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Research Article

Evaluation of Low-Carbon Scientific and Technological Innovation-Economy-Environment of High Energy-Consuming Industries

Zhao Zhao,[1,2] Zheng Liu,[1] Tianqi Peng,[1] Lingling Li,[3] and Yuanjun Zhao[4,5]

[1]*School of Management, Shanghai University of Engineering Science, Shanghai 201620, China*
[2]*Odette School of Business, University of Windsor, Canada N9B 3P4*
[3]*Department of Central Laboratory, Shanghai Children's Hospital, Shanghai Jiao Tong University, Shanghai 200062, China*
[4]*School of Accounting, Nanjing Audit University, Nanjing 211815, China*
[5]*Institute of Intelligent Management Accounting and Internal Control, Nanjing Audit University, Nanjing 211815, China*

Correspondence should be addressed to Zheng Liu; 03140011@sues.edu.cn

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The coordination of scientific and technological innovation with economy and environment is conducive to the sustainable development of high energy-consuming industries. Under the background of realizing the "carbon peak and neutrality" goal in China, this paper constructs the evaluation index system of scientific and technological innovation, economy, and environment of high energy-consuming industries. Based on the coupling coordination theory, this paper analyzes the coordinated development of scientific and technological innovation, economy, and environment of high energy-consuming industries from 2011 to 2019 and analyzes the factors restricting the coordinated development of the three systems. The results show that with the emphasis on scientific and technological innovation and ecological environment, the coordination degree of the complex system of scientific and technological innovation, economy, and environment of high energy-consuming industries is gradually increasing. R & D investment, the proportion of total industrial output value in GDP, and coal consumption per 10000 yuan of industrial output value are the main influencing factors of the coordination of the three systems.

1. Introduction

With the excessive consumption of resources, excessive emission of greenhouse gases, and other environmental problems outstanding, China proposes to achieve carbon peak in 2030 and carbon neutralization in 2050. As China's basic industry, high energy consumption industry has made great contributions to China's economic take-off and infrastructure construction. These six high energy-consuming industries, chemical raw materials and chemical product manufacturing industry, nonmetallic mineral products industry, ferrous metal smelting and rolling processing industry, nonferrous metal smelting and rolling processing industry, petroleum processing coking and nuclear fuel processing industry, and power and heat production and supply industry, contribute about one-third of the total industrial output value. At the same time, they also bring "high pollution, high energy consumption, and high material consumption." Problems such as the solidification of product structure, low energy efficiency, and weak low-carbon transformation of traditional high energy-consuming enterprises have become increasingly prominent, which objectively requires enterprises to continue to promote scientific and technological innovation and technological progress. Promoting the scientific and technological innovation of high energy-consuming industries and the coordinated development of economy and environment is conducive to solving the problems of environmental constraints, reducing carbon emissions, and realizing the goal of " carbon peak and neutrality."

In recent years, synergetic theory and order parameter principle are widely used in the evaluation of collaborative development in the fields of industrial system, interindustry, interindustry and regional, industrial cluster system, and so on. Yan et al. quantitatively studied the coupling and coordinated development of energy, economy, and ecological environment in Australia from 2007 to 2016 by constructing a coupling and coordination model based on coupling theory [1]. Xu et al. used the extended Cobb Douglas function to study the relationship between the coordination degree of the world economic forum system of 31 provinces in China and regional economic development during 2007-2018 [2]. Han et al. established a comprehensive index system and coupling coordination index (CCI) and discussed the coordination relationship within the economic resource environment (ERE) system of Beijing Tianjin Hebei Urban Agglomeration from 2008 to 2017 [3]. Xie et al. established the evaluation index system of tea industry tourism ecological environment system, determined the weight coefficient of each index by entropy weight method, and evaluated the coupling coordination degree of Fujian Province and 9 cities by constructing the coupling coordination model from 2011 to 2019 [4].

Innovation is the main engine of growth in more and more economies. Thompson introduced a collective social capital growth model based on innovation, which theoretically expressed the view that social capital affects innovation and then economic growth [5]. Martin developed the concept of elasticity and tested its usefulness as a help to understand the response of regional economies to major recession shocks [6]. By constructing an endogenous growth model including R & D distortion parameters, Jones and Williams pointed out that the investment in science and technology R & D in decentralized economies is unreasonable relative to the social optimal level [7]. Based on the panel data of 11 coastal provinces and cities in China from 2006 to 2015, Li et al. calculated the efficiency of marine scientific and technological innovation by using stochastic frontier analysis (SFA). The results show that the scale of marine scientific research institutions, the structure of scientific researchers, the development degree of marine economy, and the structure of marine industry have a significant positive impact on the efficiency of marine scientific and technological innovation [8]. Cheng et al. selected 29 provinces and cities in China from 2009 to 2018 and used the feasible generalized least squares (FGLS) method to empirically analyze the impact of the new generation of information technology on the sustainable development of regional economy [9]. Liu et al.'s study was based on the essence of the development of green finance. This paper uses fuzzy principal component analysis to construct the evaluation index system of green finance. Taking the data of three provinces and cities in the Yangtze River Delta from 2015 to 2019 as an example, this paper uses QAP analysis to study the impact of financial technology on the regional development of green finance [10].

In addition, scholars also put forward corresponding strategies for carbon emissions in different industries. Liu et al. established a game model to solve the problem of agricultural carbon emission and compared the optimal decision-making and profit under three conditions: whether manufacturers invest in emission reduction and whether retailers invest in emission reduction under decentralized decision-making or centralized decision-making [11]. Wongsapai and Daroon investigated and verified the energy consumption and efficiency data from the database of designated factories in Thailand and analyzed and estimated the greenhouse gas emission reduction potential [12]. In order to reduce the environmental pollution caused by abandoned household medical devices, Liu et al. constructed an evolutionary game model between the government and household medical device enterprises based on the dynamic punishment and dynamic subsidy measures taken by the government. This paper studies the strategic choice of the government and domestic medical device enterprises from the perspective of system dynamics [13].

Generally speaking, scientific and technological innovation not only drives economic development but also brings some help to the improvement of ecological environment. Some progress has been made in the research on the coupling and coordination between scientific and technological innovation and economy and the composite system of scientific and technological innovation and environment, but the existing research is also insufficient [14]. The existing research seldom considers the coupling and coordination among the three systems of high energy-consuming industry, scientific and technological innovation, economy, and environment, as well as the internal mechanism of the coordinated development of the three systems, which is difficult to reflect the real development status of the three systems [15–17]. Under the new situation of realizing the goal of "carbon peak and neutrality," it is necessary to conduct in-depth quantitative analysis on the interaction between technological innovation, economy, and environment of high energy-consuming industries [18–21].

Based on this, from the perspective of sustainable development of high energy-consuming industries, this paper takes the "scientific and technological innovation-economy-environment" composite system as the research object, constructs the evaluation index system of three subsystems based on the coupling coordination theory, establishes the coordination degree model of the composite system, makes an empirical study on the statistical data of high energy-consuming industries from 2011 to 2019, and calculates the scientific and technological innovation subsystem. The coupling and coordination of economic subsystem and environmental subsystem analyze the factors affecting the coordination of the three, so as to explore a new way for the coordinated development of scientific and technological innovation, economy, and environment in high energy-consuming industries, in order to provide reference for transforming the development trend of China's high energy-consuming industries, accelerating technological innovation, promoting economic progress, and improving the environment. It has important theoretical value and practical significance for exploring the basic problems of innovation driven and coordinated development of economic development and ecological environment in high energy-consuming industries.

2. Evaluation Index System and Evaluation Model

2.1. Evaluation Index System. Scientific and technological innovation and economic and environmental development are affected by many factors. The establishment of the index system should not only effectively represent the characteristics of the subsystem but also be measurable and desirable. Therefore, in order to study the coordination relationship between scientific and technological innovation system, economic system, and environmental system of high energy-consuming industries, under the principle of scientificity and systematicness, considering the availability of data and drawing on the practices of Wu, etc., the full-time equivalent of R & D personnel is selected to account for the number of labor force. The R & D investment intensity, the ratio of effective invention patents to R & D investment, and the proportion of new product sales revenue to industrial sales revenue are three indicators to measure the development status of scientific and technological innovation in high energy-consuming industries in Shanghai. Using Zheng's practice for reference, the proportion of total industrial output value to regional GDP, the growth rate of total industrial output value, the maintenance and appreciation rate of capital, and the economic development level of high energy-consuming industries are measured by the proportion of fixed asset investment in the total industrial output value. Using the practices of Zhou and Xiong for reference, the environmental status is measured by five indicators: ammonia nitrogen emission of industrial wastewater, sulfur dioxide emission of industrial waste gas, solid waste generation, coal consumption per 10000 yuan of industrial output value, and comprehensive utilization rate of industrial solid waste. The detailed evaluation index system is shown in Table 1.

2.2. Evaluation Model

2.2.1. Data Standardization Processing. Due to the different measurement standards and statistical caliber of each index, in order to eliminate the impact of index dimension, the deviation standardization method is used to standardize the statistical data. The data standardization processing formula of scientific and technological innovation, economy, and environment subsystem is as follows:

$$\text{Positive indicator}: X_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}}, \tag{1}$$

$$\text{Negative indicator}: X_{ij} = \frac{x_{\max} - x_{ij}}{x_{\max} - x_{\min}}, \tag{2}$$

where X_{ij} represents the standardized value of the j-th index of the i-th evaluation object in the evaluation index system, and $X_{ij} \in [0, 1]$; the greater the value of X_{ij}, the greater the contribution to the system; $x_{\max}$ represents the upper limit value in the evaluation index, and $x_{\min}$ represents the lower limit value in the evaluation index.

2.2.2. Determine Index Weight. In order to ensure the objectivity of the data and overcome the influence of subjective factors, the entropy method is used to determine the weight of each index, and the calculation steps are as follows.

(1) Calculate the proportion of each evaluation index

$$p_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}.. \tag{3}$$

(2) Calculate the entropy of each index

$$A_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij}.. \tag{4}$$

Among them, $k = 1/\ln n$.

(3) Determine the weight of each evaluation index

$$w_{ij} = \frac{1 - A_j}{\sum_{j=1}^{m} \left(1 - A_j\right)}, \tag{5}$$

$$\sum_{j=1}^{m} w_{ij} = 1. \tag{6}$$

2.2.3. Coupling Model. Synergetics is a widely used modern cross-sectional discipline proposed by German physicist Haken. It studies the composite system composed of a large number of subsystems interacting in a complex way. The composite system synergy model can scientifically measure the system synergy, which is favored by the majority of researchers. The determination of order parameters is conducive to grasp the development and evolution direction of low-carbon scientific and technological innovation, economy, and environment composite system of high energy-consuming industries. Based on Shi's analysis on the coupling between regional logistics capacity and regional economic development, the coupling degree model of scientific and technological innovation and environmental subsystem of high energy-consuming industry is as follows:

$$C = \left(\frac{a \times b \times c}{(a + b + c/3)^3} \right)^{1/3}. \tag{7}$$

Among them, C is the coupling degree among the three systems, and $C \in [0, 1]$. The smaller the value of C, the worse the correlation and coupling degree between the scientific and technological innovation subsystem, the economic subsystem, and the environmental subsystem, the more uncoordinated they are and develop into a disordered state. The greater the value of C, the better the correlation and coupling between scientific and technological innovation subsystem, economic subsystem, and environmental subsystem, the more coordinated they are and develop to an orderly state.

2.2.4. Coupling Coordination Model. The coupling coordination degree model can reflect the degree of orderly and coordinated development among scientific and technological innovation, economic, and environmental systems of high energy-consuming industries. The formula is as follows:

Table 1: Evaluation index system.

Subsystem	Index	Index attribute
Scientific and technological innovation subsystem	Proportion of R & D personnel full-time equivalent in labor force	+
	R & D expenditure intensity	+
	Number of valid invention patents	+
	New product sales revenue	+
Economic subsystem	Proportion of total industrial output value in regional GDP	+
	Growth rate of total industrial output value	+
	Rate of capital accumulation	+
	Proportion of fixed asset investment in total industrial output value	+
Environment subsystem	Discharge of ammonia nitrogen in industrial wastewater	-
	Sulfur dioxide emission in industrial waste gas	-
	Solid waste generation	-
	Coal consumption per 10000 yuan of industrial output value	-
	Comprehensive utilization rate of industrial solid waste	+

Table 2: Classification of coupling degree coordination.

Z value interval of coupling coordination degree	Coordination level	Coupling coordination degree
(0.0-0.1)	1	Extreme disorder
(0.1-0.2)	2	Severe imbalance
(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 coordinate
(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

(1) Comprehensive evaluation index model

$$T = \lambda_1 a + \lambda_2 b + \lambda_3 c, \tag{8}$$

where T represents the comprehensive evaluation index of scientific and technological innovation, economy, and environment system, reflecting the contribution degree of the three. λ_1, λ_2, and λ_3 are undetermined coefficients, and $\lambda_1 + \lambda_2 + \lambda_3 = 1$. Considering the current situation of scientific and technological innovation, economy, and environment development of high energy-consuming industries, assuming that the three systems have the same status, take $\lambda_1 = \lambda_2 = \lambda_3 = 1/3$.

(2) Coupling coordination model

$$Z = \sqrt{C \times T}, \tag{9}$$

where Z represents the coordination degree of scientific and technological innovation, economy, and environment system, and $Z \in [0, 1]$. The greater the value of Z, the more coordinated the scientific and technological innovation subsystem, economy subsystem, and environment subsystem. The smaller the value of Z, the more uncoordinated the scientific and technological innovation subsystem, economic subsystem, and environmental subsystem. Based on Liao's classification rules, the coordination level of coupling degree is divided as shown in Table 2 below.

3. Empirical Analysis

3.1. Data Sources. The statistical data are related to scientific and technological innovation, economy, and environment come from China Statistical Yearbook, China Environmental Statistical Yearbook, China Scientific and Technological Statistical Yearbook, and China Industrial Statistical Yearbook from 2011 to 2019. Some index data are converted by formula. The missing values of some indicators in some years are supplemented by interpolation.

3.2. Determine Index Weight. On the basis of searching the original data from 2011 to 2019, the index data of scientific and technological innovation subsystem, economic subsystem, and environmental subsystem of high energy-consuming industry are processed, and the weight of each index is determined by entropy weight method, so as to lay a foundation for further calculation of system coupling coordination degree. The weight of each index is shown in Table 3.

3.3. Analysis of Overall Development Level. On the basis of determining the weight of each index, the comprehensive development index of scientific and technological innovation, economy, and environment system is obtained. Among them, a is the comprehensive development level of scientific and technological innovation, b is the comprehensive development level of economy, and c is the comprehensive development level of environment. On the basis of calculating the

Table 3: Weight of each index.

Subsystem	Index	Weight
Scientific and technological innovation subsystem	Proportion of R & D personnel full-time equivalent in labor force	21.27%
	R & D expenditure intensity	17.37%
	Number of valid invention patents	34.21%
	New product sales revenue	27.15%
Economic subsystem	Proportion of total industrial output value in regional GDP	37.09%
	Growth rate of total industrial output value	21.80%
	Rate of capital accumulation	21.16%
	Proportion of fixed asset investment in total industrial output value	19.95%
Environment subsystem	Discharge of ammonia nitrogen in industrial wastewater	26.12%
	Sulfur dioxide emission in industrial waste gas	25.81%
	Solid waste generation	17.89%
	Coal consumption per 10000 yuan of industrial output value	16.67%
	Comprehensive utilization rate of industrial solid waste	13.50%

Table 4: Comprehensive development level and coupling coordination dispatching of each system.

Year	a	b	c	C	T	Z	Degree of coordination
2011	0.001	0.801	0.335	0.137	0.337	0.215	Moderate disorder
2012	0.133	0.632	0.381	0.694	0.336	0.483	Verge of disorder
2013	0.271	0.589	0.360	0.691	0.344	0.488	Verge of disorder
2014	0.396	0.538	0.414	0.907	0.404	0.605	Primary coordination
2015	0.501	0.412	0.338	0.483	0.316	0.391	Mild disorder
2016	0.665	0.356	0.548	0.966	0.506	0.699	Primary coordination
2017	0.765	0.415	0.538	0.970	0.565	0.740	Intermediate coordination
2018	0.873	0.493	0.670	0.980	0.744	0.854	Good coordination
2019	0.993	0.123	0.742	0.323	0.663	0.463	Verge of disorder

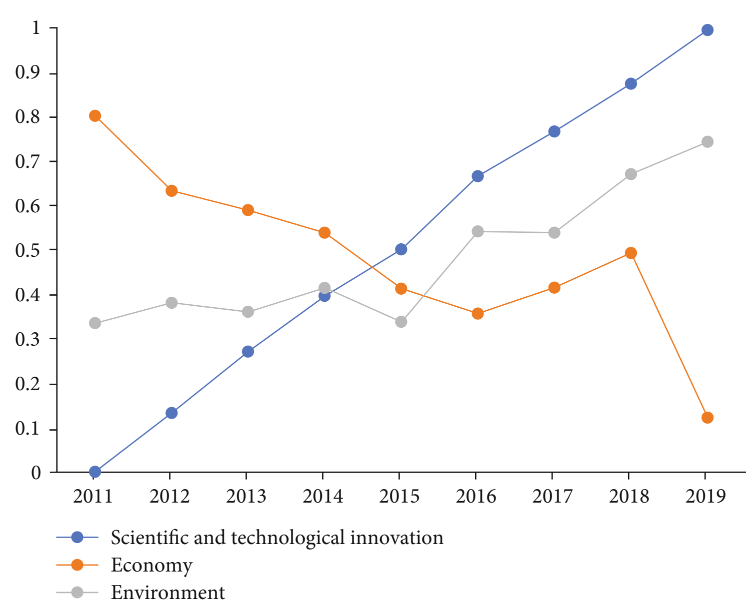

Figure 1: Comprehensive development level of scientific and technological innovation, economy, and environment of high energy-consuming industries.

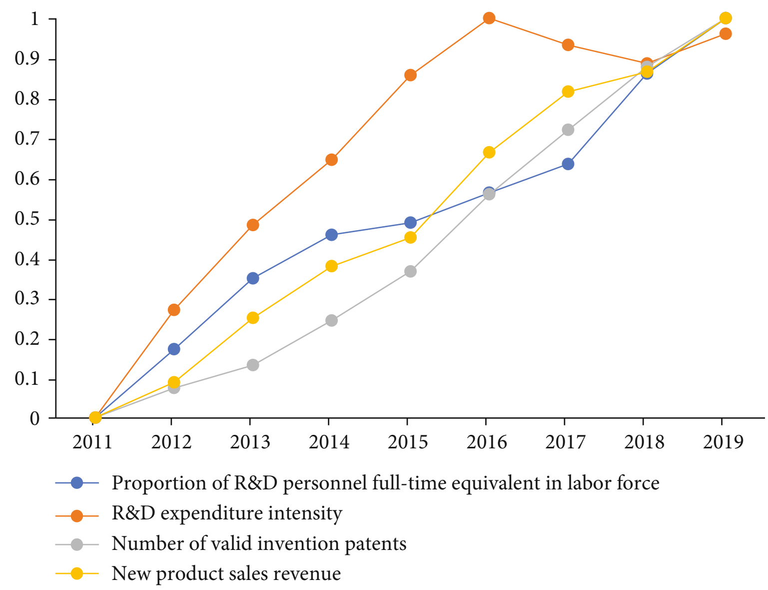

Figure 2: Order degree of scientific and technological innovation subsystem.

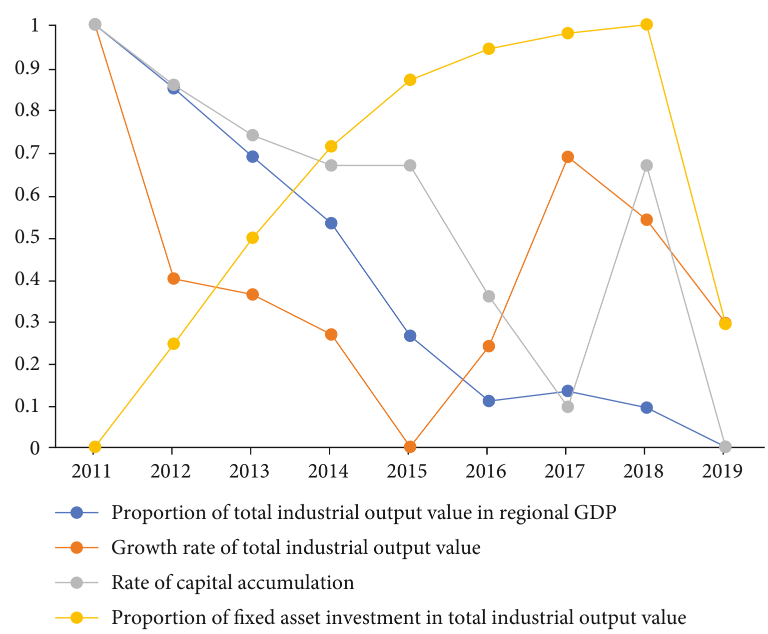

Figure 3: Order degree of economic subsystem.

comprehensive development index, the coupling coscheduling among scientific and technological innovation subsystem, economic subsystem, and environmental subsystem is calculated by bringing in formulas (7)–(9). The results are shown in Table 4 and Figure 1.

It can be seen from Table 4 above that from 2011 to 2019, the comprehensive development level of scientific and technological innovation, economy, and environment of high energy-consuming industries showed a steady upward trend year by year. The economic development lagged behind the development of scientific and technological innovation and ecological environment, which was generally characterized by lagging economic development. From 2011 to 2014, there was a large gap in the overall development level of the three systems, and the development of scientific and technological innovation and ecological environment lagged behind the economic development. The development level of the three systems was ranked as follows: economy>environment>scientific and technological innovation. Since 2015, the comprehensive development level of scientific and technological innovation has exceeded the comprehensive development level of economy and ecological environment, but the economic development level is still higher than the comprehensive development level of ecological environment. At this time, the overall development level of the three systems is as follows: scientific and technological innovation>economy>environment. From 2016 to 2019, the comprehensive development level of

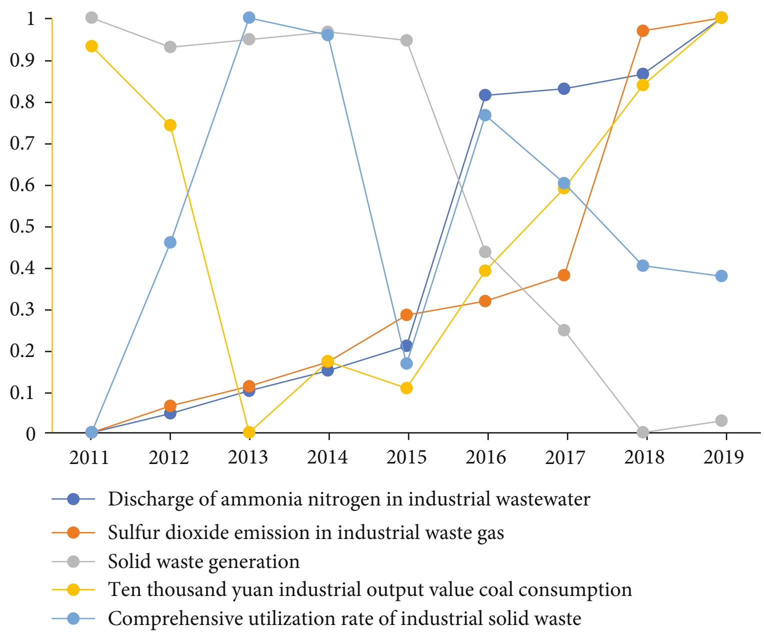

Figure 4: Order degree of environmental subsystem.

ecological environment gradually caught up with and surpassed the economic subsystem but still lagged behind the development level of scientific and technological innovation. The overall development level of the three systems is as follows: scientific and technological innovation>ecological environment>economy. On the whole, since 2010, high energy-consuming industries have attached great importance to the development of ecological environment while scientific and technological innovation and economic development. Scientific and technological innovation, as an important means to promote economic development and improve the level of ecological environment, has contributed an important amount to economic development and environmental construction.

Accordingly, the comprehensive development level of scientific and technological innovation subsystem, economic subsystem, and ecological environment system of high energy-consuming industry is gradually rising, indicating that the internal of scientific and technological innovation subsystem, economic subsystem, and ecological environment system have achieved orderly development and are in a good and orderly growth state, which jointly determines that the coupling and coordination degree of the three systems presents a rising trend.

From 2011 to 2019, the phased evolution characteristics of the coordination degree of scientific and technological innovation, economy, and ecological environment system are obvious. The coordinated development process of scientific and technological innovation, economy, and ecological environment of high energy-consuming industries is divided into three obvious stages.

In the first stage, from 2011 to 2013, the coordination of scientific and technological innovation, economy, and ecological environment system is low, and the three systems are in a state of imbalance. The coordination degree was 0.215 in 2010 and increased year by year. By 2013, the coupling coordination degree of the three systems was 0.488, which is still on the verge of imbalance. At this stage, the coordinated development level of scientific and technological innovation, economy, and ecological environment is low and the development speed is slow. This is because before 2013, the coupling and interaction between scientific and technological innovation, economy, and ecological environment of high energy-consuming industries were weak, and the interaction between them was not obvious. The extensive development mode was adopted to drive the development of the overall economy through the development of high energy-consuming industries, did not pay attention to mastering core technologies, ignored the negative impact on the ecological environment, and produced more pollutant emissions. During this period, the development of scientific and technological innovation subsystem and environment lags behind the economic subsystem, and the three subsystems with low order work together, resulting in the low level of coordinated development of the three, which is in a state of imbalance.

In the second stage, in the five years from 2014 to 2018, the coordination degree of scientific and technological innovation and economic and environmental system of high energy-consuming industries has increased significantly each year compared with the previous year, and the coordination degree has increased from 0.605 in 2014 to 0.854 in 2018. Compared with the first stage, the coordination degree has improved greatly, forming a rapid growth period, indicating the scientific and technological innovation of high energy-consuming industries. The level of coordinated economic and environmental development continued to rise rapidly. Accordingly, the coupling and interaction ability of scientific and technological innovation subsystem, economic subsystem, and environmental subsystem has gradually increased, but the speed of coupling and coordinated development has gradually slowed down in recent years. The comprehensive development level of scientific and technological innovation has gradually surpassed the comprehensive development level of economy and ecological environment, indicating that the position of scientific and technological innovation in economic development has gradually increased and become an important force to promote economic development.

In the third stage, in 2019, the coupling degree of the three systems of high energy-consuming industry, scientific and technological innovation, economy, and environment showed a downward trend compared with the previous year and was on the verge of imbalance. The interaction and coupling ability of these three systems is weak. In 2019, due to the upgrading of Sino US trade friction, insufficient market demand, falling prices of industrial products, rising costs, and other factors, the level of economic development was low. It shows that in the future development process, we should pay attention to the economic benefits brought by science and technology and use core technology to promote the improvement of the comprehensive level of economy and ecological environment.

3.4. Analysis of Influencing Factors Restricting Coupling Coordination. Coordination is a virtuous circle situation formed in order to maximize the effectiveness of the overall system and make each subsystem or module in the system to cooperate, promote, and influence each other. In order to promote the development of the coupling and coordination level of scientific and technological innovation, economy, and environment in the direction of good coordination and finally achieve high-quality coordination, it is necessary to find out the factors restricting the coordinated development of the three in the indicators of each subsystem.

Figure 2 shows the order trend of various indicators of the scientific and technological innovation subsystem. It can be seen that the indicators of the scientific and technological innovation subsystem of China's high energy-consuming industries generally fluctuate and rise by a small margin, and the change trends of the four indicators are basically the same. It can be seen from Figure 2 that in the scientific and technological innovation subsystem, the proportion of full-time equivalent of R & D personnel in the number of labor force, the number of effective invention patents, and the sales revenue of new products are increasing year by year. Increasing the proportion of full-time equivalent of R & D personnel in the number of labor force is conducive to improving the scientific and technological innovation level of high energy-consuming industries, so as to increase the number of effective invention patents and the sales revenue of new products and improve the comprehensive development level of scientific and technological innovation subsystem. From 2011 to 2016, the proportion of R & D investment in the total industrial output value increased year by year, and the growth rate decreased year by year. It showed a downward trend from 2016 to 2018 and then showed an upward trend after 2018. The proportion of R & D investment decreased. Reducing R & D investment will inevitably reduce the development speed of scientific and technological innovation and increase capital investment. R & D and mastering low-carbon technology is the key to reducing carbon emissions and an important means to achieve the goal of "carbon peak and neutrality."

It can be seen from Figure 3 that in the economic subsystem, the proportion of total industrial output value in regional GDP decreases year by year, and other industries develop rapidly and gradually catch up with and surpass the scale of industrial development. Compared with other industries, the growth of total industrial output value is slow. Due to the influence of technology, environment, and other factors, the transformation of old and new industrial kinetic energy is slow, and the industrial structure needs to be optimized and upgraded. The quality and efficiency of development need to be improved, which restricts the improvement of the comprehensive level of the economic subsystem. Both the growth rate of industrial output value and the rate of capital preservation and appreciation have experienced a process of decline, rise, and decline. In the past two years, the growth rate of industrial output value has shown a downward trend, the contribution rate to the total output value has gradually decreased, the development of industrial industry lags, and the reduction of the rate of capital preservation and appreciation has restrained the development of industrial economy to a certain extent. From 2011 to 2018, the industrial fixed asset investment showed an upward trend, but after 2018, the fixed asset investment decreased, and the lack of funds brought obstacles to the development of high energy-consuming industries, which was not conducive to the improvement of the level of industrial economic development.

In order to ensure the sustainable coupling and coordination of the three subsystems, it is also necessary to find out the short board factors restricting environmental development. Figure 4 shows the order trend of each index of the environmental subsystem. It can be seen from Figure 4 that from 2011 to 2019, the emission of ammonia nitrogen in industrial wastewater and sulfur dioxide in industrial waste gas in the environmental subsystem showed an increasing trend year by year, and the generation of industrial solid waste decreased year by year. The high emission of ammonia nitrogen and sulfur dioxide put great pressure on the improvement of ecological environment and the reduction of pollution and carbon, which is not conducive to the realization of the "carbon peak and neutrality" goal. From 2011 to 2013, the coal consumption per 10000 yuan of industrial output value showed a downward trend and increased year by year after 2013. Coal and other fossil energy are the main sources of carbon emission in China. The increase of fossil energy consumption is easy to lead to the increase of carbon emission in China and aggravate environmental pollution.

4. Conclusion

By constructing the synergy degree model of high energy-consuming industry's scientific and technological innovation economy environment composite system, this paper makes an empirical study on the coordinated development of high energy-consuming industry's technological innovation economy and ecological environment. The results show that from 2011 to 2019, the synergy of technological innovation economy environment system of high energy-consuming industries generally shows an upward trend, and the comprehensive development of scientific and technological innovation and ecological environment gradually catch up with and surpass the comprehensive economic development level. The improvement of the comprehensive development level of scientific and technological innovation drives the development of economy and ecological environment, which is directly related to the low order of technological innovation subsystem. It shows that in the development of high energy consumption industry, we should overcome the short board effect in the "barrel principle" and make the subsystems develop together. In addition, in order to promote the scientific and technological innovation of high energy-consuming industries and achieve high-quality coordination of the coupling and coordination level of economy and environment, it is necessary to find out the index factors restricting the coordinated development of the three in each subsystem. Less R & D investment is the factor restricting the development of scientific and technological innovation subsystem, the low proportion of total industrial output value in GDP is the factor restricting the development of economic subsystem, and the increase of coal consumption per 10000 yuan of industrial output value is the factor restricting the development of environmental subsystem.

Taking the high energy-consuming industry as a whole as the research object, this paper studies the coordinated development of low-carbon technological innovation, economy, and environment, without empirical research and comparative analysis on the evolution and difference of the composite system between the six high energy-consuming industries. In the follow-up research, it can be considered to study the collaborative relationship between high energy-consuming industries, so as to provide a certain reference for improving or improving the level of collaborative development among industries.

Data Availability

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

Conflicts of Interest

All authors declare no conflicts of interest in this paper.

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