method on the relationship between the logistics industry and economy has changed from qualitative analysis to quantitative research. At present, the main quantitative methods used are the vector autoregressive model, the Haken model, grey correlation analysis, the compound system synergy model, the system dynamics model, the coupled coordination model [72], etc. Among them, the coupled coordination model has been recognized by many scholars, including the perspective of spatio-temporal differences in the coupled and coordinated development of logistics and economy in provinces, and the perspective of studying the coupled and coordinated relationship between economy and logistics in an economic belt or economic region [73,74].

To summarize, the interaction between economy and logistics is the focus of scholars’ continuous attention, but there are some deficiencies: there is a lack of a study on the coupling and coordinated development of the two under the background of high-quality development. Most of them take the single development index of economy or logistics as the variable of model construction and do not consider the requirements of high-quality

development in the system, and they are rarely evaluated as a system before coupling and coordinated analysis. At the same time, there is little analysis on the relationship between the coupling and coordination of the two industries and other factors.

### 3. Methodology

#### 3.1. Variable Selection

It mainly investigates the measurement index system of high-quality economy and logistics industry, and the coupling and coordinated relationship between them.

##### 3.1.1. Measurement Index System of High-Quality Economic Development Level

For the measurement of high-quality economic development level, starting from the connotation of high-quality economic development, it comprehensively refers to the index system of many scholars to simplify it and fit the five development concepts. It not only pays attention to the direct and indirect effects of economic development, but also focuses on the development objectives of high-quality economy, focusing on the upgrading of economic form structural rationalization and even optimization of the division of labor, as well as imbalance and insufficiency in economic development. Because of this, the high-quality economic development index system constructed in this paper includes five dimensions: innovation, coordination, green, openness and sharing. When selecting the corresponding secondary indexes, this paper starts from the deep connotation of the above-mentioned high-quality economy and mainly selects the indexes most recognized by many scholars to build the corresponding index system.

(1) Innovation indexes. Innovation includes institutional innovation, theoretical innovation, scientific and technological innovation, and cultural innovation. The new growth theory shows that scientific and technological innovation is the source of economic growth, and knowledge is the source of theoretical innovation, scientific and technological innovation and cultural innovation. Innovation requires a lot of human and material resources. At the same time, the innovation effect is also reflected in the transformation of achievements after innovation. Therefore, this paper selects capital productivity, labor productivity, R&D investment intensity and the number of patent applications authorized per capita to measure the level of innovation and development.

(2) Coordinated indexes. From the perspective of the economy, coordination is mainly reflected in the coordinated development of industrial structures. From the perspective of society, it is more reflected in the coordination of urban and rural development. Therefore, this paper selects the rationalization of industrial structure, the upgrading of industrial structure, urbanization rate, urban–rural per capita income ratio, and urban–rural per capita consumption ratio to measure the level of coordinated development.

(3) Green indexes. Green development is mainly aimed at China's transformation from extensive development to intensive development. China has put forward the requirements of "energy conservation and emission reduction" in the outline of the 11th five-year plan. This paper mainly selects the energy consumption per unit of GDP, forest coverage, harmless treatment rate of domestic waste, the proportion of environmental pollution control investment in  $SO_2$  emission per unit of GDP, and other indexes to measure green development indexes.

(4) Open indexes. Open development mainly reflects the degree of China's participation in global economic development, including China's utilization of foreign capital and the contribution of import and export trade to the national economy. This paper uses foreign capital dependence and foreign trade dependence to measure the open development indexes.

(5) Sharing indexes. The sharing indexes more reflect the extent to which the whole of society shares the fruits of economic development; they more reflect the basic guarantee of people's livelihood. Therefore, this paper uses the unemployment rate, the number of hospital beds per 10,000 people, and the per capita education expenditure to measure the sharing development indexes.

The indexes of the above five dimensions are shown in Table 1.

**Table 1.** Description of measurement indexes of high-quality economic development level.

Primary Indexes	Secondary Indexes	Index Measurement	Index Attribute
Innovation	Capital productivity	GDP/Capital stock	+
	Labor productivity	GDP/Total employment	+
	R&D investment intensity	R&D expenditure/GDP	+
	Number of patent applications authorized per capita	Number of patent applications/population	+
Coordination	Rational structure of production	Theil index	−
	Advanced industrial structure	Output value of tertiary industry/output value of secondary industry	+
	Urbanization rate	Original statistics	+
	Urban–rural per capita income ratio	Urban per capita income/rural per capita income	−
	Per capita consumption ratio between urban and rural areas	Urban per capita consumption/rural per capita consumption	−
Green	Energy consumption per unit of GDP	Total energy consumption/GDP	−
	Forest coverage	Forest area/land area	+
	Harmless treatment rate of domestic waste	Original statistics	+
	Proportion of investment in environmental pollution control	Investment in environmental pollution control/GDP	+
	SO <sub>2</sub> emission per unit of GDP	SO <sub>2</sub> emission/GDP	−
Openness	Foreign capital dependence	FDI/GDP	+
	Dependence on foreign trade	Total imports and exports/GDP	+
Sharing	Unemployment rate	Original statistics	−
	Number of hospital beds per 10,000 people	Original statistics	+
	Per capita education expenditure	Education expenditure/population	+

Note: In the above data, except for the ratios involving similar indexes, the GDP values are constant price GDP adjusted based on 2001. Based on the data and methods provided by Zhang [75] and others, the capital stock is calculated by using the perpetual inventory method according to the total annual fixed asset investment formation of each province, taking 2001 as the base period.

### 3.1.2. Measurement Index System of High-Quality Development Level of Logistics Industry

For the measurement of the high-quality development level of the logistics industry, this paper starts from the connotation of it, comprehensively refers to the index system of many scholars, and simplifies it as much as possible. It not only pays attention to the direct and indirect effects of the development of the logistics industry, but also focuses on the high-quality development objectives of the logistics industry, considering the availability of data, starting from the above-mentioned deep connotation of high-quality economy, and mainly selecting the indexes most recognized by many scholars to build the corresponding index system. In terms of input indexes, in Western economic theory, production factors include land, labor and capital; however, when land is basically a known fixed quantity and has little impact on the research industry, labor input and capital input are usually regarded as input indexes. In terms of output indexes, it focuses on selecting representative evaluation indexes from two aspects of scale and quality. Therefore, based on the relevant theories of Western economics, it constructs an evaluation index system to evaluate the development quality of the regional logistics industry.

(1) Input indexes. In the input-output, people usually pay attention to the investment in material resources and manpower, and the energy consumption of the logistics industry is also one of the important input elements of the logistics industry. Therefore, the input indexes mainly include the investment in fixed assets, the number of employees and the energy consumption of the logistics industry. Due to the lack of relevant data of the logistics industry, transportation, storage and postal data were used to replace the logistics data [76].

(2) Output indexes. From the perspective of the impact of the logistics industry on the economy and society, one of its main outputs is the added value of the logistics industry, and the other is the carbon emission of the logistics industry. Therefore, the output indexes mainly include the added value and the carbon emission of the logistics industry. Similarly, the transportation, storage and postal data were used to replace the data of the logistics industry.

### 3.2. Data Source and Description

Because the data of Hong Kong, Macao, Taiwan and Tibet are partially missing, it selects the data of the other 30 provinces in China as the research sample, and the period is 2001–2019. The data are mainly from the China Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook, historical statistical yearbooks of 30 provinces, and statistical bulletins of the national economic and social development of provinces. When some data are inconsistent in different yearbooks, the data published in the China Statistical Yearbook and the website of the National Bureau of Statistics shall prevail. The original data of carbon emission mainly come from the energy consumption and carbon emission list of various industries in China and provinces from 2001 to 2018 provided by the CEDAs database, which are the most authoritative statistical data for accounting for China's energy utilization and carbon emission level at present. If some original data are missing, they shall be supplemented by interpolation. Finally, 19 indexes to measure the high-quality economic development of 30 provinces (as shown in Table 2) and 5 indexes to measure the high-quality development of the logistics industry (as shown in Table 3) were selected.

**Table 2.** Descriptive statistics of core variables in the index system of high-quality economic development level.

Name	Sample	Min	Max	Mean	SD	Kurtosis	Skewness
Capital productivity	570	1.750	8.330	3.302	1.087	4.587	1.868
Labor productivity	570	0.548	19.166	4.324	3.036	3.424	1.674
R&D investment intensity	570	0.001	0.049	0.010	0.008	6.221	2.274
Patent application authorization per capita	570	0.130	61.149	6.004	9.573	8.441	2.809
Rational structure of production	570	0.233	2.553	1.062	0.364	1.127	0.429
Advanced industrial structure	570	0.527	5.234	1.149	0.604	16.832	3.641
Urbanization rate	570	20.350	89.607	51.376	14.759	0.198	0.673
Income ratio of urban and rural residents	570	1.845	4.759	2.855	0.562	0.487	0.934
Consumption ratio of urban and rural residents	570	1.635	4.497	2.659	0.597	−0.193	0.591
Energy consumption per 10,000 yuan of GDP	570	0.379	4.920	1.574	0.972	1.680	1.451
Forest coverage	570	2.900	66.800	32.072	17.912	−1.169	0.090
Harmless treatment rate of domestic waste	570	9.580	100.000	74.411	25.106	−0.668	−0.757
Proportion of investment in environmental pollution control	570	0.000	0.011	0.002	0.001	8.973	2.503
SO2 emissions per unit of GDP	570	0.000	0.122	0.012	0.015	12.467	2.972
Foreign capital dependence	570	0.000	0.163	0.026	0.024	4.960	1.949
Dependence on foreign trade	570	0.010	1.710	0.314	0.372	2.984	1.934
Unemployment rate	570	1.200	6.500	3.526	0.715	2.310	−0.482
Number of beds in medical institutions per 10,000 people	570	15.271	75.439	40.313	14.197	−0.831	0.344
Education expenditure per capita	570	177.090	11421.979	1685.855	1252.857	6.971	1.691

Note: Some data are displayed as 0 because the ratio result is small.

**Table 3.** Descriptive statistics of core variables in the index system of high-quality logistics development level.

Name	Sample	Min	Max	Mean	SD	Kurtosis	Skewness
Fixed asset investment in logistics industry	570	29.99	3364.121	644.115	608.479	3.046	1.731
Number of employees in logistics industry	570	2.800	86.400	23.546	14.244	2.929	1.329
Energy consumption of logistics industry	570	23.913	3559.573	848.715	641.55	1.938	1.332
Added value of logistics industry	570	19.500	3985.168	762.484	682.951	3.500	1.739
Carbon emission of logistics industry	570	0.500	69.248	16.433	12.658	2.338	1.430



The high-quality economic index system includes two indexes with different dimensions and orders of magnitude. To eliminate their impact on the analysis, the range processing method was used to standardize the data first, so that all data are in [0,1]. The formula for range standardization is:

$$x'_{ij} = \frac{x_{ij} - \min\{x_{1j}, \dots, x_{nj}\}}{\max\{x_{1j}, \dots, x_{nj}\} - \min\{x_{1j}, \dots, x_{nj}\}} \quad (\text{positive index}) \quad (1)$$

$$x'_{ij} = \frac{\max\{x_{1j}, \dots, x_{nj}\} - x_{ij}}{\max\{x_{1j}, \dots, x_{nj}\} - \min\{x_{1j}, \dots, x_{nj}\}} \quad (\text{negative index}) \quad (2)$$

where  $i$  and  $j$  represent the region and year, respectively,  $x_{ij}$  represents the original data, and  $x'_{ij}$  represents the standardized data. To avoid the situation that the index is 0, the standardized data are processed, and the formula is:

$$y'_{ij} = 0.1 + 0.9 * x'_{ij} \quad (3)$$

### 3.3. Model Setting

#### 3.3.1. Economic High-Quality Evaluation Method

The establishment of the evaluation index system mainly includes Analytic Hierarchy Process, Factor Analysis, Principal Component Analysis, and Entropy Method. Analytic Hierarchy Process is more subjective than the other three methods. At present, for the measurement of high-quality economic development level, the weighting methods mainly used by scholars include Entropy Method, Entropy TOPSIS Method, Principal Component Analysis Method and Equal Weight Method. The Equal Weight Method is simple. Considering the time-series change trend of indexes and the correlation between indexes, the Principal Component Analysis method is finally selected for measurement [8,77].

#### 3.3.2. High-Quality Evaluation Method of Logistics Industry

##### Super-SBM Model

The evaluation of the development quality of the logistics industry is mostly based on the DEA model. It takes the input-output efficiency of the logistics industry as an index to measure the high-quality development level of the logistics industry. The SBM (Slacks-based Measure) model, that is, the non-radial DEA model based on the measure of relaxation variables, which brings the relaxation variables of input and output into the model function, overcomes the disadvantage that the traditional DEA model does not consider the relaxation of variables. The Super-SBM model is derived from the SBM model. Its main advantages are: (1) The efficiency value is not limited by 1, which solves the ranking problem when two or more decision-making units (DMU) are effective, and makes up for the shortcomings of the SBM model; (2) It can analyze the expected output and unexpected output, which makes up for the shortcomings of the traditional DEA model.

If there are  $n$  DMU, each contains three vectors—an input vector, expected output vector and unexpected output vector. It is assumed that their vector forms are, respectively,  $x \in R^m, y^d \in R^{r_1}, y^u \in R^{r_2}$ ; the corresponding matrix is  $Y^d$  and  $Y^u$ , where  $X = [x_1, x_2, \dots, x_n] \in R^{m \times n}, Y^d = [y^d_1, y^d_2, \dots, y^d_n] \in R^{r_1 \times n}$ , and  $Y^u = [y^u_1, y^u_2, \dots, y^u_n] \in R^{r_2 \times n}$ . The actual input level shall not be lower than the frontier input level, the actual expected output level shall not exceed the frontier expected output level, and the actual unexpected output level shall not be lower than the frontier unexpected output level. The expression of the Super-SBM model considering unexpected output is:

$$\min \rho = \frac{\frac{1}{m} \sum_{i=1}^m \bar{x}_{ik}}{\frac{1}{r_1+r_2} \left( \sum_{s=1}^{r_1} \frac{y^d_{sk}}{y^d_{sk}} + \sum_{q=1}^{r_2} \frac{y^u_{qk}}{y^u_{qk}} \right)} \quad (4)$$

$$\text{s.t.} \left\{ \begin{array}{l} \bar{x} \geq \sum_{j=1, \neq k}^n x_{ij} \lambda_j \\ \bar{y}^d \leq \sum_{j=1, \neq k}^n y_{sj}^d \lambda_j \\ \bar{y}^u \geq \sum_{j=1, \neq k}^n \lambda_j y_{qj}^u \\ \lambda_j > 0 \\ \bar{x} \geq x_k \\ \bar{y}^d \leq y_k^d \\ \bar{y}^u \leq y_k^u \end{array} \right. \quad (5)$$

$$i = 1, \dots, m, j = 1, \dots, n, s = 1, \dots, r_1, q = 1, \dots, r_2$$

where  $\rho$  is the efficiency value; when  $\rho \geq 1$ , the DMU is effective; when  $0 \leq \rho \leq 1$ , the DMU is invalid, showing that there is efficiency loss in the DMU.  $\lambda$  is the weight vector,  $x, y^d, y^u$  are the relaxation variables of input, expected output and unexpected output.

According to the SBM model, when the efficiency value of the logistics industry is greater than 1, it shows that the logistics industry in this region is developing well, and the government should maintain the current development policy. When the efficiency value is greater than 1, the relaxation data can reflect the reason for the high-efficiency value. When the efficiency value of the logistics industry is less than 1, it shows that the development of the logistics industry in this region has a large development space, and the government should pay more attention to it. When the efficiency value of the logistics industry is less than 1, the relaxation data can reflect the cause of loss.

#### Malmquist Index

The Malmquist index (MI) can reflect the change of efficiency over time in different periods. The MI from  $t$  to  $t + 1$  can be expressed as:

$$M_0 = \left[ \frac{D_0^t(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)} \times \frac{D_0^{t+1}(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_t, y_t)} \right]^{\frac{1}{2}} \quad (6)$$

where  $(x_t, y_t)$  represents the input-output vector in period  $t$ , and  $D_0^t(x_t, y_t)$  represents a distance function. If  $M_0 > 1$ , it shows that the efficiency of the DMU is improved from  $t$  to  $t + 1$ ; otherwise, the efficiency of the DMU decreases. If  $M_0 = 1$ , it shows that the efficiency of the DMU has not changed. MI can be divided into the technical progress index (Techch) and technical efficiency index (Effch) when the return to scale remains unchanged, as shown in the following formula:

$$M_0 = \text{Techch} \times \text{Effch} \quad (7)$$

where the technological progress index (Techch) refers to the impact of the progress of production technology on efficiency. If its value is greater than 1, it indicates that there is technological progress; otherwise, it means retrogression. If it is 1, it means unchanged. The technical efficiency index (Effch) can be further divided into the pure technical efficiency change index (Pech) and scale efficiency change index (Sech):

$$\text{Effch} = \text{Pech} \times \text{Sech} \quad (8)$$

where the technical efficiency index (Effch) reflects the improvement of management level, and its value is greater than 1, indicating that the DMU is close to the efficiency frontier. If Pech is greater than 1, it indicates the progress of pure technical efficiency; alternatively, it will regress. If it is 1, it means that it is unchanged. If Sech is greater than 1, it means that phase  $t + 1$  is closer to the fixed scale return than phase  $t$  or is gradually approaching

the long-term optimal scale; alternatively, it could mean that the return to scale is getting farther and farther away.

### 3.3.3. Measurement of Coupling and Coordinated Development of Logistics Industry and Economy

The coupling coordination degree is derived from the capacity coupling coefficient model in physics. The coupling degree can be used to measure the interaction and influence of multiple systems and reflect the connection strength of each system. Its calculation formula is as follows:

$$C = \sqrt{\frac{U_1 \cdot U_2}{\left(\frac{U_1 + U_2}{2}\right)^2}} \quad (9)$$

where  $U_1$  and  $U_2$  represent the logistics industry development index and economic high-quality development index, respectively.

Coupling coordination degree is an index used to evaluate the development level of coupling coordination among systems, reflecting the level of organic combination and interaction between systems. The greater the value, the higher the coupling coordination degree between systems. Its calculation formula is as follows:

$$D = \sqrt{C \cdot (0.5 \cdot U_1 + 0.5 \cdot U_2)} \quad (10)$$

where  $(0.5 \cdot U_1 + 0.5 \cdot U_2)$  is often called coordination degree  $T$ . Coordination degree refers to the degree of benign coupling in interaction, which reflects the quality of coordination, and can represent whether the functions promote each other at a high level or restrict each other at a low level.

The measurement results of the high-quality development level of China's economy and logistics industry were selected as the research object. The measurement results were analyzed according to the coupling coordination degree classification standard shown in Table 4.

**Table 4.** Classification standard of coupling coordination degree.

D-Value Interval of Coupling Coordination Degree	Coordination Level	Coupling Coordination Degree
(0.0~0.1)	1	Extreme disorder
[0.1~0.2)	2	Severe disorder
[0.2~0.3)	3	Moderate disorder
[0.3~0.4)	4	Mild disorder
[0.4~0.5)	5	Verge of disorder
[0.5~0.6)	6	Reluctantly coordination
[0.6~0.7)	7	Primary coordination
[0.7~0.8)	8	Intermediate coordination
[0.8~0.9)	9	Good coordination
[0.9~1.0)	10	High quality coordination

### 3.3.4. Classification Method

In order to classify and analyze the characteristics of different provinces, the relationship between the mean and standard deviation [78] was used to classify 30 provinces according to different indexes, and the setting of the classification boundary is shown in Table 5.

**Table 5.** Criteria for setting classification boundaries.

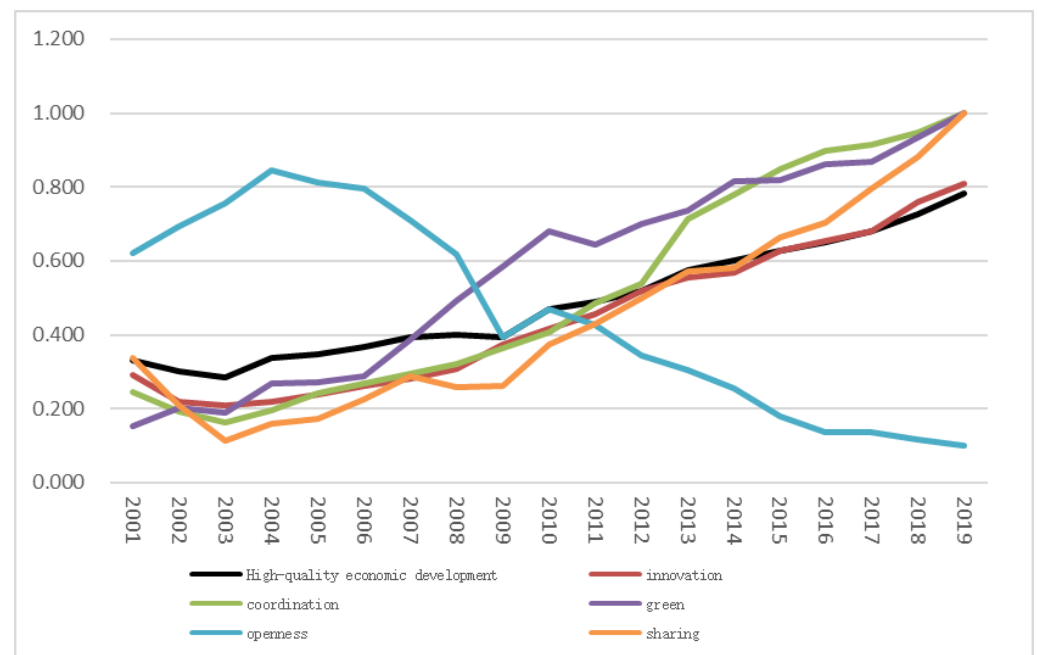
Category	Backward/IV Provinces	Catch-Up/III Provinces	Progressive/II Provinces	Advanced/I Provinces
Classification criteria	<(Mean - 0.5 × SD)	(Mean - 0.5 × SD)~Mean	Mean~(Mean + 0.5 × SD)	>(Mean + 0.5 × SD)

## 4. Results and Analysis

### 4.1. Measurement Results of High-Quality Economic Development

Based on the above data collection and processing, using the constructed evaluation index system of high-quality economic development and MAXDEA ultra 7.10 software, the measurement results of high-quality economic development level in China and 30 provinces were obtained.

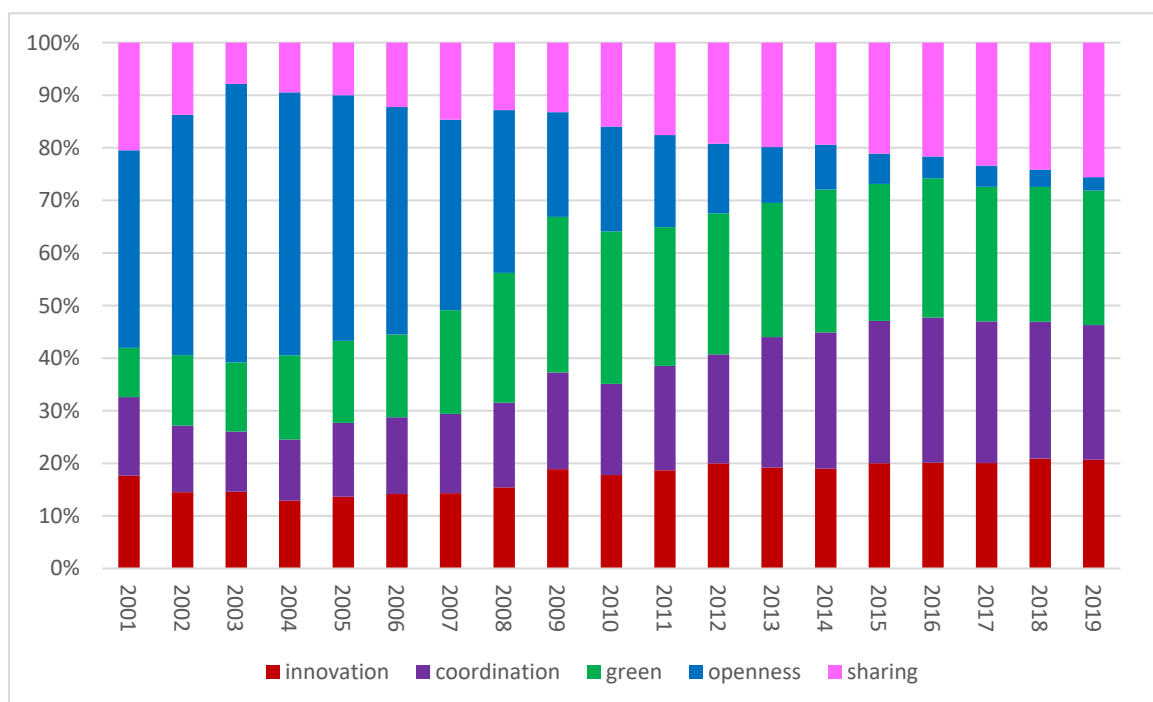
The general index of the high-quality development of China's economy and the development trend of five sub-indexes were obtained by calculating the high-quality development level of China's economy from 2001 to 2019. See Figure 1.



**Figure 1.** High-quality development trend of China's economy from 2001 to 2019.

Overall, China's high-quality economic development level has shown a fluctuating upward trend over time, rising from 0.330 in 2001 to 0.782 in 2019, an increase of 136.949%. Except for a small decline in 2002, 2003 and 2009, it has increased steadily in other years, with an average annual growth rate of 5.108%. From the five development indexes of innovation, coordination, green, openness, and sharing, the innovation, coordination, green, and sharing indexes show a large upward trend. Among them, the innovation index has increased from 0.291 in 2001 to 0.809 in 2019, an increase of 178.033% and an average annual growth rate of 6.292%, which also reflects the significant improvement trend of the national economic innovation level. The coordination index rose from 0.247 in 2001 to 1.000 in 2019, an increase of 305.463% and an average annual growth rate of 8.829%, reflecting the further coordination of China's industrial and social development. The green index has also improved in fluctuation, from 0.155 in 2001 to 0.999 in 2019, an increase of 545.703% and an average annual growth rate of 11.720%, which is in line with the concept of green development emphasized by China in recent years. The sharing index increased from 0.338 in 2001 to 1.000 in 2019, an increase of 195.931% and an average annual growth rate of 9.061%, which also reflects the fact that more and more development achievements are shared by the whole of society in the process of high-quality economic development. The openness index showed a fluctuating downward trend, from 0.620 in 2001 to 0.100 in 2019, a decrease of 83.861% and an average annual decrease of 8.462%. However, it does not mean that China's opening-up level is decreasing, but that the role of opening-up in China's high-quality economic development is decreasing year by year. Figure 2 also shows the proportion of these five indexes in China's high-quality economic development,

which also reflects the main role of various indicators in promoting high-quality economic development. It can be seen that compared with opening-up, the other four aspects are gradually strengthened. The role of the openness index in China's high-quality economic development has decreased year by year, which is also in line with China's 2020 plan to give full play to the domestic market potential and gradually form a new development pattern with the domestic cycle as the main body and the domestic and international double cycles promoting each other. Building a new development pattern based on "double-cycle" is a major strategic deployment of the CPC Central Committee to promote the development of China's open economy to a higher level under the background of significant changes in the domestic and international environment. It is also an important layout to further promote China's current high-quality economic development.



**Figure 2.** Development proportion of five high-quality indexes of China's economy from 2001 to 2019.

#### 4.2. Measurement Results of Quality Development of China's Logistics Industry

Based on data collection and processing, using the constructed logistics industry quality development evaluation index system and MAXDEA ultra 7.10 software, the measurement results of the logistics industry quality development level in China and 30 provinces in China were obtained.

##### 4.2.1. Analysis on the Measurement Results of Logistics Quality Development Level from the Overall Perspective

From the trend of China's overall high-quality development level (comprehensive technical efficiency) of the logistics industry and the development trend of a high-quality economy from 2001 to 2019, it was found that, with the gradual fluctuation and rise of China's high-quality economy, the quality development of China's logistics industry does not show a corresponding obvious upward trend. At the same time, the change rate of logistics green total factor productivity (the Malmquist index) fluctuates around 1. From the average trend of the high-quality development of China's logistics industry in the four regions from 2001 to 2019, it can be seen that, based on the average value of comprehensive technical efficiency in the four regions, only the Northeast has an obvious upward trend after 2015, and the values of the other three regions fluctuate up and down, which shows that the overall development level of China's logistics industry has made little progress and

there is much room for progress. (According to the division method of the National Bureau of statistics, China's economic regions are divided into four regions: the Eastern, the Central, the Western and the Northeast. Among them, the Eastern includes 10 provinces: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. The central region includes six provinces: Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan. The Western region includes 12 provinces: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang (only 11 provinces are included in the Western region of this paper due to the lack of Tibet data); Northeast China includes 3 provinces: Liaoning, Jilin and Heilongjiang.)

#### 4.2.2. Spatial Distribution Characteristics of Logistics Quality Development

According to the comprehensive technical efficiency of China's logistics industry in 30 regions from 2001 to 2019, there are obvious regional differences in the high-quality development of China's logistics industry. Some regions show the trend of first being high and then being low, and some regions have been at a low level without obvious progress. Generally speaking, the high-quality development level of the logistics industry in the Central and Eastern regions is slightly higher. According to the average score over the years, it was found that the mean of Anhui is the highest in China, 1.100, and that of Yunnan is the lowest, 0.162. The average value of the 30 provinces is 0.429, the standard deviation is 0.224, and the coefficient of variation (CV) is 521.99%. There are great differences among provinces.

#### 4.2.3. Time Distribution Characteristics of Logistics Quality Development

The Malmquist index (MI) can reflect the changes in the quality development of the logistics industry over time. By decomposing the MI of the quality development of China's logistics industry from 2001 to 2019, the results shown in Figure 3 can be obtained.

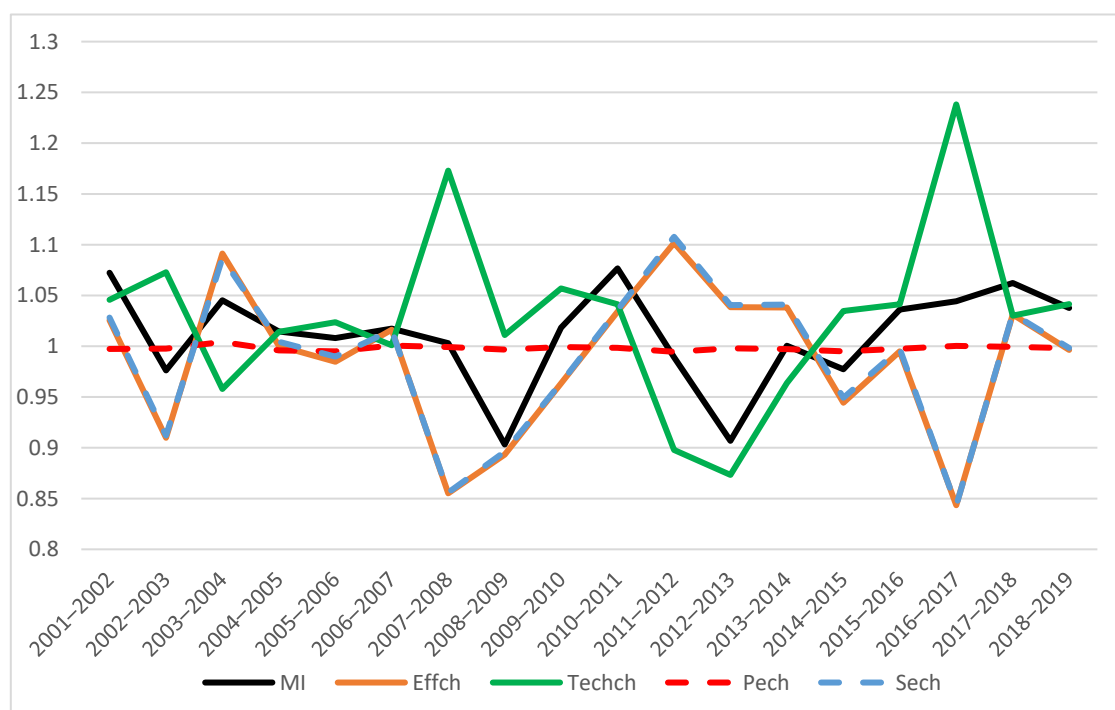


Figure 3. MI of the high-quality development of China's logistics industry from 2001 to 2019.

It can be seen from Figure 3 that, from 2001 to 2019, the Malmquist index (MI), technological progress index (Techch) and technical efficiency index (Effch) are unstable, and the changes of the technical efficiency index (Effch) and scale efficiency index (Sech) are

basically the same, which also shows that the change of the green total factor productivity of China's logistics industry is mostly caused by the change of scale. The pure technical efficiency index (Pech) is close to 1, which also shows that the technical efficiency of China's logistics industry has not changed significantly, providing a way for the high-quality development of the logistics industry in the future.

According to the MI of 30 provinces in China from 2001 to 2019, the minimum value is 0.991 (Sichuan), the maximum value is 1.154 (Liaoning), the average value is 1.043, the standard deviation is 0.032, and the coefficient of variation (CV) is 30.45%. The difference among provinces is relatively small. The mean of MI shows the changes of logistics green total factor productivity in 30 provinces of China. Among them, Liaoning, Shanxi, Tianjin and Shanghai belong to regions with a high change rate, while Fujian and Beijing are still backward provinces at this time. Some provinces in the Western region have also made some positive changes, such as Gansu, Ningxia, Guizhou and Xinjiang, which are included in progressive provinces.

#### 4.2.4. Quality Development Characteristics of Logistics Industry in Various Regions

The input-output data, the comprehensive technical efficiency of the logistics industry, and the MI of the logistics industry in 30 provinces of China from 2001 to 2019 were averaged, respectively, and 30 provinces were classified. The results are shown in Table 6.

**Table 6.** Classification of input and output of China's logistics industry.

Province	Investment	Employed Persons	Energy Consumption	Added Value	Carbon Emission	Comprehensive Technical Efficiency of Logistics	MI
Beijing	III	I	III	III	III	III	IV
Tianjin	IV	IV	II	II	II	I	I
Hebei	I	II	I	I	I	I	II
Shanxi	IV	III	IV	III	IV	II	I
Inner Mongolia	III	III	III	IV	III	II	III
Liaoning	III	I	I	I	I	I	I
Jilin	IV	III	I	I	I	III	IV
Heilongjiang	IV	II	II	II	II	IV	II
Shanghai	III	I	III	I	III	II	I
Jiangsu	I	I	III	II	III	II	II
Zhejiang	I	II	IV	III	IV	III	III
Anhui	III	III	I	I	I	I	III
Fujian	I	III	II	I	II	I	IV
Jiangxi	IV	III	I	II	I	II	III
Shandong	I	I	II	II	II	I	II
Henan	I	I	I	I	I	I	III
Hubei	I	I	III	IV	III	IV	II
Hunan	II	II	IV	IV	IV	II	IV
Guangdong	I	I	IV	IV	III	III	III
Guangxi	II	III	II	IV	II	IV	IV
Hainan	IV	IV	IV	IV	IV	IV	III
Chongqing	III	III	III	IV	III	IV	IV
Sichuan	I	II	III	IV	III	IV	IV
Guizhou	III	IV	IV	IV	IV	IV	II
Yunnan	I	IV	IV	IV	IV	IV	III
Shannxi	III	III	IV	IV	IV	IV	IV
Gansu	IV	IV	III	IV	III	IV	II
Qinghai	IV	IV	III	III	III	IV	IV
Ningxia	IV	IV	II	II	II	IV	II
Xinjiang	IV	IV	I	I	I	III	II

As can be seen from Table 6, seven provinces belong to the high-efficiency region of category I of logistics technical efficiency regions (Tianjin, Hebei, Liaoning, Anhui, Fujian, Shandong, Henan). The seven provinces are not necessarily high-input regions. For example, the three input categories of Tianjin belong to category IV, although the added value of its logistics industry belongs to category III, its carbon emission is low and only belongs to category IV, at the same time, the change rate of its green total factor productivity belongs to category I. Anhui's three inputs belong to category III, but its added

value of the logistics industry belongs to category I, and its carbon emission belongs to category III with low carbon emission. There are also regions with high input, high output and high carbon emission, such as Shandong. The input and output belong to category I, the logistics efficiency also belongs to category I, the carbon emission is also very high, belonging to category I, and its MI belongs to category II. There are 12 regions that belong to the category IV of logistics efficiency (Heilongjiang, Hubei, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Shannxi, Gansu, Qinghai, Ningxia), among which Hainan, Gansu, Qinghai, and Ningxia all belong to category IV, that is, low input, low output and low carbon emission, but their MI is different. The MI grade of Gansu and Ningxia is slightly higher, which has a better development trend compared with the other two provinces. Six provinces (Shanghai, Jiangsu, Guangdong, Hubei, Liaoning and Shanghai) belong to high-carbon-emission regions of logistics, among which Hubei belongs to the category IV of technical efficiency of logistics, and Guangdong belongs to category III. It can be seen that high carbon emission is an important factor affecting logistics efficiency. Although Tianjin's input belongs to category IV, its logistics efficiency belongs to category I. It can be seen that low carbon emission is an important factor for its high efficiency. From the perspective of the added value of the logistics industry, most of the provinces belong to category I, and the corresponding carbon emissions are categories I, II and III. In the provinces with category IV of added value, most of their inputs are categories III and IV, and most of their carbon emissions are categories III and IV, which also confirms that fixed-asset investment, employees and energy consumption are important factors affecting the added value of the logistics industry. It is worth mentioning that Anhui's input category is category III, but its added value belongs to category I, and its carbon emission belongs to category III. The technical efficiency of logistics also belongs to category I, which can be used for reference.

#### 4.3. Empirical Results of Coupling and Coordinated Development of Logistics Industry and High-Quality Economic Development

##### 4.3.1. Analysis of the Coupling Coordination Degree between China's Logistics Industry and High-Quality Economic Development

Using SPSSAU software, the coupling and coordination analysis of the logistics and economic high-quality development index from 2001 to 2019 is shown in Table 7.

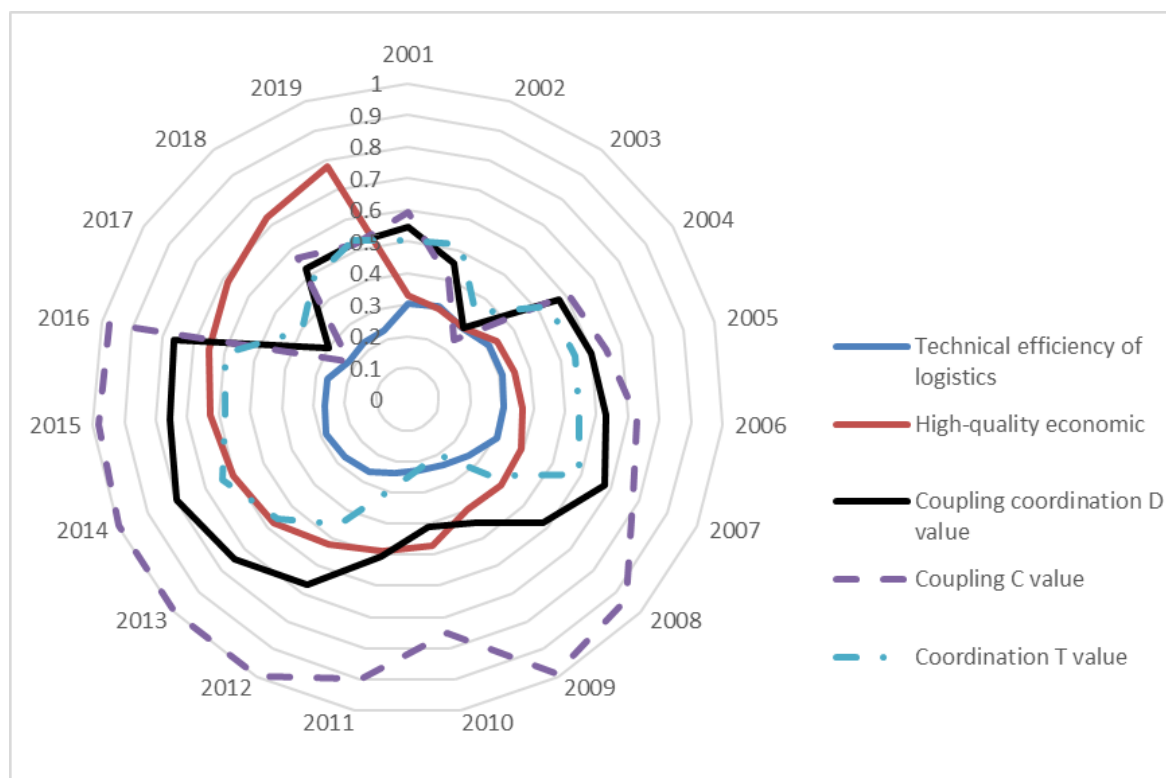
**Table 7.** Calculation results of coupling coordination degree between logistics industry and high-quality economic development.

Year	Coupling C Value	Coordination T Value	Coupling Coordination D Value	Coordination Level	Coupling Coordination Degree
2001	0.594	0.502	0.546	6	Reluctantly coordination
2002	0.403	0.517	0.457	5	Verge of disorder
2003	0.238	0.347	0.288	3	Moderate disorder
2004	0.610	0.539	0.573	6	Reluctantly coordination
2005	0.650	0.549	0.598	6	Reluctantly coordination
2006	0.729	0.543	0.629	7	Primary coordination
2007	0.778	0.595	0.680	7	Primary coordination
2008	0.940	0.358	0.580	6	Reluctantly coordination
2009	0.990	0.199	0.444	5	Verge of disorder
2010	0.751	0.225	0.411	5	Verge of disorder
2011	0.899	0.286	0.507	6	Reluctantly coordination
2012	0.998	0.449	0.669	7	Primary coordination
2013	0.999	0.559	0.747	8	Intermediate coordination
2014	1.000	0.639	0.799	8	Intermediate coordination
2015	0.983	0.581	0.756	8	Intermediate coordination
2016	0.974	0.596	0.762	8	Intermediate coordination
2017	0.222	0.399	0.298	3	Moderate disorder
2018	0.568	0.485	0.525	6	Reluctantly coordination
2019	0.517	0.533	0.525	6	Reluctantly coordination



It can be seen from Table 7 that the overall development of China's logistics industry and high-quality economic development have not been coordinated all the time—in fact, they were on the verge of disorder and then they began to rise in fluctuations. They reached intermediate coordination from 2013 to 2016, but decreased significantly in 2017, and then they reached reluctantly coordination in 2018 and 2019.

By observing the coupling index, it was found that the high-quality development of China's logistics industry and economy belongs to the state of high coupling before, that is, the positive promotion effect between them is obvious, but the coupling degree fluctuates and has decreased in recent years. By observing the coordination index, it can also be found that the coordination between the logistics industry and high-quality economic development mostly belongs to the situation of low-level mutual restriction, which has not yet reached a high-level mutual promotion, resulting in the overall coupling coordination degree basically being in the state of reliable coordination. Further observing the radar chart of China's logistics industry and high-quality economic development (Figure 4), it can be found that the main reason for this coupling and coordination is the inconsistency between the development of logistics efficiency and high-quality economic development.



**Figure 4.** Coupling coordination characteristics of China's high-quality logistics industry and economy from 2001 to 2019.

Through the coupling coordination analysis of China's MI and high-quality economic development index from 2002 to 2019, considering that MI represents the change of total factor productivity from year  $t - 1$  to year  $t$ , and its effect is year  $t$ ,  $MI(t, t - 1)$  is relative to the economic high-quality efficiency value in year  $t$ , and the results are shown in Table 8.

As can be seen from Table 8, the change of green total factor productivity of the logistics industry has gradually moved towards coordination with the high-quality economic development efficiency in fluctuation, and showed high-quality coordination in 2018 and 2019, which also fully shows that the high-quality development of the logistics industry is consistent with and closely related to the trend of high-quality economic development.

**Table 8.** Coupling coordination of logistics industry and economy development.

Year	Coupling C Value	Coordination T Value	Coupling Coordination D Value	Coordination Level	Coupling Coordination Degree
2002	0.408	0.505	0.454	5	Verge of disorder
2003	0.301	0.216	0.255	3	Moderate disorder
2004	0.652	0.462	0.549	6	Reluctantly coordination
2005	0.753	0.385	0.539	6	Reluctantly coordination
2006	0.831	0.387	0.567	6	Reluctantly coordination
2007	0.869	0.438	0.617	7	Primary coordination
2008	0.908	0.405	0.606	7	Primary coordination
2009	0.402	0.118	0.218	3	Moderate disorder
2010	0.961	0.517	0.704	8	Intermediate coordination
2011	0.911	0.701	0.799	8	Intermediate coordination
2012	1.000	0.485	0.696	7	Primary coordination
2013	0.437	0.308	0.367	4	Mild disorder
2014	0.998	0.596	0.771	8	Intermediate coordination
2015	0.973	0.558	0.737	8	Intermediate coordination
2016	1.000	0.746	0.864	9	Good coordination
2017	1.000	0.798	0.893	9	Good coordination
2018	1.000	0.896	0.947	10	High-quality coordination
2019	0.992	0.880	0.934	10	High-quality coordination

#### 4.3.2. Analysis on the Characteristics of Coupling Coordination between Logistics Industry and Economy Development in Various Provinces of China

According to the average value of the coupling coordination degree of 30 provinces in China from 2001 to 2019, 30 provinces are classified, and the results are shown in Table 9.

**Table 9.** Classification of coupling coordination degree from 2001 to 2019.

Province	High-Quality Economic	Logistics Efficiency	MI	Coupling Degree	Coordination Degree	Coupling Coordination Degree
Beijing	I	III	IV	IV	I	I
Tianjin	I	I	II	I	I	I
Hebei	IV	I	IV	II	I	I
Shanxi	IV	II	III	I	III	III
Inner Mongolia	IV	II	II	I	III	II
Liaoning	I	I	IV	II	I	I
Jilin	III	III	III	I	III	II
Heilongjiang	III	IV	II	IV	IV	IV
Shanghai	I	II	II	IV	I	I
Jiangsu	I	II	III	I	I	I
Zhejiang	I	IV	IV	III	II	II
Anhui	III	I	II	III	I	I
Fujian	I	I	II	I	I	I
Jiangxi	III	II	III	I	II	II
Shandong	II	I	IV	I	I	I
Henan	IV	I	IV	I	II	II
Hubei	III	IV	IV	II	IV	III
Hunan	III	II	II	I	III	II
Guangdong	I	III	III	II	I	I
Guangxi	IV	IV	III	IV	IV	IV
Hainan	II	IV	III	IV	III	IV
Chongqing	III	IV	II	IV	IV	IV
Sichuan	III	IV	I	IV	IV	IV
Guizhou	IV	IV	I	III	IV	IV
Yunnan	IV	IV	IV	IV	IV	IV
Shannxi	IV	IV	IV	III	IV	IV
Gansu	IV	IV	I	I	IV	IV
Qinghai	IV	IV	II	IV	IV	IV
Ningxia	IV	IV	I	I	IV	IV
Xinjiang	IV	III	III	I	IV	III

It can be seen from Table 9 that, from the overall average situation from 2001 to 2019, there are many provinces with coupling coordination degree I, and their coordination degree is I. While there are four types of coupling degree, MI does not have I, economic efficiency is mostly I, and logistics efficiency does not have IV. It can be seen that, in these provinces, logistics and economy show common progress, but the relationship between them is not necessarily very close. There are few regions with coupling coordination degree II, the coupling degree is mainly I, and the coordination degree is II and III. There are four categories of economic quality efficiency and logistics efficiency, indicating that, in these provinces, the relationship between logistics and economy is relatively close, but their development is not completely the same. There are few regions with coupling coordination degree III, their coordination degree is III and IV, and the coupling degree is I and II. There is no I in high-quality economic and logistics efficiency, indicating that, in these provinces, the relationship between logistics and economy is relatively close, but their development is not completely synchronized. There are many provinces with coupling coordination degree IV, and there are four types of coupling degree, the coordination degree is generally IV. At the same time, there is no I in high-quality economic development, and logistics efficiency is mainly IV, indicating that the development synchronization between logistics and economy is poor in these provinces.

According to the coupling coordination degree of 30 provinces in China in 2019, 30 provinces are classified, and the results are shown in Table 10.

**Table 10.** Classification of coupling coordination degree in 2019.

Province	High-Quality Economic	Logistics Efficiency	MI	Coupling Degree	Coordination Degree	Coupling Coordination Degree
Beijing	I	III	I	III	I	I
Tianjin	I	I	IV	I	I	I
Hebei	III	I	IV	I	I	I
Shanxi	IV	I	I	I	II	I
Inner Mongolia	IV	II	IV	I	III	II
Liaoning	III	I	II	II	I	I
Jilin	III	II	IV	I	III	II
Heilongjiang	II	III	IV	II	III	III
Shanghai	I	II	III	II	I	I
Jiangsu	I	II	II	I	I	I
Zhejiang	I	IV	II	IV	III	II
Anhui	III	I	IV	I	I	I
Fujian	II	III	III	II	III	II
Jiangxi	II	III	IV	II	III	II
Shandong	II	II	II	I	II	I
Henan	III	II	I	I	II	II
Hubei	III	III	IV	II	III	III
Hunan	III	III	IV	II	III	III
Guangdong	I	III	IV	II	II	II
Guangxi	III	IV	III	IV	IV	IV
Hainan	II	IV	I	III	III	III
Chongqing	II	IV	III	IV	IV	IV
Sichuan	III	IV	I	IV	IV	IV
Guizhou	IV	IV	III	III	IV	IV
Yunnan	IV	IV	I	IV	IV	IV
Shannxi	III	IV	III	IV	IV	IV
Gansu	IV	IV	I	II	IV	IV
Qinghai	IV	IV	III	III	IV	IV
Ningxia	IV	IV	III	II	IV	IV
Xinjiang	IV	I	IV	I	II	II

It can be seen from Table 10 that, among the 30 provinces in 2019, for the provinces with coupling coordination degree I, the coupling degree and coordination degree are also I, the technical efficiency of logistics has no IV or MI, and economic efficiency is in four categories, which shows that, in these provinces, the logistics industry and economy are closely related and progress together. For provinces with coupling coordination degree II, the coordination degree is of II and III, the coupling degree is mainly of I and II, and there

are four categories of economic efficiency and logistics efficiency. MI is mainly of IV, the logistics and economy of these provinces can make common progress, and most of them are closely related, but one needs to pay attention to the development of logistics green total factor productivity. There are few provinces with category III of coupling coordination degree. Their coordination degree is III, the coupling degree is II, the economic efficiency and logistics technical efficiency are mainly III, and the MI is IV. In this type of province, it is necessary to strengthen the common development of logistics and economy and to continue to pay attention to the growth of logistics green total factor productivity. In provinces with IV of coupling coordination degree, the coordination degree is all IV, and there is no I of coupling degree, the economic efficiency is mainly III and IV, the technical efficiency of logistics is all IV, and the MI are I and III. In this type of province, it is necessary to strengthen the connection between logistics and the economy and their common progress.

## 5. Conclusions

The goal of high-quality economic development is the all-around development in the five dimensions of innovation, coordination, green, openness, and sharing; it is not the improvement of a single index, let alone the improvement of GDP. China's high-quality economic development has gradually improved from the initial opening-up to the other four aspects. The role of the openness index in China's high-quality economic development is decreasing year by year. The Eastern region has the highest level of high-quality economic development, and there is still a big gap between the Northeast, Central and Western regions and the Eastern region in the process of promoting high-quality economic development. It still needs to continue to strengthen efforts to revitalize the Northeast and realize the rise of the Central and Western regions. In the Eastern region, the proportion of the openness index is the highest, which is also in line with the geographical characteristics of the Eastern region; however, the proportion of the innovation index in the four regions is not high and the change is not obvious, which can become a way to improve the high-quality economic development of our country. The high-quality development level of the logistics industry in each region has not improved, and the overall development level is not high, with severe fluctuations. Whether one is considering the average level or the high-quality development of the logistics industry in 2019, there are significant regional differences. The Central and the Eastern regions are leading, the Northeast is quite different, and the development of the Western region is backward. In some provinces with a better economic development level, the performance of logistics and ultra-high-quality development does not match that of the high-quality economic development level. In some provinces with an average economic development level, the high-quality development level of the logistics industry is better than expected. The quality development of logistics in China is mostly caused by the change of scale, but there is no obvious change in technical efficiency, which also provides a way for the high-quality development of the logistics industry in the future. At present, the coupling coordination degree between the logistics industry and high-quality economic development is generally not high, which is mainly due to the poor coordination between the logistics industry and high-quality economic development. It requires vigorously improving the high-quality level of the logistics industry and strengthening the high-quality relationship between the logistics industry and the economy to form a situation of mutual promotion and common development.

Both the high-quality development of the economy and the high-quality development of the logistics industry have the same goal, which is to achieve the sustainable development of the economy, society, and environment. In the past, the high-quality development level of the economy and the logistics industry, and even the coupling and coordination degree of the high-quality development of the economy and logistics industry, has not been high, which may indicate that, in the previous economic development, many regions only focused on the growth of GDP, and the logistics industry was only a subordinate. The core of high-quality development is high-quality economic development, but it is not equivalent to high-quality economic development. We need to pay attention to the

comprehensive development of innovation, coordination, green, openness, sharing and other dimensions, as the focus of development has expanded from material production to the development of economic, political, cultural, social and ecological civilization, solving outstanding problems such as employment, education, medical treatment, housing, social security, environment and safety.

High-quality development must attach importance to regional coordinated development. Instead of simply requiring all regions to reach the same level of economic and social development, we should recognize objective differences and better promote the common development of developed and underdeveloped regions, the East, Central and Western regions and the Northeast, by improving mechanisms such as regional strategic planning, regional cooperation, mutual assistance, and interregional interest compensation. At the same time, all regions should combine the actual situation, adapt measures to local conditions, develop their strengths and make up for their weaknesses, and walk out of a high-quality development road suitable for the actual situation of the region.

High-quality development is by no means a temporary move and must be adhered to for a long time. Novel coronavirus pneumonia is a major global change, the world is undergoing a century of great change, the international environment is becoming more complex, instability and uncertainty are increasing, and COVID-19 has accelerated the great change. We must prepare ourselves for all kinds of complex and difficult situations. Based on the new and higher requirement for economic and social development, high-quality development cannot be achieved easily, and we must be prepared to make more arduous efforts.

For future research, we will try to establish a simple and practical evaluation index system of high-quality economic development that can be compared all over the world and explore the coupling and coordinated development of the logistics industry and major industries, especially the manufacturing industry, under the background of high-quality development. Additionally, some of the most representative computational intelligence algorithms may be used to solve the problems, such as monarch butterfly optimization (MBO), the earthworm optimization algorithm (EWA), elephant herding optimization (EHO), the moth search (MS) algorithm, the slime mould algorithm (SMA), and Harris hawks optimization (HHO) [79,80], which we will try it in our future work.

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