

Research Article

If There Appears a Path to Improve Chinese Logistics Industry Efficiency in Low-Carbon Perspective? A Qualitative Comparative Analysis of Provincial Data

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Received 18 March 2021; Revised 9 May 2021; Accepted 22 May 2021; Published 31 May 2021

Academic Editor: Zeljko Stevic

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Taking the data of 30 Chinese provinces as a sample in which CO₂ emission is denoted by undesirable output, this paper calculated the efficiencies of the logistics industry by applying the Data Envelopment Analysis (DEA) method and analyzed the factors that affect logistics industry efficiency by applying the Qualitative Comparative Analysis (QCA) method based on configuration thinking. It is found that the efficiency of China's low-carbon logistics industry has presented an increasing trend and the efficiency gaps among the regions have been enlarged in the last 10 years. Two highly efficient paths have been formed in the three years after 2015. The path of management opening type has a high coverage ratio; logistics management level and operation are the core factors that improve logistics efficiency. The path of economy driving type covers few cases and it mainly relies on relative priority to influence and drive the development of regional logistics.

1. Introduction

As a basic and strategic industry for the economic development of a country or region, the efficiency of the logistics industry not only directly affects the economic situation of a country or region at the macrolevel but also has great significance for the stability and smoothness of the enterprise supply chain and the improvement of the overall competitiveness at the microlevel. At the same time, the logistics industry has strong dependence on energy. With the rapid development of the logistics industry, its total energy consumption is unceasingly rising, followed by the increase of carbon emissions [1]. It has become a necessary trend for the sustainable development of China's logistics industry to develop healthy, efficient, and low-carbon logistics. However, China's logistics industry management is practiced generally in an extensive mode and the application of advanced management and technology is insufficient in the promotion of logistics efficiency, which caused a huge disadvantageous influence on resources and environment.

In recent years, the Chinese government has issued a series of policies and documents to promote the development of logistics industry, which plays a vital part in guiding the development of logistics industry in the whole country and every provincial region. In response to the demand raised by the country, every region actively accelerates the development of the logistics industry, which says "accelerate the development of modern logistics industry, promote the adjustment of industrial structure, reduce the cost, and improve logistics efficiency." It is a noteworthy subject to examine and view the integral operation efficiency of logistics in the low-carbon perspective.

Increasing efficiency is one of the principal questions studied in economics and management research. The increase of social-economic efficiency depends on the increase of enterprises' efficiency. Nevertheless, all the enterprises stay in the outside environment and their operations are necessarily influenced by the other environmental conditions, so the efficiency of the logistics industry is necessarily influenced by the operation and management level and

regional environmental factors together. There has already been quite a good deal of literature that selected and evaluated the influence of environmental factors on logistics efficiency, but there is a lack of attention paid to estimating the logistics industry's management level. Meanwhile, for analyzing the effect of environmental factors, the traditional statistic methods usually were applied and based on the atomic perspective and focused on analyzing the unique "net effect" of a single variable [2].

However, most causes and conditions of the occurrence of social phenomenon are not dependent on each other and the independent variables produce multicollinearity because of interrelated relationships, which show that the unique effect of a single variable could be covered by the correlated variable. Though the test on multicollinearity is performed before the analysis of model or the analysis of model is performed with the method of adjusting variables, it is hard to explain three and more cross variables. Therefore, as for explaining the occurrence of social phenomenon, it is preferable to take on an integral and assembled method; especially, for the multiple concurrence property of antecedent, it is suitable to seek a corresponding path in configuration view [3].

This research selected the logistics data with a provincial level of 30 provinces in China during a decade to search and observe whether the low-carbon logistics efficiency with provincial level is increased and the corresponding paths are formed. This paper has two contributions: (1) this is innovatively the first time to bring the management and operation level of logistics enterprise into the analysis of the influence of logistics industry efficiency on the basis of the calculation of low-carbon logistics efficiency of different regions; that is to say, the total amount of the regional A-class logistics enterprise is used to measure the management and operation level of the logistics industry; (2) it is creatively used in configuration views with the method of Qualitative Comparative Analysis (QCA), which is more suitable to explain social phenomenon. The empirical analysis is conducted for exploring the specific paths to improve Chinese logistics industry efficiency in a low-carbon view.

This paper is organized as follows: Section 1 presents the introduction. Section 2 sums up the relative literature. Section 3 presents the study design. Section 4 presents data and variable selection. Section 5 presents statistics results. Section 6 analyzes research results. The final section is about conclusions and implications.

2. Literature Summary

2.1. The Method of Logistics Industry Efficiency Research. Research of logistics industry always is a hot spot to which the scholars pay attention. The representative research methods just are parametric method and nonparametric method; here, the former is Stochastic Frontier Analysis (SFA), and the latter is Data Envelopment Analysis (DEA) [4, 5]. SFA can distinguish the effect of technical inefficiency factors and statistics error on efficiency, and yet it needs to set a specific function form just for individual output

variables and put forward higher requirements for the distribution characteristics of error terms. The DEA model does not need to consider the form of production function and is able to consider multiple output indexes, so it is extensively used in every field. For instance, Min and Joo [6] analyzed the third-part logistics operation efficiency with the DEA method. Hamdan and Rogers [7] calculated the efficiency of 19 American warehouses. Anthony et al. [8] think that DEA is a nonstatistical method methodology that is used to measure performance in a relative manner and each producer unit or decision-maker is compared to the best unit in that industry. And through the method of DEA, there is no need for a definite form of production function as it is in the economy, and this technique can be used with minimal data.

For the influence factors of efficiency, Blagojević et al. [9] studied the efficiency evaluation of railway enterprises by using the DEA method, which included resources, operation, finance, quality, and safety into the evaluation criteria. Fried et al. [10] think that the three factors of ineffectiveness, which are management, environment variables, and random noise, can influence the DEA model to analyze decision unit efficiency, but there is always a lack of better index to measure the management factors directly. In addition, because there may be relativity among the factors and the convergence speed of efficiency values obtained though calculation is lower, there is obviously a lack of means for conducting the 2-stage DEA analysis [11]. The method of the 3-stage DEA builds a linear regress model with slack variable to explained variable to eliminate the influence of environmental factors and random interference. Though it is thought and more accurate efficiency can be obtained, the relativity among variables cannot be obtained as usual; moreover, the obtained efficiency value is only used in comparison and evaluation and cannot be measured in contrast to specific management index [12]. Hassanpour [13] thinks that DEA is a prominent procedure in the decision-making process with a pivotal role in the Sustainable Development (SD) assay and Environmental Impact Assessment (EIA) is the first step of SD assay.

2.2. Low-Carbon Logistics Industry Efficiency Research.

With the conspicuously negative influence of the logistics industry on environment, the scholars begin to bring energy consumption and carbon emission into the evaluation system of logistics industry efficiency [14]. For example, Rogers and Weber [15] measured the energy efficiency of the load-carrying transport industry by taking energy consumption, labor investment, and highway mileage as input indexes, taking the added value of the load-carrying transport industry as desirable output, and taking CO₂ emission and total traffic deaths as undesirable output. Yao et al. [16] in one belt, one road, selected the data from provinces from 2010 to 2015. Using the three-stage DEA and Malmquist models, the carbon dioxide emissions from undesirable outputs were taken as input variables, and the efficiency of the logistics industry in the provinces along the route was measured from static and dynamic.

Tang and Lu [17] used the 3-stage DEA model to comprehensively measure and evaluate the logistics industry efficiency of the ten provinces and municipalities in East China. As a kind of undesirable output, CO₂ emission is analyzed as input indexes. Taking the bad output indexes as input variables to deal with is a common method in calculating efficiency, which is expected to be as little as possible [18].

2.3. The Empirical Research on Chinese Logistics Industry Efficiency. Chinese scholars have conducted a great deal of empirical researches on logistics industry efficiency and low-carbon logistics efficiency. They analyzed the annual data and panel data for concrete enterprises or provincial regions. In the research of the provincial regions, the influence of many specific elements shows different results. Just like the understanding of economic environment and the degree of opening to the outside world, in theory, it is generally deemed that they should positively increase logistics efficiency, so that some authors empirically obtained the positive effect of the level of economic development on logistics efficiency [19, 20]. In contrast, the results showed that there was no direct positive correlation between the level of economic development and regional logistics industry efficiency [21, 22]. Although others drew the conclusion that there is positive influence between the degree of opening to the outside world and logistics efficiency [23, 24], the conclusion is that the degree of opening to the outside world cannot positively influence logistics efficiency [22, 25]. Deng et al. [26] considered carbon emissions, used the DEA method to measure and evaluate the logistics performance of 30 provinces and cities in China, and analyzed the characteristics of the efficiency of China's logistics industry on the overall level and space.

To a certain extent, it is closely related to data selection, variable choice, and research method to analyze the reason why divergence exists in the understanding of influence factor in the above literature about logistics efficiency. Firstly, logistics data itself leads to the instability of conclusion. In recent years, the development of logistics has been in a high-speed and fluctuating state. There was a quite big difference among different years and different regions, which did not form an identical regularity. Secondly, due to the availability of data, the support of selected variables was finite, or the key variables were omitted. For instance, the higher management level necessarily promoted the increase of logistics efficiency, but the degree of management level is not easily measured and compared, so the influence of this important index was not considered in the literature. Thirdly, when the 2-stage DEA or 3-stage DEA is applied, for all of them, the traditional statistics method should be used to set up a regress model, which still focuses on the analysis of the unique "net effect" of a single variable [2]; however, it does not apply the configuration method which is more suitable for the study of social phenomena, accepting the interaction between variables rather than being independent of each other.

Therefore, it is a new perspective to research development of the Chinese logistics industry to pay attention to the

operation and management level of logistics enterprise, which analyzes the combined actions of regional environment factors on low-carbon efficiency with the configuration method and explores if the effective path to increase logistics industry efficiency was formed during the process of the development of Chinese logistics in recent years.

3. Research Design

This section introduces the research and designs ideas of this paper. Firstly, based on certain data collection, this paper uses the method of DEA. In this method, CO₂ emission is regarded as the unexpected output to calculate the efficiency of low-carbon logistics. Then, based on the perspective of configuration analysis, the low-carbon logistics is analyzed. Efficiency is the explained variable, and management level, economic environment, openness, government regulation, and technological innovation are the five variables. In order to improve the efficiency of China's logistics industry, the QCA method is used to analyze the influence between explanatory variables and explained variables.

3.1. The Evaluation Method of Efficiency for the Low-Carbon Logistics Industry. For the conditions of each China's province of either the input or the output, the efficiency in the low carbon of the logistics industry should be firstly evaluated with DEA. DEA was used to evaluate the relative effectiveness of the operations' performance with the principle of "more investment, more output" for an organization or an object (decision unit DMU) [27]. Zhou and Ang [28] further proposed DEA's efficiency evaluation model that includes an undesirable output. In this paper, we choose the input-oriented BCC model and use CO₂ as an undesirable output to evaluate the efficiency of China's provincial low-carbon logistics industry.

3.2. The Path Analysis Method for Efficiency Improvement of Low-Carbon Logistics Industry. The traditional statistics methods (including regress analysis, typical correlation analysis, discrimination analysis, and cluster analysis) are not good for revealing the complexity of variable relationship and multiple and concurrent relationships of cause and effect among various antecedents, and each factor is considered as the antecedent of result in these methods. Instead, this research explores the specific path of increasing efficiency of the low-carbon logistics industry using the method of QCA, which is good at explaining the social phenomenon. QCA is initiated by an American sociologist, Ragin, in the 1980s, a "case-oriented" method for qualitative and quantitative cross-case comparison of causal complexity phenomena using Boolean algebra and set theory [3]. QCA consists of the crisp set QCA (csQCA) and fuzzy set QCA (fsQCA), where csQCA is a special case of fsQCA. This research uses fsQCA, which is extensively used in the literature for analyzing data.

Configuration and asymmetry are two characteristics of QCA. Based on the universal "multiple conjunctural causation" in the social phenomenon that roots in configuration

thought of and with the holistic perspective method, QCA holds that organization is best understood as an interconnected structure and practical colony rather than the solid which is divided into units or slackly assembled together, so organization cannot be understood in the way of analyzing solitarily component parts [3]. After determining the specific results and conditions for explanation, the logical relationship between result and condition can be identified through cross-case comparison. Consequently, the condition combinations that lead to results can be simplified.

In general, this combination is not unique, and the multiple combinations are equivalent to each other. Every combination can be reviewed as a specific path. Therefore, different routes lead to the same destination. This implies that it can be explained that different cases may result in the same results. In addition, the corresponding condition or condition combination should be pointed out if they can be constituted as the “necessary” or “sufficient” condition.

The other characteristic of QCA is asymmetry. This can be expressed as “happy families are all alike and every unhappy family is in its own way,” and the reasons of success or failure are different. The cause-and-effect asymmetry softens the assumption of unity on causality effect in the linear regress, which can better explain the difference among cases, and the independent configuration effect between conditions [3].

4. Selection of Data and Variables

4.1. Data Selection. The data used in this paper as observation samples are from the *China Statistical Yearbook* and the *China Energy Statistical Yearbook* for thirty provinces, municipalities, and autonomous regions, from 2008 to 2017. Following Zhang et al. [29], we select data for industries of transportation, warehouse, and postal, as representatives of the development level of China’s logistics industry.

4.2. Variable Selection. The explained variable is the efficiency of the low-carbon logistics industry. For input-output, the efficiency of the logistics industry is defined as the ratio of the investment of economic elements in logistics activities to actual output [20]; in addition to the two indexes of logistics added value and the amount of freight turnover, CO₂ emission should be measured [22], calculated, and then used as the undesirable output. To calculate the efficiency, the output index should be disposed, which is expected to be as little as possible [18].

The explanatory variable represents the main factors that influence the efficiency of the regional low-carbon logistics industry. Factors that influence the efficiency of enterprises in the logistics industry depend on an enterprise’s inner management, including organization structure, business process, employee quality, and corporation culture, and the factors outside an enterprise, such as politics, economy, social culture, and technology (PEST). They mutually influence and restrain. The content of political economy, social culture, and technology is broad. For better measurement,

the government’s rules and regulations, area economy, degree of opening, and scientific and technological innovation are used to reflect the content of PEST for a certain degree.

Concerning the different research emphasis of the existing literature, generally, four or five main influence factors are taken into consideration. To a different degree, the environmental factors appear in the existing research such as development level of regional economy, utilization ratio of logistics resource, marketization degree, informatization level, institutional factors, location factors, industrial structure, agglomeration degree of the logistics industry, degree of opening to the outside world, government’s support, and scientific and technological innovation. And yet, as for the management factors, there is a lack of analysis. This research adds the influence of management factors and brings the level of operation and management of logistics enterprise into the explanatory variables and at the same time considers the four factors of regional government’s rules and regulations, area economic environment, opening degree, and scientific and technological innovation. The five explained variables comparatively conform with the demand of the QCA method. Because QCA considers all possible combinations of explanatory conditions, the number of combinations increases exponentially with the addition of conditions by a factor of 2^k (k = number of conditions). So, adding a variable will easily cause the result that the configuration exceeds the observed case in number; thus, the finite diversification of case emerges, and the ideal number is from 4 to 8 [2].

The input-output indexes and the description of all explanatory variables are shown in Table 1.

4.2.1. Investment Index. Labor investment is reflected by the gross payroll of an employee of the logistics industry in different regions. The fixed assets investment of the logistics industry in different regions is the basal data of capital investment. The capital stock is estimated with the perpetual inventory method. The depreciation fund is calculated by 10% [21]. Regarding the year of 2008 as the base period, the fixed assets stock in the base period is calculated by Goto and Suzuki’s method [30]. To eliminate the interference of price factors, capital stock is calculated by applying fixed assets investment indexes to deflate fixed assets investment.

4.2.2. Output Index. To eliminate the interference of price, all the added value of different regions in different years is deflated by the GDP deflation indexes of different regions regarding the year 2008 as the base period. The turnover volume of freight transport can better reflex the actual logistics situation; therefore, we choose the turnover volume of freight transport as an output index. For energy consumption output, the carbon emission of the logistics industry is taken as measure index; that is to say, according to the CO₂ emission coefficient of the corresponding energy published in ICPP of the UN, we calculate the main energy

TABLE 1: Model variable and description.

Variables		Description	Unit
Explained variable	Logistics industry total efficiency (TE): considering input and output, it is calculated by the DEA method	Input index	Labor (L): salary of employee of logistics 100 million Capital (K): fund stock of logistics 100 million
		Output index	Added value (Add) Freight turnover (turn) Carbon emission 100 million Ton/ kilometer —
		Operation and management level (5A)	The total amount of A-class logistics enterprise of different regions Piece
Explanatory variable	Economic environment (GDP)	Regional GDP (price deflated value)	100 million
	Opening degree (open)	The ratio of the total amount of imports and exports to GDP	—
	Regulations and rules (Regu)	Investment of environmental pollution treatment in every region	100 million
	Scientific and technological innovation (R&D)	R&D investment of different regions	100 million

consumption of the logistics industry in the different regions and sum up the CO₂ emission.

4.2.3. Explanatory Variable. The first explanatory variable is operation and management level. Comprehensive evaluation and certification of A-class logistics enterprise are carried out according to *the Classification and Evaluation Index for Logistics Enterprise*, which sets five classes from A to 5A and includes 16 to 18 items of index, involving 6 dimensions of enterprise operation situation, asset situation, service and management, employee quality, the informatization level, and so on. Therefore, to a certain extent, the total amount of the A-class enterprise of different regions reflects the strength and the operation and management level of the mentioned above logistics enterprise. This kind of certification is organized by the China Federation of Logistics and Purchasing. Except in the year of 2012, it was just only organized once; in the other years, it is organized once every six months at the beginning of a year and at the end of a year. The amount of the enterprises that passed certification at the beginning of a year was counted in the total number of A-class enterprises of the previous year, and the amount of the enterprises that passed certification in the second half of a year was counted in the total number of A-class enterprises of this year.

The other explanatory variables are environmental factors. The development of area economy can effectively promote the development of the logistics industry. The GDP of different regions represents the regional economic environment. The variables can comprehensively reflect the overall level of economic development in a region. To eliminate the interference of price, the price index of different regions is used to deflate it, and its unit is 100 million Yuan. The degree of opening is reflected by the ratio of the total export-import volume to GDP. The government's regulations and rules are characterized by investment of environmental pollution treatment from the view of environmental pollution treatment. The regional R&D fund

index is chosen to reflect the level of scientific and technological innovation.

5. Statistics Result

This section will be divided into three parts to describe the statistical results. First, we make a statistical description of the collected data. To understand the characteristics of each variable. Then, based on the existing data, the DEA method is used to calculate the efficiency of the low-carbon logistics industry. Finally, the QCA method is used to analyze the configuration of explanatory variables and explained variables.

5.1. Descriptive Statistics. All the following statistical analysis is conducted annually. For the input-output indexes and the factors that influence logistics efficiency, we first conduct a descriptive statistical analysis year by year to understand the characters of variables. The result is shown in Tables 2 and 3.

Over ten years, the labor investment of the logistics industry increased by 175.60%, and capital investment increased by 227.65%. In the aspect of output, the added value of the logistics industry increased by 100.31%, and the volume of freight turnover increased by 152.89%. During the ten years, the carbon emission increased by 50.20% on average and assumed a trend of overall fluctuation amplitude diminution and overall decline. The average increase of the years of 2010 and 2011 is above 8% but it decreased to a certain extent in 2013. After 2014, the increase ratio is about 4%–6%, and it may be related to the technological progress and the continuous effects of China's energy-saving and emission reduction policies.

The increase of A-class logistics enterprises in number shows that the logistics enterprises attach great importance to management and improve their operation level, which plays a vital role in increasing the overall development of the logistics industry. But from the fact that in 2017 the maximum is 591 and the minimum is only 16, we can see the

TABLE 2: Descriptive statistics of logistics industry input and output in China from 2008 to 2017.

Variable		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Labor investment	Mean	66.77	74.95	82.59	94.76	105.94	141.21	155.68	166.39	172.66	184.02
	Std dev	48.79	55.85	62.84	73.90	77.67	100.50	115.63	122.69	126.12	135.05
	Min	8.31	9.53	9.91	11.53	15.68	18.64	19.10	19.74	20.23	21.61
	Max	212.18	246.96	272.36	314.76	344.39	454.46	541.41	576.72	575.70	626.25
Capital investment	Mean	2500.12	2936.80	3453.53	3851.60	4297.92	4860.36	5543.16	6363.75	7257.56	8191.60
	Std dev	2369.01	2322.24	2345.33	2369.98	2459.91	2678.08	2934.04	3238.70	3574.19	4053.53
	Min	275.88	338.16	420.08	472.07	524.26	607.40	736.12	896.70	1137.47	1303.84
	Max	12689.56	12201.66	12059.83	11704.68	11525.87	11839.37	12336.75	13411.82	14856.21	16951.35
Carbon emission	Mean	434.19	460.79	500.35	541.52	578.06	545.35	579.56	604.44	636.37	652.09
	Std dev	299.54	315.05	335.88	355.69	377.91	306.19	318.49	331.38	369.20	389.13
	Min	51.32	57.19	63.92	68.42	69.53	72.75	77.63	84.76	97.40	103.28
	Max	1245.51	1317.52	1444.30	1541.65	1718.77	1490.06	1559.13	1624.51	1814.82	1847.16
Added value of logistics industry	Mean	571.22	611.73	675.51	730.45	808.85	879.35	927.51	1001.72	1052.85	1144.22
	Std dev	422.39	440.87	494.65	550.43	605.13	660.69	652.18	698.87	728.09	804.58
	Min	40.72	48.29	55.37	56.01	59.03	60.88	66.74	76.27	81.19	93.20
	Max	1873.58	1791.99	1970.05	2228.63	2397.61	2622.93	2474.68	2659.78	2821.83	3185.55
Freight turnover volume	Mean	2500.10	3701.67	4349.08	4951.01	5285.28	4873.82	5494.66	5218.03	5558.58	6322.44
	Std dev	3234.36	3363.54	4070.71	4452.12	4477.61	3972.49	4739.53	4640.51	5267.77	6516.76
	Min	335.66	364.16	419.68	486.38	527.62	451.95	506.94	445.58	475.80	519.46
	Max	16029.84	14372.56	18918.15	20309.56	20373.37	14332.71	18633.36	19495.88	21801.65	27919.79

TABLE 3: Descriptive statistics of logistics industry efficiency explanatory variables from 2008 to 2017.

Variable		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Management level (5A)	Mean	14.37	24.67	35.07	42.83	59.27	76.07	93.07	108.00	127.47	151.90
	Std dev	16.79	27.43	38.10	46.25	64.71	79.75	95.38	110.52	130.39	156.73
	Min	0.00	2.00	3.00	6.00	10.00	10.00	12.00	13.00	14.00	16.00
	Max	62.00	101.00	153.00	191.00	268.00	325.00	378.00	435.00	506.00	591.00
Economic environment (GDP)	Mean	10894.13	12163.55	13758.40	15378.69	16957.23	18558.66	20089.41	21656.03	23240.75	24920.95
	Std dev	8652.10	9582.53	10748.84	11832.36	12868.62	14001.82	15147.13	16367.12	17595.76	19234.03
	Min	961.53	1058.64	1220.62	1385.40	1555.14	1723.10	1881.62	2035.92	2198.79	2359.30
	Max	35696.50	39159.00	44014.70	48416.20	52364.80	56815.80	61226.80	66122.20	71083.70	76445.81
Opening to the outside world (Open)	Mean	0.24	0.22	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05
	Std dev	0.25	0.24	0.04	0.05	0.06	0.06	0.06	0.06	0.05	0.07
	Min	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Max	1.05	1.02	0.18	0.20	0.22	0.23	0.24	0.21	0.18	0.26
Regulations and rules (Regu)	Mean	316.96	305.91	285.43	303.56	298.55	264.10	221.74	208.93	138.14	126.34
	Std dev	221.43	210.97	197.35	203.11	196.31	181.22	157.20	251.79	97.04	119.37
	Min	41.10	30.30	22.20	21.10	26.60	24.10	26.20	17.00	12.30	12.70
	Max	948.80	780.80	952.50	880.60	881.00	739.10	623.90	1416.20	459.50	519.70
Scientific and technological innovation (R&D)	Mean	89.38	107.03	147.36	199.82	240.04	277.26	308.88	333.89	365.18	400.42
	Std dev	110.09	127.79	175.13	241.20	289.72	333.30	371.98	409.73	451.37	509.41
	Min	0.63	1.44	4.75	5.78	7.81	8.95	9.25	6.50	7.79	7.48
	Max	410.96	500.07	719.96	899.89	1080.31	1239.57	1376.54	1520.55	1676.27	1865.03

greater difference among regions. In terms of the external environment, the national economy has developed at a high speed. After the year of 2009, the average value of the degree

of opening to the outside world varied slightly, but by comparing the maximum with the minimum, the difference among the regions can be obviously seen. As for the

government's rules and regulations, the average investment of environmental pollution treatment shows a trend of decline, and the level of scientific and technological innovation shows an increase in fluctuation.

5.2. Calculation of Low-Carbon Logistics Industry Efficiency.

By using Deap2.1, the low-carbon logistics industry efficiency of 30 provinces, municipalities, and autonomous regions from 2008 to 2017 was calculated year by year. Table 4 shows the annual average efficiency of the low-carbon logistics industry in East, Central, and West China.

From Table 4, the national comprehensive efficiency was lower from 2008 to 2017. The average values are between 0.580 and 0.652, pure technical efficiency is between 0.689 and 0.751, and scale efficiency is between 0.844 and 0.905. The pure technical efficiency is lower than the mean of scale efficiency, but the increasing trend is clearer than that of the mean of pure technical efficiency; therefore, the increase of mean of pure technical efficiency contributed relatively more to the efficiency of low-carbon logistics. Concerning regions, the comprehensive efficiency of East China is higher than that of Central China, and that of Central China is higher than that of West China. The low-carbon efficiency of East China assumes an increasing trend in general and the efficiency of West China fluctuates and shows a declining trend in recent years, which bears relation to higher investment of fixed assets. Statistics of the ten years between 2008 and 2017 show that the average growth ratio of fixed assets investment of the logistics industry in East China, Central China, and West China, respectively, is 13.6%, 17.3%, and 23.8%. West China is a strategically important area for China's development in the future. Increasing the economic level not only is a question to cover the gap but also is the security for China's advance to become an economic powerhouse [24]. Therefore, the construction and upgrade of base facilities of this area still need to be enforced unceasingly in order to recover its hub function of traffic and transport in the connection of Eurasian Land Bridge.

5.3. *Efficiency Configuration of the Low-Carbon Logistics Industry.* Combining the above calculated provincial comprehensive efficiency with the five explanatory variables, this research conducted a specific analysis by using fsQCA as follows.

5.3.1. *Calibration.* In the fsQCA method, it needs to determine the fuzzy set, which is different from the routine variables and must be calibrated, namely, to assign a value to the set as the membership degree [3]. For calibration, combining theory with practical knowledge or standards, three thresholds for full membership, full nonmembership, and the crossover point need to be set. Then every variable is converted to a degree of set membership between 0 and 1. This research sets three anchor points of the five explanatory variables and high efficiency of the logistics industry, respectively, as upper quartile, average of upper quartile and

lower quartile, and lower quartile in the sample data sequence [31]. The calibration principle of the nonhigh efficiency is the opposite of high efficiency. After the anchor points have been set, all variables will be calibrated with the calibration function in the software fsQCA 3.0.

5.3.2. *Results.* Firstly, an analysis of necessary condition is performed, which is to test if the single condition (nonstable included) could become the necessary condition of high efficiency. It depends on the consistency value of the result, when the value is above 0.9, just like the coefficient significance of regress analysis, the variables can be thought of as the necessary condition of the explained results. Through the software fsQCA 3.0 to test the data from 2008 to 2017 year by year for the necessary condition of operation, it has been obtained that all the values of consistency between single variables and the explained variables are less than 0.9, which means the data does not constitute necessary condition. And this demonstrates that all the explanatory forces of single antecedents for high (or nonhigh) efficiency are weaker, so these antecedents need to bring into fsQCA for configuration.

According to the commonly used setting method, the frequency threshold is set to 1, the consistency threshold is set to 0.8, and the proportional reduction in inconsistency (PRI) is set to 0.70 [32]. The fsQCA analysis is conducted on the data from 2008 to 2017 year by year. The numbers of high-efficiency cases, nonefficient cases, and the overall coverage (OCV) are shown in Table 5.

As can be seen in Table 5, from 2008 to 2014, the number of high-efficiency cases is relatively small, and the coverage (CV) is between 0 and 0.38. Among them, the five-year average from 2008 to 2012 is less than 0.2, so path analysis is of little significance. However, in the past three years (i.e., 2015–2017), the number of high-efficiency cases has increased significantly, with more than 9 high-efficiency cases in the three years, and the configuration coverage (CV) is 0.580, 0.578, and 0.552, all above 0.550. Therefore, the following is a specific analysis of the path of 2015–2017.

The fsQCA can produce three results: complex solution, parsimonious solution, and intermediate solution. It is generally considered that the intermediate solution can best reflect the research results, and if the antecedent condition appears in both the parsimonious solution and the intermediate solution, it is the core condition; if only the intermediate solution appears, it is considered the peripheral condition [3].

If the presence or absence of the five conditional variables may improve the efficiency of the logistics industry, the operation of fsQCA software can obtain the configuration (path) with high efficiency and nonhigh efficiency, as well as the consistency (CS), overall solution consistency (OCS), and overall solution coverage (OCV). The high-efficiency configuration of 2015–2017 is shown in Table 6.

Taking 2017 as a sample, three high-efficiency configurations (showed in Table 6) were obtained through running the software fs/QCA, which consistency are, respectively, 0.851, 0.872, and 0.901. It indicates that all the three

TABLE 4: Regional comprehensive and average efficiency from the perspective of low carbon in 2008–2017.

Annual efficiency value	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Mean
Eastern comprehensive efficiency	0.623	0.664	0.718	0.738	0.753	0.689	0.718	0.760	0.777	0.795	0.724
Central comprehensive efficiency	0.631	0.632	0.631	0.621	0.659	0.661	0.691	0.700	0.718	0.740	0.668
Western comprehensive efficiency	0.486	0.525	0.512	0.503	0.522	0.509	0.463	0.468	0.455	0.416	0.486
Mean of combined efficiency	0.580	0.608	0.623	0.625	0.648	0.621	0.625	0.645	0.652	0.652	0.628
Mean of pure technical efficiency	0.692	0.689	0.693	0.692	0.719	0.706	0.718	0.737	0.751	0.751	0.715
Mean of scale efficiency	0.844	0.888	0.902	0.905	0.902	0.887	0.879	0.879	0.869	0.864	0.882

TABLE 5: Analysis results of cases using fsQCA in 2008–2017.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of high-efficiency cases	3	1	2	2	1	3	4	9	10	10
Overall coverage (OCV)	0.172	0.113	0.195	0.153	0.176	0.214	0.379	0.580	0.578	0.552
Number of nonhigh-efficiency cases	5	1	7	5	11	6	5	6	9	9
Overall coverage (OCV)	0.372	0.145	0.342	0.272	0.480	0.342	0.255	0.374	0.605	0.517

TABLE 6: High-efficiency configuration of the regional logistics industry in 2015–2017.

Configuration	Solution								
	2015		2016			2017			
	1	2	1a	1b	2	1a	1b	2	
Management level (5A)	●	⊗	●	●	⊗	●	●	⊗	●
Economic environment (GDP)	●	●	●	⊗	●	●	⊗	●	●
Opening to the outside world (open)	●	⊗	●	⊗	⊗	●	⊗	⊗	⊗
Regulations and rules (Regu)		●		●	●		●		●
Scientific and technological innovation (R&D)	●	●	●	⊗	●	●	⊗	●	●
Consistency	0.907	0.899	0.926	0.844	0.905	0.851	0.872	0.901	
Raw coverage	0.475	0.180	0.435	0.071	0.160	0.415	0.080	0.142	
Unique coverage	0.401	0.105	0.367	0.021	0.071	0.363	0.044	0.089	
Overall solution consistency	0.914		0.933			0.878			
Overall solution coverage	0.580		0.578			0.552			

Black circles indicate the presence of a condition, and circles with “x” indicate its absence. Large circles indicate core conditions; small circles indicate peripheral conditions. Blank spaces indicate “do not care.”

configurations are sufficient condition. The overall solution consistency (OCS) is 0.898, and it further indicates that the three configurations which covered most cases are indeed sufficient condition of high efficiency. It follows from the fact that the overall solution coverage (OCV) is 0.552; the three configurations explained the reason of 55.2% high efficiency.

The situation of nonhigh-efficiency configuration is shown in Table 7 (for the year of 2015, set the consistency threshold as 0.77). The result of that in 2017 shows that there are 2 nonhigh-efficiency configurations (showed in Table 7). The consistency of configuration 1 is 0.854, which indicates that this configuration is the sufficient condition of the nonhigh efficiency, and the overall solution coverage (OCV) is 0.517, which means that this configuration explains the reason of 51.1% nonhigh efficiency. As for configuration 2, the consistency is 2, whereas the overall solution coverage (OCV) is only 0.101 and only Henan case can be included. In 2015 and 2016, there are, respectively, 3 and 1 nonhigh-efficiency configurations. Their overall consistency (OCS) is, respectively, 0.790 and 0.834, which indicates that they are sufficient conditions of nonhigh efficiency.

6. The Analysis of Research Result

6.1. The Main Path with High Efficiency Conspicuously Emerges. In association with Tables 5 and 6, since 2015, the paths of high efficiency of the logistics industry have formed preliminarily. By the analyzing the core conditions that constitute variable, we can sum up two paths. One is open management type (configuration 1 in 2015 and configuration 1a in 2016 and 2017; at the same time, configuration 1b in 2016 and 2017 just have one case and display a higher management level, for this reason, which are sorted into this type). The other is economy-oriented type (configuration 2 of that in 2015, 2016, and 2017).

6.1.1. Open Management-Type Path. This is a quite solid main path that had formed in the three years (marked by a shadow background). In the configuration of “5A × GDP × Open × R&D,” high operation and management (5A) and high openness (Open) are two core conditions of high efficiency, and high economic environment (GDP) and high scientific and technological innovation

TABLE 7: Nonhigh-efficiency configuration of the regional logistics industry in 2015–2017.

Configuration	Solution					
	2015		2016		2017	
	1a	1b	2	1	1	2
Management level (5A)	⊗	⊗	●	⊗	⊗	●
Economic environment (GDP)	⊗	⊗	●	⊗	⊗	●
Opening to the outside world (open)		⊗	⊗		⊗	⊗
Regulations and rules (Regu)	⊗		⊗	⊗	⊗	⊗
Scientific and technological innovation (R&D)	⊗	⊗	●	⊗	⊗	●
Consistency	0.800	0.763	0.815	0.834	0.854	0.800
Raw coverage	0.555	0.544	0.129	0.605	0.517	0.101
Unique coverage	0.090	0.079	0.094	0.605	0.477	0.061
Overall solution consistency		0.790		0.834		0.841
Overall solution coverage		0.728		0.605		0.578

(R&D) are peripheral conditions. The sufficiency of this kind of path indicates that the level of operation and management and the degree of opening play an important role in increasing the efficiency of the logistics industry. The cases covered by this path in the three years are exactly the same. They are such provinces in East China as Jiangsu, Guangdong, Zhejiang, Fujian, Shanghai, Shandong, and Liaoning. As for the other configuration mode, the coverage is lower. This main path’s formation reflects that the management mode of the logistics industry of every region is turning from extensive to intensive, its idea is turning from close to open, and its science and technology are turning from traditional to modern. This is the result of the leading and support of the national logistics policies for many years also is an initial appearance of the effects of carrying out *Medium and long-term planning for logistics industry development (2014–2020)*.

The A-class logistics enterprise’s evaluation and identification are organized and implemented by the China Federation of Logistics and Purchasing. By January 2019, 27 batches of 5680 A-class enterprises have passed the evaluation and identification. More and more logistics enterprises that represent the direction and level of the development of the logistics industry have entered the rank of A-class logistics enterprise. From the first batch of 26 enterprises that passed identification to August 2018, the 496 enterprises of the 26th batch (79 enterprises upgraded included) that passed identification, the amount of A-class logistics enterprise grew rapidly, and the identification work was advanced continuously. Among the logistics enterprises across the country, this situation really has promoted communication and study, demonstration, and lead, and at the same time, it has played a positive role in promoting the development of logistics industry in the way of standardization, modernization, and scale. By improving the level of logistics management, the efficiency of regional and even national logistics industry has been significantly improved.

Meanwhile, in order to play a better role, the high level of operation and management must associate with the other core condition-opened regional environment. Yu et al. [33] hold that the international trade influences the productivity of both trade parties, even the third party. Particularly, with regard to the import part, the existence of import learning effect and competitive effect impels the enterprise to reduce

the cost and reform productive idea to extremely promote the productivity of enterprise. Therefore, in a certain region, the opened regional environment will certainly drive the whole logistics industry to increase the management awareness and management level; as a result, the high efficiency of the logistics industry will be realized.

In the empirical results, for those seven provinces and municipalities, besides the high level of operation and management and the high open degree, their indexes of economic environment and R&D are higher too, and R&D index reflects the level of scientific and technological innovation. But, as the peripheral condition, they only play the auxiliary and secondary roles. The government’s rules and regulations did not appear, so the fact indicates that the investment of environmental pollution treatment for CO₂ emission of logistics industry did not produce a benefit. The development of the logistics industry in those regions depends on their own internal strength so that it is sustainable. In addition, the 1b configuration in 2016 and 2017 only includes the case of Jiangxi, and the efficiency is mainly achieved through the level of logistics management and nonhigh scientific and technological innovation.

6.1.2. Economy-Oriented Path. Configuration 2 in all the years of 2015, 2016, and 2017 includes the two provinces of Henan and Hebei, and all the constituent factors are “~5A × GDP × ~Open × Regu × R&D.” The core factors and peripheral condition of that in 2016 are not the same as that in 2015 and 2017, but in the three years, the nonhigh operation and management is their common factor. Specifically, in 2015 and 2017, the low-carbon logistics efficiency of the two provinces is due to the comparative advantage of the economic environment, which plays the role of the core factors. In 2016, the government’s rules and regulations as well as scientific and technological innovation are core factors. The economic environment takes the role of peripheral condition.

The regional economic situation is the base of logistics development, but if it just depends on that base, the long-term influence on increasing logistics efficiency is insufficient. The coverage of this path is low, so it should be

considered to convert the development thinking to depending on increasing the level of operation and management to increase logistics efficiency.

6.2. Different Nonhigh-Efficiency Path in Different Years. The nonhigh-efficiency path possesses asymmetry to high efficiency and the paths in different years are not the same. In 2015, configuration 1a is “ $\sim 5A \times \sim GDP \times \sim Regu \times \sim RandD$,” while configuration 1b is “ $\sim 5A \times \sim GDP \times \sim Open \times \sim RandD$,” in which the factors of “ $\sim Regu$ ” and “ $\sim Open$ ” are alternative, “ $\sim RandD$ ” is the common core factor of two paths, and “ $\sim 5A$ ” and “ $\sim GDP$ ” are the common peripheral factors. With comparison to configuration 1 in 2016 and 2017, the peripheral factors of “ $\sim 5A$ ” and “ $\sim GDP$ ” are their common factors, whereas the core factors of that in 2016 are “ $\sim Regu$ ” and “ $\sim RandD$,” and core factors of that in 2017 are “ $\sim Open$ ” and “ $\sim Regu$.” This kind of situation in the three years is different. Further analysis is performed on configuration 1a in 2015 and configuration 1a in 2016 and 2017. The coverage, respectively, is 0.555, 0.60, and 0.517, while there are 7 commonly covered cases includes Qinghai, Hainan, Yunnan, Guizhou, Gansu, Jilin, and Ningxia, which indicates that the explanatory force on nonhigh efficiency is stronger. All the consistency is above 0.8, which indicates that these configurations constitute the sufficient condition of nonhigh efficiency.

In 2015 and 2017, there are two identical configuration 2, that is “ $5A \times GDP \times \sim Open \times \sim Regu \times RandD$,” and the core factor is “ $\sim Open \times \sim Regu$.” It can be seen that the reasons that cause high efficiency mainly lie on the nonhigh degree of opening to the outside world and nonhigh rules and regulations, whereas the coverage of this configuration is lower. The coverage in 2015 is 0.129; there are only two cases of Hubei and Sichuan. The coverage in 2017 is 0.101; there is only one case of Hunan.

7. Conclusion and Enlightenment

In recent years, led and driven by a series of China’s logistics policies, the national logistics industry is developing rapidly; meanwhile, concerning the actual efficiency of the logistics industry, there is a big difference among the different provinces and municipalities. At the end of February 2019, China’s government issued *the opinions on promoting the high-quality development of logistics industry and forming strong domestic market*. The opinion points out that the high-quality development of logistics is an important component of the high-quality development of economy and is an indispensable important strength to drive the high-quality development of economy as well. Therefore, we should not only understand the influence of logistics on economy but also understand the fact that the high-quality development of the logistics industry has become an important handle of improving industrial development and investment environment for now and a period in future, which is the key to cultivating the new energy for the development of regional economy.

7.1. The Main Research Conclusions. From configuration perspective, this research analyzes the constitution of the path with high efficiency and nonhigh efficiency of the low-carbon logistics industry and explored more enlightenment for the development of the logistics industry in different provinces and municipalities. The main research conclusions are as follows:

- (1) In recent years, the development of the efficiency of China’s low-carbon logistics industry assumed an increasing trend, concrete representations were that the scale efficiency is relatively high, and with a slight fluctuation, the pure technology efficiency is lower and still has a quite big increase space.
- (2) In the three years since 2015, two paths of high efficiency had formed. Concerning the path of management open type, its coverage is higher; the core factors of increasing logistics efficiency are the level of operation and management and the degree of opening to the outside world. Concerning the path of economy-oriented type, there are fewer covered cases. Influencing and driving the development of the regional logistics industry mainly depend on the relative advantage of economic environment.
- (3) In an inefficient path conforming to the asymmetric character and higher coverage, the core factors are nonhigh scientific and technological innovation and the level of opening and the common peripheral factors are nonhigh operation and management and economic level.

The theoretic contribution mainly manifests as follows: It is an innovation to consider the influence of management level on the efficiency of logistics industry. This research measured the operation and management level of the logistics industry with the total amount of regional A-class logistics enterprises and provided a better reference for future research to choose index. This research applied the QCA method which is more suitable for explaining the social phenomenon and brought the configuration thought into the empirical analysis on the influence factor of low-carbon logistics so as to provide a new theoretical perspective for explaining the phenomenon that the factors got from the previous literature by different scholars are contrary to each other and lay a foundation for the further research on the high-quality development of logistics industry.

7.2. The Main Enlightenment. The main enlightenment on the regional development is shown in the following aspects:

- (1) The internal strength to increase the development of low-carbon logistics with high efficiency comes from the improvement of operation and management and open to the outside world. Presently, formed in the different provinces of East China, the “management open” type configuration provides a better experience and clear path for the development of the national logistics industry.

For the central and western regions of China, the key to push the development of logistics industry is to promote the development of high-quality logistics as an opportunity, open mind, learn benchmarking, and improve the level of management.

- (2) Though nonhigh-efficiency configuration and high-efficiency configuration show asymmetry, the regions of West China display nonhigh-efficiency configuration generally, and the level of management and the total amount of economy are common peripheral factors which constitute the path. In comparison with the core factors of two high-efficiency paths, the commonness is worth getting more attention. After all, logistics serves the development of the whole economy, so the better economic environment is obvious stimulation and promotion for the increase of low-carbon efficiency, which is a traditional path; however, if we consider adopting the transformation development which depends on improving the level of operation and management, it should be very beneficial to increasing regional logistics efficiency. It is effective to pay attention to training, strengthen communication, and take community action as the leading measure.

7.3. Insufficient Research. Though this research has a certain theoretical and practical significance, there are still many defects. For instance, the analysis of influencing factors is not combined with more indexes, which may cause some paths to remain undetected, such as degree of marketization, space contiguity, and industrial cluster. Besides, the growth of carbon emission of logistics industry not only has a relation with fossil energy, which is directly consumed in logistics, but also has a close relationship with the carbon emission of other industries; it is worth being concerned in the further study.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (Grant no. 72001182), the Ministry of Education of Humanities and Social Sciences (Grant nos. 18YJA630071 and 19YJC630159), the Special Fund for Humanities and Social Sciences of Southwest Petroleum University (Grant no. 2020RW037), and the Business Management Advantage Discipline Climbing Project of Shanxi Province Higher Education (Grand no. 4[2018], Shanxi Province Teaching Research).

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