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Research Article

Construction and Application of Relationship Model between Development of Mining Industry and Carbon Emission of Energy Consumption

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With the world's consensus on low-carbon emission reduction, all walks of life have formulated low-carbon development goals. As a high-energy consumption industry, it is urgent for mining industry to implement the development strategy of low-carbon emission reduction. Therefore, this study tries to provide reasonable suggestions and references for the low-carbon development of the mining industry. Firstly, this study analyzes the industry development, energy consumption, and carbon emission of mining industry from 2000 to 2020. Then, using the Tapio theory, this study constructs the analysis model of decoupling between carbon emission of mining industry and industry growth. The analysis method of decoupling state assignment is proposed for the first time in the model. At the same time, the energy efficiency decoupling index and energy structure decoupling index are introduced to explain the causes of carbon emission decoupling. The research shows that the carbon emission of energy consumption in China's mining industry peaked in 2013, and the energy efficiency decoupling in 2001–2014 is the main driver of carbon emission decoupling. The sharp growth of industrial output value leads to the decoupling of energy efficiency. At present, the improvement of energy efficiency of China's mining industry faces great resistance. At the same time, the inhibition effect of energy efficiency on carbon emissions is limited, and the energy structure will be the main factor to inhibit carbon emissions.

1. Introduction and Literature Review

China is not only the country with the largest energy production and consumption in the world but also the country with the largest carbon emissions [1]. In 2020, China's carbon emissions are 9.9 billion tons. Since 2006, China has been the world's largest carbon emitter [2]. In September 2020, China promised the world that it would achieve carbon peak by 2030 and carbon neutrality by 2060 [3]. The proposal of "double carbon target" puts forward higher requirements for China's mining carbon emission reduction and low-carbon development [4]. As a high-energy consumption industry, it is of great significance to study the carbon emission of energy consumption in China's mining industry and its relationship with the growth of industrial output value and analyze its reasons for the green and low-carbon development of mining industry.

The decoupling theory was originally used in physics to study the comparison of the change trends of two variables. Later, OECD [5] put forward the concept and model of "decoupling" in the economic sense for the first time in the report of *Indicators for Measuring the Decoupling Relationship between Economic Growth and Environmental Impact* and discussed how to reduce or even block the correlation between economic growth and environmental pollution. At present, research mainly focuses on energy conservation and emission reduction, and the decoupling method is applied to different levels, including industry level, regional level, and national level. The later research involves the influencing factors of carbon emission and further refines the decoupling indicators into primary decoupling and secondary decoupling [6]. Primary decoupling is the decoupling between economic growth and natural resources, while the decoupling between economic growth and environmental pollution is called secondary decoupling. Tapio constructed a complete decoupling index system and studied the decoupling between the development of the European transportation industry and transportation volume and CO_2 [7]. Then, Gray et al. [8], Diakoulaki and Mandaraka [9], Freitas and Kaneko [10], Csereklyei and Stern [11], and Conte Grand [12] applied the Tapio decoupling model to analyze the decoupling relationship between economic growth and carbon emissions at the national and industrial levels. In the field of energy conservation, Zhao et al. [13] and Wang [14] used the decoupling theory to study the correlation between China's economic growth and energy consumption. In the field of emission reduction, Peng et al. [15] and Wang et al. [16] studied the decoupling relationship and degree between China's economic growth and energy carbon emissions by constructing the decoupling analysis model of economy and energy carbon emissions and analyzed the temporal and spatial evolution trend of their decoupling development. Yue and Li [17] studied the decoupling relationship between economic growth and carbon emissions in some provinces from a regional perspective. Subsequently, Ren et al. [18], Lu et al. [19], and Wang and Yang [20] constructed the influencing factor model of carbon dioxide emission.

The main methods to measure the decoupling relationship between carbon emissions and economic growth are the elasticity coefficient proposed by Tapio and the decoupling factor proposed by OECD. In contrast, Tapio is better able to eliminate the error in the selection of base period [7, 21]. Therefore, this study uses the Tapio index to measure the relationship between environmental pressure represented by economic growth and carbon emission. The analysis of relevant literature found that the research on the decoupling of carbon emissions from mining energy consumption is less and not in-depth. Combined with the particularity of China's mining industry, this study constructs the decoupling model of carbon emission in mining industry using the Tapio theory. In the model, the analysis method of assigning value to the decoupling state is proposed for the first time. The original decoupling model cannot directly reflect the change law of carbon emission decoupling state when analyzing the characteristics of time evolution. To better analyze the causes of carbon emission decoupling, two intermediate variables, energy efficiency decoupling index and energy structure decoupling index, are introduced. Because there are great differences among the subsectors of the mining industry, this study not only studies the decoupling relationship between the carbon emissions and the growth of the whole mining industry but also studies the five subsectors.

2. Research Methods and Data Sources

2.1. Introduction to Decoupling Theory. The decoupling theory is a basic theory to describe the relationship between economic growth and resource consumption or environmental pollution. Decoupling analysis has become a research hotspot in the field of resources and environment. At present, speed decoupling analysis mainly includes OECD model and Tapio decoupling model [22]. The decoupling factor method of OECD model is based on the initial value and the final value. It is sensitive to the selection of values, and the calculation results are prone to deviation [5]. The Tapio decoupling model can not only analyze the impact of various factors on decoupling indicators by constructing a causal chain but also integrate two types of indicators: total amount change and relative amount change. It adopts the elastic analysis method with the period as the time scale to reflect the decoupling relationship between variables, which effectively alleviates the calculation deviation caused by the high sensitivity or extreme value selected at the beginning and end of the OECD index model. It further improves the objectivity and accuracy of decoupling relationship measurement and analysis [7]. Therefore, this study adopts the Tapio decoupling analysis model. The calculation formula is as follows:

$$e = \frac{\%\Delta C}{\%\Delta GDP}, \tag{1}$$

where e represents the decoupling index between economic growth and carbon emissions; GDP represents output value; C represents carbon emissions; and $\%\Delta C$ and $\%\Delta$GDP represent the change rates of C and GDP, respectively.

The decoupling degree is determined according to the decoupling index. The Tapio decoupling model takes 0, 0.8, and 1.2 as the critical values of decoupling index and divides the decoupling relationship into three states: negative decoupling, decoupling, and connection [7]. According to the positive and negative change rate of carbon emission and GDP, the decoupling relationship is further divided into eight decoupling states: weak negative decoupling, strong negative decoupling, expansion negative decoupling, decline decoupling, strong decoupling, weak decoupling, recession connection, and expansion connection, as shown in Table 1.

2.2. Construction of Decoupling Analysis Model of Carbon Emission in Mining Industry

2.2.1. Construction of Carbon Emission Decoupling Analysis Model. According to the decoupling theory introduced above, the calculation formula of carbon emission decoupling index is transformed as follows:

$$e = \frac{\%\Delta C}{\%\Delta G} = \frac{\left(C^t - C^{t-1}\right)/C^{t-1}}{\left(G^t - G^{t-1}\right)/G^{t-1}} = \frac{\Delta C/C^{t-1}}{\Delta G/G^{t-1}}, \tag{2}$$

where e refers to the decoupling index between carbon emissions and industrial output value; $\% \ \Delta C$ and $\%\Delta G$ represent the change rate of carbon emission and industrial output value, respectively, C^t and G^t represent carbon emissions and industrial output value in period t; C^{t-1} and G^{t-1} represent carbon emissions and industrial output value in $t-1$ period, ΔC refers to the difference between carbon emissions in phase t and phase $t-1$, and ΔG represents the difference between the industrial output value of phase t and the industrial output value of phase $t-1$.

According to formula (2), the calculation formula of carbon emission decoupling index of mining industry and its subsectors is as follows:

Table 1: Classification of the decoupling status by the Tapio model.

State	%ΔC	%ΔGDP	e
Strong decoupling	<0	>0	$e<0$
Weak decoupling	>0	>0	$0<e<0.8$
Decline decoupling	<0	<0	$e>1.2$
Expansion connection	>0	>0	$0.8\leq e\leq 1.2$
Recession connection	<0	<0	$0.8\leq e\leq 1.2$
Expansion negative decoupling	>0	>0	$e>1.2$
Weak negative decoupling	<0	<0	$0<e<0.8$
Strong negative decoupling	>0	<0	$e<0$

$$e_i = \frac{\%\Delta C_i}{\%\Delta G_i}, \tag{3}$$

where e_i refers to the decoupling index between the carbon emissions and the output value of i sector; $\%\Delta C_i$ and $\%\Delta G_i$ represent the change rate of the carbon emission and output value of i sector, respectively; and e, e_1, e_2, e_3, e_4, and e_5, respectively, represent the carbon emission decoupling index of mining industry (all sectors), coal sector, petroleum and natural gas sector, ferrous metal sector, nonferrous metal sector, and nonmetal sector.

Formula (2) can be abbreviated as follows:

$$e = \frac{\Delta C/C^{t-1}}{\Delta G/G^{t-1}} = \frac{\Delta C/C}{\Delta G/G}. \tag{4}$$

Next, formulas (2)–(4) are decomposed as follows:

$$e = \frac{\Delta C/C}{\Delta G/G} = \frac{\Delta C/C}{\Delta E/E} \times \frac{\Delta E/CE}{\Delta G/G}, \tag{5}$$

where e represents the decoupling index between carbon emissions and industrial output value; $\Delta C/C = \%\Delta C$ represents the change rate of carbon emissions of the industry; $\Delta G/G = \%\Delta G$ represents the change rate of industrial output value; and $\Delta E/E = \%\Delta E$ represents the change rate of energy consumption in the industry.

$$Let\ e_K = \frac{\Delta C/C}{\Delta E/E} = \frac{\%\Delta C}{\%\Delta E}, \tag{6}$$

where e_K refers to the decoupling index between carbon emissions and energy consumption, which is called the decoupling index of energy structure. $\%\Delta C$ and $\%\Delta E$, respectively, represent the change rate of carbon emission and energy consumption. This index reflects the relationship between the change in carbon emission and the change in energy consumption. Generally, it is mainly determined by the proportion of all kinds of energy consumed, that is, by the structure of energy consumption.

According to formula (6), the calculation formula of decoupling index of energy structure of mining industry and its subindustries is as follows:

$$e_{Ki} = \frac{\%\Delta C_i}{\%\Delta E_i}, \tag{7}$$

where e_{ki} represents the decoupling index of carbon emission and energy consumption of i sector; $\%\Delta C_i$ and $\%\Delta E_i$ represent the change rate of carbon emission and output value of i sector, respectively; and e_k, e_{k1}, e_{k2}, e_{k3}, e_{k4}, and e_{k5}, respectively, represent the decoupling index of energy structure of mining industry (all sectors), coal sector, petroleum and natural gas sector, ferrous metal sector, nonferrous metal sector, and nonmetal sector.

$$Let\ e_T = \frac{\Delta E/E}{\Delta G/G} = \frac{\%\Delta E}{\%\Delta G}, \tag{8}$$

where e_T represents the decoupling index between energy consumption and industrial output value, which is called the energy efficiency decoupling index. This index reflects the energy consumption per unit output value. Generally, it is mainly related to energy-saving technologies and energy-saving and emission reduction measures.

According to formula (8), the calculation formula of energy efficiency decoupling index of mining industry and its subindustries is as follows:

$$e_{Ti} = \frac{\%\Delta E_i}{\%\Delta G_i}, \tag{9}$$

where e_{Ti} represents the decoupling index of energy consumption and output value of i sector; $\%\Delta E_i$ and $\%\Delta G_i$, respectively, represent the change rate of energy consumption and industrial output value of i sector; and e_T, e_{T1}, e_{T2}, e_{T3}, e_{T4}, and e_{T5}, respectively, represent the energy efficiency decoupling index of mining industry (all sectors), coal sector, petroleum and natural gas sector, ferrous metal sector, nonferrous metal sector, and nonmetal sector.

The following formula can be obtained from formulas (5), (6), and (8):

$$e = e_K \times e_T. \tag{10}$$

Formula (10) shows that the carbon emission decoupling index is the product of energy structure index and energy efficiency index [15]. Therefore, to further understand the reasons for the decoupling between output growth and carbon emission, based on logical causality, the carbon emission decoupling index can be decomposed into two intermediate variables. The intermediate variables are the decoupling index between output growth and energy consumption and the decoupling index between energy consumption and carbon emission.

2.2.2. Analysis Model of Decoupling State of Carbon Emission. According to the previous description, among the decoupling states of carbon emissions, the most ideal state is the strong decoupling state, indicating that the economic growth is positive and the carbon emission growth is negative. The strong negative decoupling is the most unsatisfactory state, indicating that the economic growth is negative while the environmental pressure is increasing. When the economic aggregate maintains continuous growth (ΔGDP > 0), the smaller the GDP elasticity of energy carbon emissions, the more significant the decoupling, that is, the higher the decoupling degree.

To intuitively reflect the decoupling state of carbon emissions in each period, a two-dimensional coordinate diagram can be used to reflect the decoupling state and its formation mechanism, as shown in Figure 1 [7, 23]. To facilitate the presentation of the decoupling state, each decoupling state is corresponding to a symbol with a positive and negative sign. The symbol with "+" indicates the decoupling state, which means that the environmental pressure decreases and is conducive to carbon emission reduction; the symbol with "−" indicates the negative decoupling state, which means that the environmental pressure increases, as shown in Table 2. To further visually show the decoupling states according to the time series in the figure for comparison and analysis, each decoupling state is now corresponding to different values, and the values from large to small are corresponding to the ideal and unsatisfactory decoupling states, as shown in Table 2. In other words, strong decoupling state "+*I*," the most ideal state, corresponds to "3," and strong negative decoupling state "−*I*," the least ideal state, corresponds to "−3."

According to the above analysis theory, the energy structure decoupling analysis model and energy efficiency decoupling analysis model have the same theory of the carbon emission decoupling analysis model. The decoupling analysis model of energy structure is given, as shown in Table 3; the energy efficiency decoupling analysis model is shown in Table 4.

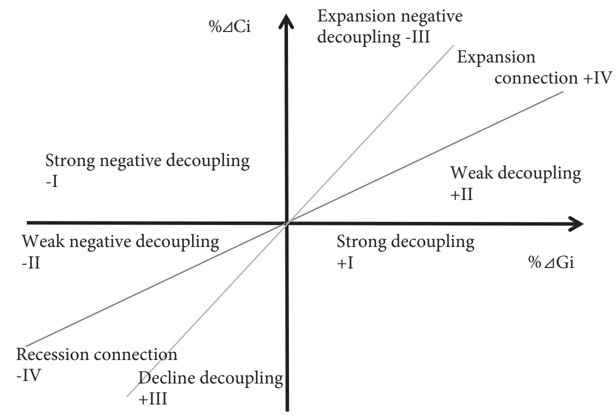

Figure 1: Framework for decoupling judgments.

2.3. Data Source and Data Processing

2.3.1. Research Object and Data Scope. The research object is the mining industry and its subsectors from 2000 to 2020. The subsectors include mining and washing of coal, extraction of petroleum and natural gas, mining and processing of ferrous metal ores, mining and processing of nonferrous metal ores, and mining and processing of nonmetal ores. In addition to five sectors, China's mining industry also includes "Professional and support activities for mining" and "Mining of other ores." Because the output value of "Mining of other ores" accounts for less than 0.1%, "Professional and support activities for mining" only appeared in 2012, and the proportion of output value is also very low. Therefore, the research object of this study is the five main subsectors of China's mining industry.

In this study, energy is divided into four categories: coal products, petroleum products, natural gas, and secondary energy. Among them, coal products include raw coal, cleaned coal, other coal washing, coke, coke oven gas, blast furnace gas, other gas, and other coking products. Petroleum products include crude oil, gasoline, diesel oil, kerosene, fuel oil, liquefied petroleum gas, refinery dry gas, naphtha, and other petroleum products. Natural gas includes natural gas and liquefied natural gas. Secondary energy includes electricity and heat.

2.3.2. Data Sources. The industrial output value comes from *China Statistical Yearbook* [24]. The specific sources of data are as follows: the industrial output value data from 2000 to 2004 adopt the product sales revenue of industrial enterprises above designated size in the Statistical Yearbook; the industrial output value data from 2005 to 2017 adopt the main business income of industrial enterprises above designated size in the Statistical Yearbook; and the industrial output value data from 2018 to 2020 adopt the business income of industrial enterprises above designated size in the Statistical Yearbook.

The industrial energy consumption data are from the end energy consumption of industrial subindustries in the *China Energy Statistics Yearbook* from 2000 to 2020 [25]. To avoid repeated calculation and unclear conversion coefficient of standard coal, standard coal equivalent in Statistical Yearbook is adopted. Due to the partial lack of industry end energy consumption data in 2020, it is estimated according to the changes in industrial output value and summary of Statistical Yearbook in 2020.

2.3.3. Data Processing. To avoid the impact of inflation on the annual output value, the industrial output value is treated to eliminate inflation, and the output value from 2001 to 2020 is treated as the base period based on the ex-factory price index of industrial producers in 2000.

The five subsectors are abbreviated as coal sector, petroleum and natural gas sector, ferrous metal sector, nonferrous metal sector, and nonmetal sector. For the calculation method and process of carbon emissions of mining industry and subindustries involved in this study, Wei's et al.'s research is referred [26].

The carbon emission decoupling index, energy structure decoupling index, and energy efficiency decoupling index of mining industry are expressed as e, e_K, and e_T, respectively. The carbon emission decoupling index of coal sector, petroleum and natural gas sector, ferrous metal sector, nonferrous metal sector, and nonmetal sector is expressed as e_1, e_2, e_3, e_4, and e_5, respectively. The decoupling index of energy structure of coal sector, petroleum and natural gas sector, ferrous metal sector, nonferrous metal sector, and nonmetal sector is expressed as e_{k1}, e_{k2}, e_{k3}, e_{k4}, and e_{k5}, respectively. The energy efficiency decoupling index of coal sector, petroleum and natural gas sector, ferrous metal sector, nonferrous metal sector, and nonmetal sector is expressed as e_{T1}, e_{T2}, e_{T3}, e_{T4}, and e_{T5}, respectively.

Table 2: Analysis model of decoupling state of carbon emission.

State	State symbol	State value	$\%\Delta C_i$	$\%\Delta G_i$	e_i
Strong decoupling	+I	3	<0	>0	$e < 0$
Weak decoupling	+II	2	>0	>0	$0 < e < 0.8$
Decline decoupling	+III	1	<0	<0	$e > 1.2$
Expansion connection	+IV	0	>0	>0	$0.8 \leq e \leq 1.2$
Recession connection	−IV	0	<0	<0	$0.8 \leq e \leq 1.2$
Expansion negative decoupling	−III	−1	>0	>0	$e > 1.2$
Weak negative decoupling	−II	−2	<0	<0	$0 < e < 0.8$
Strong negative decoupling	−I	−3	>0	<0	$e < 0$

Table 3: Analysis model of decoupling state of energy structure.

State	State symbol	State value	$\%\Delta C_i$	$\%\Delta E_i$	e_{Ki}
Strong decoupling	+I	3	<0	>0	$e < 0$
Weak decoupling	+II	2	>0	>0	$0 < e < 0.8$
Decline decoupling	+III	1	<0	<0	$e > 1.2$
Expansion connection	+IV	0	>0	>0	$0.8 \leq e \leq 1.2$
Recession connection	−IV	0	<0	<0	$0.8 \leq e \leq 1.2$
Expansion negative decoupling	−III	−1	>0	>0	$e > 1.2$
Weak negative decoupling	−II	−2	<0	<0	$0 < e < 0.8$
Strong negative decoupling	−I	−3	>0	<0	$e < 0$

Table 4: Analysis model of decoupling state of energy efficiency.

State	State symbol	State value	$\%\Delta E_i$	$\%\Delta G_i$	e_{Ti}
Strong decoupling	+I	3	<0	>0	$e < 0$
Weak decoupling	+II	2	>0	>0	$0 < e < 0.8$
Decline decoupling	+III	1	<0	<0	$e > 1.2$
Expansion connection	+IV	0	>0	>0	$0.8 \leq e \leq 1.2$
Recession connection	−IV	0	<0	<0	$0.8 \leq e \leq 1.2$
Expansion negative decoupling	−III	−1	>0	>0	$e > 1.2$
Weak negative decoupling	−II	−2	<0	<0	$0 < e < 0.8$
Strong negative decoupling	−I	−3	>0	<0	$e < 0$

3. Analysis of Calculation Results of Energy Consumption and Carbon Emission of Mining Industry

3.1. Growth Analysis of Mining Industry and Its Subsectors. According to the collected data, the fixed base output value of mining industry and its five subindustries is obtained, as shown in Table 5.

As a basic industry, mining belongs to the traditional industry sector and its development is greatly affected by the macroeconomic environment and has obvious cyclical characteristics. China's mining industry has grown rapidly since 2003. In 2008, the total output value of mining industry exceeded trillion, reaching 1178.138 billion CNY. By 2014, the output value had reached 2659.354 billion CNY, the highest in history, as shown in Figure 2. From 2002 to 2014, the total output value increased by 10.52% annually. On the contrary, the output value has been declining from 2015 to 2019, and the output value fell to 163.1195 billion CNY in 2019. During the whole period, except for the petroleum and natural gas sector, the change in output value of other subsectors is almost consistent with the change in total output value, and there is a trend of first rising and then falling. The output value of the petroleum and natural gas sector has fluctuated unstable, as shown in Figure 2.

3.2. Analysis of Mining Energy Consumption. According to the collected data, the energy consumption of mining industry and its five subindustries is obtained, as shown in Table 6.

The total energy consumption of China's mining industry has been rising steadily from 2000 to 2013. In 2013, the energy consumption reached a peak of 119.7685 million tons of standard coal, which is consistent with the increasing trend of mining output value. From 2014 to 2016, the energy consumption decreased significantly to 83.9234 million tons of standard coal, and there is little change in energy consumption from 2017 to 2020. From the perspective of energy consumption of each subsector, the energy consumption of coal sector has always been the highest, accounting for more than 40%, followed by petroleum and natural gas sector. The energy consumption of other sectors accounts for less, but shows an upward trend, exceeding 20% by 2020, as shown in Figure 3.

Table 5: Fixed base output value of mining industry and its subsectors from 2000 to 2020.

Year	Coal sector (10^8CNY)	Petroleum and natural gas sector (10^8CNY)	Ferrous metal sector (10^8CNY)	Nonferrous metal sector (10^8CNY)	Nonmetal sector (10^8CNY)	All sectors (10^8CNY)
2000	1213.77	2914.99	152.84	375.18	323.20	4979.98
2001	1411.41	2682.46	178.36	390.09	343.84	5006.16
2002	1650.30	2798.88	211.21	421.02	385.50	5466.91
2003	1946.62	3091.59	306.48	476.55	397.35	6218.60
2004	2598.28	3290.07	351.75	545.35	485.83	7271.29
2005	3232.01	3630.00	525.16	689.63	549.55	8626.35
2006	3884.37	3768.48	754.65	855.58	725.67	9988.75
2007	4811.45	4029.57	1030.07	992.26	918.04	11781.38
2008	5968.44	4292.88	1375.24	1144.09	1163.43	13944.08
2009	6646.81	4654.25	1837.04	1359.72	1460.52	15958.34
2010	8208.45	4534.22	2658.26	1533.11	1843.55	18777.59
2011	9910.69	4418.75	3119.56	1712.76	2104.92	21266.70
2012	11080.22	4016.41	3782.20	2013.20	2291.45	23183.47
2013	12091.39	4137.20	4387.27	2305.65	2658.62	25580.13
2014	12502.30	4221.89	4561.09	2428.21	2880.06	26593.54
2015	11489.95	4660.90	4415.80	2588.11	3024.87	26179.64
2016	10979.68	4561.11	3863.83	2505.52	3067.20	24977.34
2017	9539.57	4131.47	2232.24	1816.75	2278.61	19998.65
2018	9037.60	3829.75	1799.28	1271.38	1712.77	17650.79
2019	7999.75	3965.62	1716.35	927.27	1702.95	16311.95
2020	8007.05	4181.83	1846.01	883.60	1727.68	16646.17

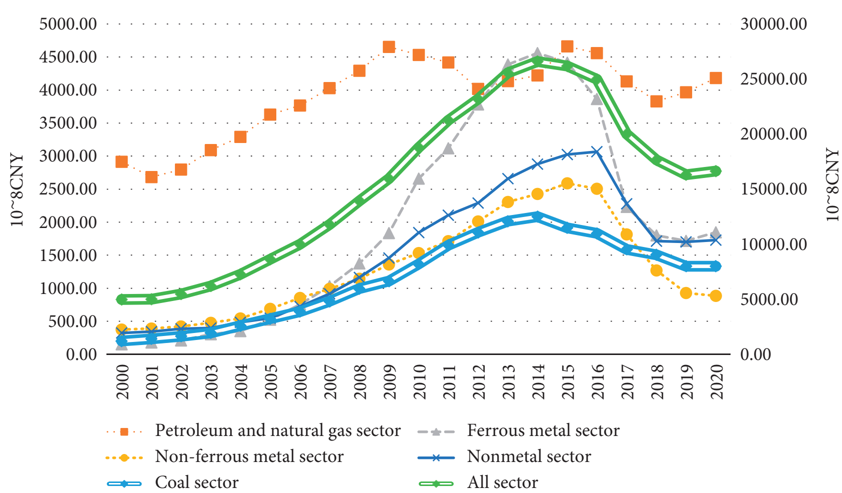

Figure 2: Changes in output value of China's mining industry and its subsectors from 2000 to 2020. *Note.* In Figure 2, the values of coal sector and all sectors correspond to the right coordinate axis, and the values of other subsectors correspond to the left coordinate axis.

The proportion of secondary energy in China's mining energy consumption structure continues to increase. The proportion of secondary energy increased from 20.57% in 2009 to 22.84% in 2010. After that, the proportion of secondary energy consumption continued to increase to 39.28% in 2020, reaching an all-time high. While increasing the consumption of secondary energy, the consumption of coal products is reduced. For example, the proportion of coal in the history of 2009 decreased from 52.62% to 24.38% in 2020. The proportion of natural gas consumption has increased significantly since 2014, which is mainly due to the continuous increase in natural gas consumption in the petroleum and natural gas sector. By 2020, the proportion of natural gas in the energy consumption of the petroleum and natural gas sector reached 60%, as shown in Figure 4, but statistics show that the proportion of coal energy in primary energy consumption has been very high, reaching 66.59% in 2012 and 40.15% in 2020, as shown in Figure 4.

Mining activities need to consume a lot of energy, which is the main source of carbon emissions. Low-carbon, green, and sustainable development requires industrial activities to reduce energy consumption and pollutant emissions [27]. From 2001 to 2016, China's mining energy intensity continued to decline, from 1.26 tce/10^4CNY to 0.34 tce/10^4CNY, increased slightly in 2017, and reached 0.54 tce/10^4CNY in 2020, as shown in Figure 3. In terms of comparison of various subsectors, the energy intensity of the coal sector decreased the fastest, from 2.06 tce/10^4CNY in 2000 to 0.29 tce/10^4CNY in

Table 6: Energy consumption of mining industry and its subsectors from 2000 to 2020.

Year	Coal sector (10^4tce)	Petroleum and natural gas sector (10^4tce)	Ferrous metal sector (10^4tce)	Nonferrous metal sector (10^4tce)	Nonmetal sector (10^4tce)	All sectors (10^4tce)
2000	2504.00	2645.84	157.43	192.59	423.37	5923.23
2001	2656.52	2837.84	165.36	208.27	462.02	6330.01
2002	2899.91	2938.14	262.23	247.68	534.57	6882.53
2003	3511.94	3017.35	276.26	271.60	598.25	7675.40
2004	4226.67	2579.36	307.61	278.80	532.44	7924.88
2005	4240.53	2643.75	401.76	290.55	575.64	8152.23
2006	4163.68	2681.31	450.45	307.74	586.39	8189.57
2007	4580.79	2747.59	524.33	345.37	611.44	8809.51
2008	4016.09	2998.69	833.35	468.19	911.75	9228.07
2009	6080.10	2975.44	572.21	380.67	746.11	10754.53
2010	5959.84	3120.18	711.85	429.78	726.40	10948.05
2011	6245.63	2917.73	853.01	527.06	735.44	11278.87
2012	6453.00	2895.21	1053.81	586.30	979.72	11968.04
2013	6310.61	3096.36	1088.31	598.28	883.29	11976.85
2014	3653.96	3184.60	1047.70	598.00	911.24	9395.50
2015	4229.60	3149.46	820.27	561.94	864.22	9625.49
2016	3507.90	2867.48	677.91	519.28	819.77	8392.34
2017	4058.21	2872.61	697.57	524.23	737.72	8890.34
2018	3716.41	2850.63	714.70	578.67	838.03	8698.44
2019	3872.12	2904.64	729.61	575.42	835.22	8917.01
2020	3875.65	3063.00	784.73	548.32	847.35	9119.05

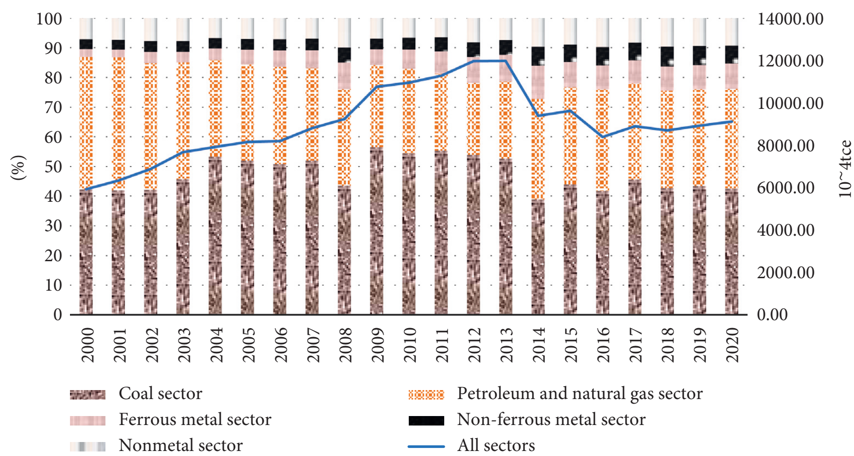

Figure 3: Comparative analysis of energy consumption of China's mining industry and its subsectors from 2000 to 2020. *Note.* In Figure 3, the value of "all sectors" corresponds to the left coordinate, and other values correspond to the right coordinate.

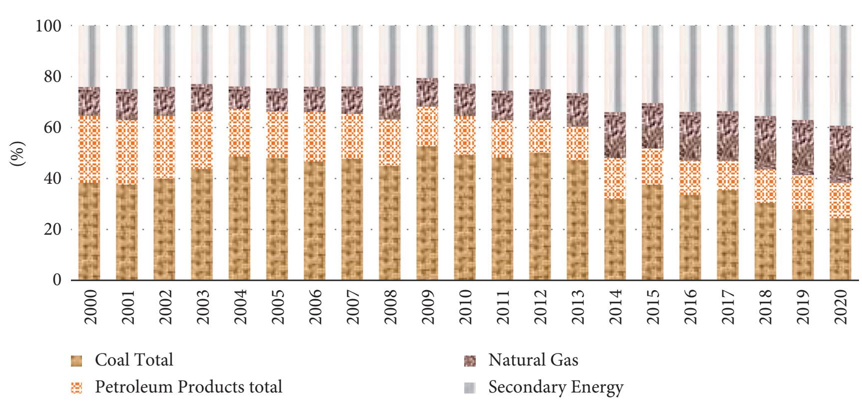

Figure 4: Comparative analysis of energy consumption structure of mining industry from 2000 to 2020.

2014, with a decrease rate of 85.92%, and rebounded to 0.49 tce/10^4CNY in 2020 in the later stage. At the same time, the energy intensity of ferrous metal sector and nonmetal ores sector has also decreased significantly. On the contrary, the energy intensity of nonferrous metal ores sector first decreased and then increased to 0.62 tce/10^4CNY in 2020, becoming the highest in history. The energy intensity of petroleum and natural gas sector is 0.73 tce/10^4CNY in 2020, which has become the sector with the highest energy consumption per unit output value, as shown in Figure 5.

3.3. Analysis of Calculation Results of Carbon Emission of Energy Consumption in Mining Industry. The calculation process of carbon emission of energy consumption in mining industry and its subdivisions refers to the research of Wei et al. [26], and the specific calculation results are shown in Table 7.

From 2000 to 2020, the change trend of carbon emissions from energy consumption of China's mining industry is to rise for a long time, then decline sharply, and finally stabilize, as shown in Figure 6. The lowest carbon emission in 2000 was 179.4723 million tons, and the carbon peak in 2013 was 388.740300 million tons. From 2014 to 2016, carbon emissions decreased rapidly to 278.6806 million tons, a decrease of 28.31% compared with 2013. The highest carbon emission of the coal sector was 205.9115 million tons in 2013, and the carbon emission of the sector changed steadily. The highest value of the petroleum and natural gas sector is 76.9346 million tons in 2015, and the change in carbon emission in the sector is unstable. The highest carbon emission of ferrous metal sector is 51.0265 million tons in 2013, and the change in carbon emission of the sector is relatively stable. The highest carbon emission of nonferrous metal sector is 26.1781 million tons in 2019, and the carbon emission variable of the sector is unstable. The highest carbon emission of nonmetal sector is 34.5513 million tons in 2012, and the change in carbon emission of the sector is basically stable, as shown in Figure 6.

From the perspective of carbon emissions of various industries, the coal sector accounts for the largest proportion of carbon emissions, accounting for more than 40% from 2000 to 2020. Followed by the petroleum and natural gas sector, the proportion fluctuated greatly. The carbon emission of ferrous metal sector is the third, but the change is very large. The nonmetal sector ranks fourth, with a very stable proportion. The nonferrous metal sector accounts for the smallest proportion and the industry scale is small, but it has maintained growth, as shown in Figure 7.

4. Empirical Analysis on the Decoupling Relationship between Carbon Emission and Industrial Growth in Mining Industry

Due to the great differences in the production of each subsector, this study not only studies the decoupling of the carbon emission of the mining industry, but also studies the decoupling states of carbon emissions in five subsectors, respectively.

4.1. Decoupling Analysis of Carbon Emissions from the Coal Sector. According to the collected data of the coal sector from 2000 to 2020, this part calculates the carbon emission change rate $\%\Delta C_1$, the energy consumption change rate $\%\Delta E_{1,}$ and the industrial output value change rate $\%\Delta G_1$ and then calculates the carbon emission decoupling index e_1, the energy structure decoupling index $e_{K1,}$ and the energy efficiency decoupling index e_{T1} using formulas (3), (7), and (9). The decoupling state of carbon emission is judged according to the decoupling model, as shown in Table 2; the decoupling state of energy structure is judged according to the decoupling model, as shown in Table 3; and the decoupling state of energy efficiency is judged according to the decoupling model, as shown in Table 4. All calculation results are shown in Table 8.

According to Figure 8, in the 20 years from 2001 to 2020, there are 13 times of decoupling between carbon emission and output value growth of the coal sector, including 4 times of strong decoupling, 8 times of weak decoupling, and 1 time of recession decoupling. There are 6 times of negative decoupling, including 3 times of strong negative decoupling, 2 times of weak negative decoupling, and 1 time of expansion negative decoupling. The expansion connection occurred 1 time. From the whole research period, most of the carbon emissions are decoupled from the output value growth, which proves that the carbon emission reduction in the coal sector is effective.

As shown in Figure 9, from the perspective of time evolution characteristics, the decoupling state of the coal sector is consistent. The period from 2001 to 2020 can be divided into two stages. The first is 2001–2014, which is the decoupling state between carbon emission and output value growth of the coal sector. In addition to the weak negative decoupling affected by the financial storm in 2009, this period shows the rapid growth of output value, but the growth of carbon emission is slow or even negative; this period is not only the golden decade of rapid development of the mining industry but also the stage of rapid development of China's economy. Finally, 2015–2020 is the negative decoupling stage between carbon emission and output value growth of the coal sector, which is reflected in the negative growth of output value, but the slow reduction or even increase in carbon emission. During this period, the market demand for coal products decreased, because China's economic development slowed down and the country put forward macro-policies such as supply-side reform and industrial structure optimization. At the same time, as China's main petrochemical energy, the development of coal sector is restricted by environmental factors.

To further analyze the reasons for the decoupling between energy carbon emission and output value growth in the coal sector, the carbon emission decoupling index e_1 is decomposed into two intermediate variables: energy efficiency decoupling e_{T1} and energy structure decoupling e_{K1}. The relationship between intermediate variables and carbon emission decoupling index is shown in Figure 10. According to Figure 10, the fluctuation of carbon emission decoupling index and energy efficiency decoupling index in the coal sector is almost identical, indicating that the decoupling

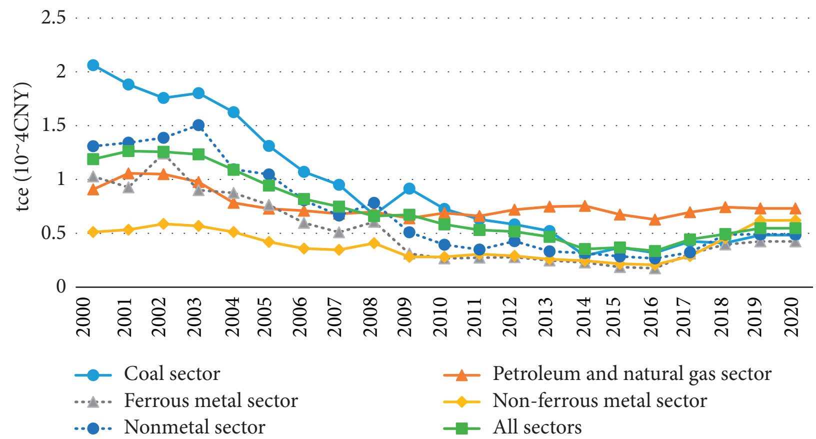

Figure 5: Comparative analysis of energy intensity of mining industry and its subsectors from 2000 to 2020.

Table 7: Carbon emissions of mining industry and its subsectors from 2000 to 2020.

Year	Coal sector (10^4t)	Petroleum and natural gas sector (10^4t)	Ferrous metal sector (10^4t)	Nonferrous metal sector (10^4t)	Nonmetal sector (10^4t)	All sectors (10^4t)
2000	8264.86	6630.87	754.94	806.89	1489.67	17947.23
2001	8821.33	7224.24	796.31	869.51	1630.07	19341.46
2002	9472.94	7442.95	941.15	929.14	1739.59	20525.77
2003	11393.53	7609.33	1246.00	1194.46	2036.44	23479.75
2004	13451.44	6712.31	1389.39	1183.82	1829.99	24566.95
2005	13544.54	6919.98	1870.04	1260.67	1911.92	25507.15
2006	13329.34	6661.88	2187.24	1361.47	1980.72	25520.66
2007	14594.01	6704.67	2589.68	1560.68	2097.78	27546.82
2008	13127.86	7113.56	3466.87	1916.14	2903.04	28527.48
2009	18966.27	7104.76	2584.34	1659.99	2486.78	32802.14
2010	18781.23	7394.48	3301.66	1912.25	2499.19	33888.80
2011	19769.17	7105.40	4047.41	2304.65	2640.93	35867.57
2012	20540.05	7084.64	4636.35	2510.34	3455.13	38226.50
2013	20591.15	7465.77	5102.65	2605.86	3108.61	38874.03
2014	13015.30	7671.99	4995.94	2596.87	3189.36	31469.46
2015	14309.50	7693.46	3865.09	2415.69	3005.72	31289.45
2016	12169.03	7173.64	3385.83	2245.97	2893.60	27868.06
2017	13773.09	7112.47	3436.50	2313.86	2683.12	29319.03
2018	13002.64	6918.40	3538.35	2610.47	3001.20	29071.06
2019	13396.44	7051.19	3780.76	2617.81	3001.36	29847.56
2020	13408.66	7435.62	4066.37	2494.52	3044.95	30450.11

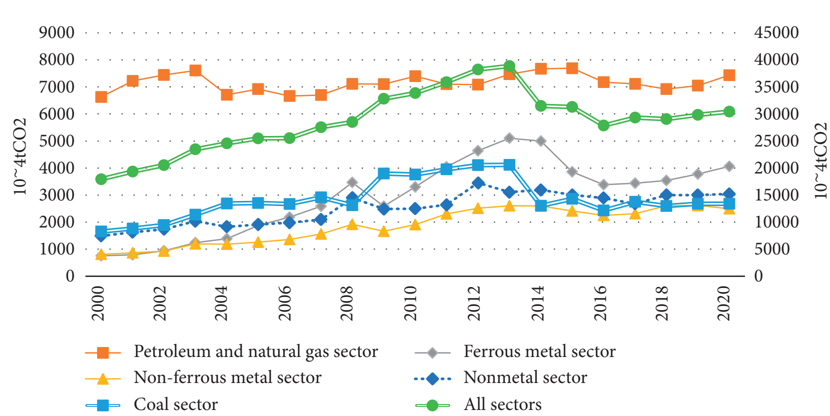

Figure 6: Carbon emissions of China's mining industry and subsectors from 2000 to 2020. *Note.* In Figure 6, the value of coal sector and all sectors adopts the right longitudinal axis coordinates, and the other values are the left longitudinal axis coordinates.

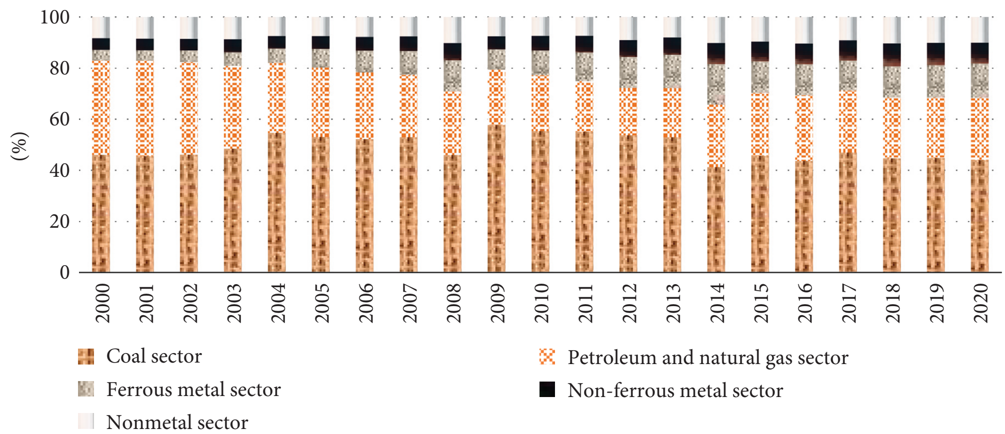

Figure 7: Analysis on the proportion of carbon emissions of various sectors from 2000 to 2020.

Table 8: Decoupling index and decoupling relationship of the coal sector from 2001 to 2020.

Year	$\%\Delta E_1$	$\%\Delta G_1$	$\%\Delta C_1$	e_{T1}	e_{T1} state		e_{K1}	e_{K1} state		e_1	e_1 state	
2001	0.06	0.16	0.07	0.37	+II	2	1.11	+IV	0	0.41	+II	2
2002	0.09	0.17	0.07	0.54	+II	2	0.81	+IV	0	0.44	+II	2
2003	0.21	0.18	0.20	1.18	+IV	0	0.96	+IV	0	1.13	+IV	0
2004	0.20	0.33	0.18	0.61	+II	2	0.89	+IV	0	0.54	+II	2
2005	0.00	0.24	0.01	0.01	+II	2	2.11	−III	−1	0.03	+II	2
2006	−0.02	0.20	−0.02	−0.09	+I	3	0.88	−IV	0	−0.08	+I	3
2007	0.10	0.24	0.09	0.42	+II	2	0.95	+IV	0	0.40	+II	2
2008	−0.12	0.24	−0.10	−0.51	+I	3	0.81	+IV	0	−0.42	+I	3
2009	0.51	0.11	0.44	4.52	−III	−1	0.87	+IV	0	3.91	−III	−1
2010	−0.02	0.23	−0.01	−0.08	+I	3	0.49	−II	−2	−0.04	+I	3
2011	0.05	0.21	0.05	0.23	+II	2	1.10	+IV	0	0.25	+II	2
2012	0.03	0.12	0.04	0.28	+II	2	1.17	+IV	0	0.33	+II	2
2013	−0.02	0.09	0.00	−0.24	+I	3	−0.11	−I	−3	0.03	+II	2
2014	−0.42	0.03	−0.37	−12.39	+I	3	0.87	−IV	0	−10.83	+I	3
2015	0.16	−0.08	0.10	−1.95	−I	−3	0.63	+II	2	−1.23	−I	−3
2016	−0.17	−0.04	−0.15	3.84	+III	1	0.88	−IV	0	3.37	+III	1
2017	0.16	−0.13	0.13	−1.20	−I	−3	0.84	+IV	0	−1.00	−I	−3
2018	−0.08	−0.05	−0.06	1.60	+III	1	0.66	−II	−2	1.06	−II	−2
2019	0.04	−0.11	0.03	−0.36	−I	−3	0.72	+II	2	−0.26	−I	−3
2020	−0.03	+0.00	0.00	−1.00	−II	−2	1.00	−IV	0	1.00	−II	−2

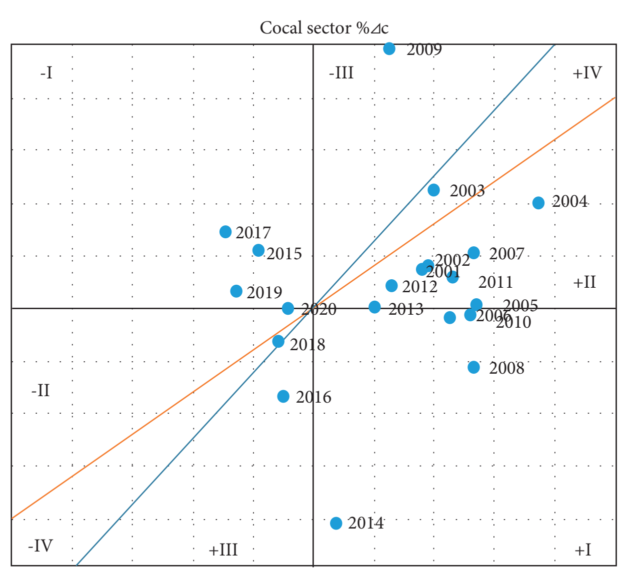

Figure 8: Carbon emission decoupling states of energy consumption in coal sector from 2001 to 2020.

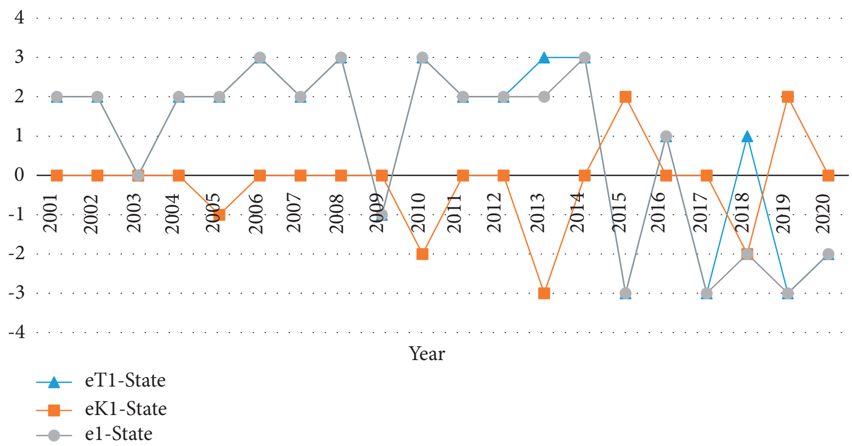

Figure 9: Decoupling of energy efficiency, energy structure, and carbon emission in coal sector from 2001 to 2020.

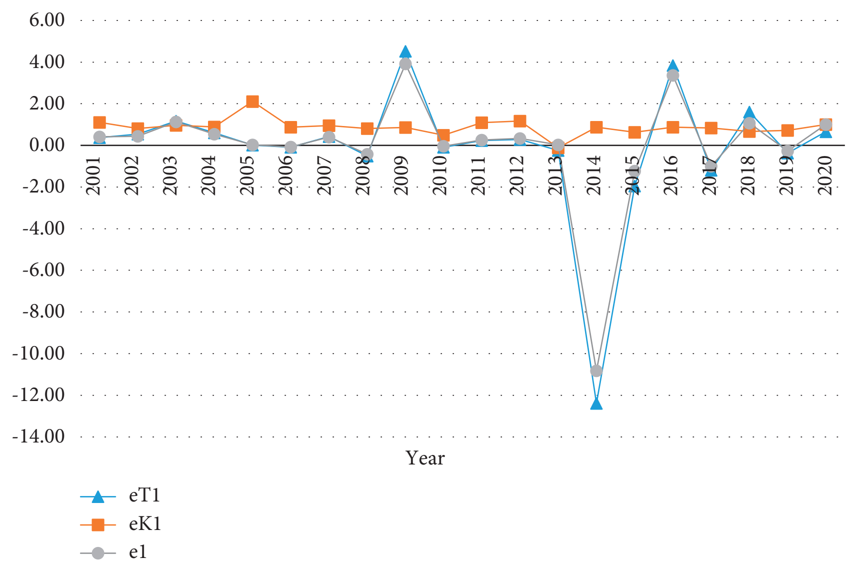

Figure 10: Relationship between carbon emission decoupling index and intermediate variables in coal sector from 2001 to 2020.

state of carbon emission is determined by the energy efficiency decoupling index. That is to say, the main driving factor of carbon emission reduction in the coal sector is energy efficiency. Energy efficiency is mainly affected by energy-saving measures and improving the level of energy utilization technology. Therefore, these two aspects are very important for carbon emission reduction in the coal sector. At the same time, in-depth analysis found that the positive and substantial growth of output value will lead to strong decoupling of carbon emissions. For example, the growth rate of output value from 2004 to 2012 exceeded 20%, which corresponds to strong decoupling or weak decoupling of carbon emissions. On the contrary, the growth of output value from 2015 to 2019 is negative, resulting in strong negative decoupling or weak negative decoupling of carbon emissions, as shown in Figure 9. Through this phenomenon, this study believes that at present, the adjustable range of production capacity of the coal sector is very limited, and the coal supply lacks elasticity; that is, the industry is still in the stage of economies of scale. When the coal output is reduced, the corresponding energy consumption and operating costs cannot be reduced.

According to Figures 9 and 10, it can be seen that the decoupling index of energy structure has a little impact on the decoupling state of carbon emissions during the whole period. The decoupling of energy structure has been getting better and better since 2014, and the decoupling state has occurred many times, which has an increasing inhibitory effect on carbon emissions. The decoupling of energy efficiency has a great inhibitory effect on carbon emissions from 2001 to 2014, but its inhibitory effect has decreased and even promoted carbon emissions since 2015. It can be seen from Figure 9 that the effect of energy conservation and emission reduction in the coal sector from 2001 to 2014 is very prominent, and the energy intensity has been declining. It is obvious that the energy efficiency of the coal sector has stabilized or even rebounded since 2015. It can be seen that the energy efficiency of the coal sector has tended to the limit, and its inhibitory effect on carbon emissions has begun to decrease. At the same time, according to the previous

Table 9: Decoupling index and decoupling relationship of the petroleum and natural gas sector from 2001 to 2020.

Year	$\%\Delta E_2$	$\%\Delta G_2$	$\%\Delta C_2$	e_{T2}	e_{T2} state		e_{K2}	e_{K2} state		e_2	e_2 state	
2001	0.07	−0.08	0.09	−0.91	−I	−3	1.23	−III	−1	−1.12	−I	−3
2002	0.04	0.04	0.03	0.81	+IV	0	0.86	+IV	0	0.70	+II	2
2003	0.03	0.10	0.02	0.26	+II	2	0.83	+IV	0	0.21	+II	2
2004	−0.15	0.06	−0.12	−2.26	+I	3	0.81	−IV	0	−1.84	+I	3
2005	0.02	0.10	0.03	0.24	+II	2	1.24	−III	−1	0.30	+II	2
2006	0.01	0.04	−0.04	0.37	+II	2	−2.63	+I	3	−0.98	+I	3
2007	0.02	0.07	0.01	0.36	+II	2	0.26	+II	2	0.09	+II	2
2008	0.09	0.07	0.06	1.40	−III	−1	0.67	+II	2	0.93	+IV	0
2009	−0.01	0.08	0.00	−0.09	+I	3	0.16	−II	−2	−0.01	+I	3
2010	0.05	−0.03	0.04	−1.89	−I	−3	0.84	+IV	0	−1.58	−I	−3
2011	−0.06	−0.03	−0.04	2.55	+III	1	0.60	−II	−2	1.54	+III	1
2012	−0.01	−0.09	0.00	0.08	−II	−2	0.38	−II	−2	0.03	−II	−2
2013	0.07	0.03	0.05	2.31	−III	−1	0.77	+II	2	1.79	−III	−1
2014	0.03	0.02	0.03	1.39	−III	−1	0.97	+IV	0	1.35	−III	−1
2015	−0.01	0.10	0.00	−0.11	+I	3	−0.25	−I	−3	0.03	+II	2
2016	−0.09	−0.02	−0.07	4.18	+III	1	0.75	+II	2	3.16	+III	1
2017	+0.00	−0.09	−0.01	−0.02	−I	−3	−4.77	+I	3	0.09	−II	−2
2018	−0.01	−0.07	−0.03	0.10	−II	−2	3.57	+III	1	0.37	−II	−2
2019	0.02	0.04	0.02	0.53	+II	2	1.01	+IV	0	0.54	+II	2
2020	−0.02	0.06	0.05	−0.33	+I	3	−2.86	−I	−3	0.95	+IV	0

analysis, with the development of new energy, the future energy structure should be the main factor to curb carbon emissions from coal sector.

4.2. Decoupling Analysis of Carbon Emissions from the Petroleum and Natural Gas Sector. According to the collected data of the petroleum and natural gas sector from 2000 to 2020, this part calculates the carbon emission change rate $\%\Delta C_2$, the energy consumption change rate $\%\Delta E_2$, and the industrial output value change rate $\%\Delta G_2$ and then calculates the carbon emission decoupling index e_2, the energy structure decoupling index e_{K2}, and the energy efficiency decoupling index e_{T2} using formulas (3), (7), and (9). The decoupling state of carbon emission is judged according to the decoupling model, as shown in Table 2; the decoupling state of energy structure is judged according to the decoupling model, as shown in Table 3; and the decoupling state of energy efficiency is judged according to the decoupling model, as shown in Table 4. All calculation results are shown in Table 9.

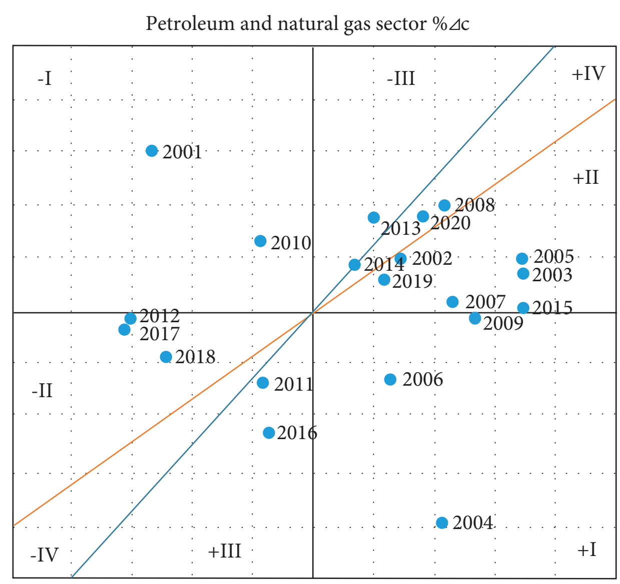

Figure 11: Carbon emission decoupling states of energy consumption in the petroleum and natural gas sector from 2001 to 2020.

According to Figure 11, from 2001 to 2020, there are 11 times of decoupling between carbon emission and output value growth of the petroleum and natural gas sector, including 3 times of strong decoupling, 6 times of weak decoupling, and 2 times of recession decoupling. There are 7 times of negative decoupling, including 2 times of strong negative decoupling, 3 times of weak negative decoupling, and 2 times of expansion negative decoupling. There are 2 times of expansion connection. From the whole research period, most of the carbon emissions are decoupled from the growth of output value, which proves that the energy conservation and emission reduction in the petroleum and natural gas sector have a certain effect, but the effect is not good.

As shown in Figure 12, from the perspective of time evolution characteristics, the decoupling state of carbon emissions in the petroleum and natural gas sector showed phased changes from 2001 to 2020, which is divided into three stages according to the decoupling index. The first stage from 2001 to 2009 is the decoupling state of carbon emissions. In addition to the strong negative decoupling state in 2001, the following eight years are almost the decoupling state. In particular, observing the decoupling index, it can be considered that this stage is more inclined to the strong decoupling state. The output value has been increasing steadily from 2002 to 2009, but the carbon emissions have decreased. This stage is the period with the best emission reduction effect in the petroleum and natural

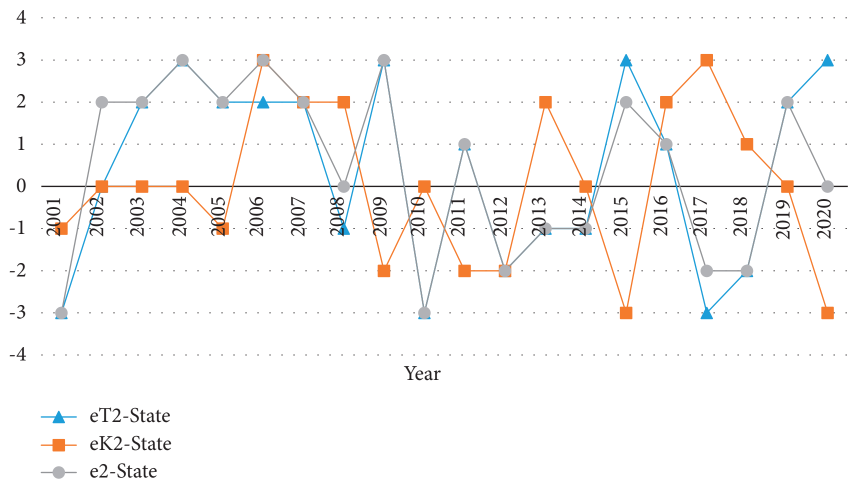

Figure 12: Decoupling of energy efficiency, energy structure, and carbon emission in the petroleum and natural gas sector from 2001 to 2020.

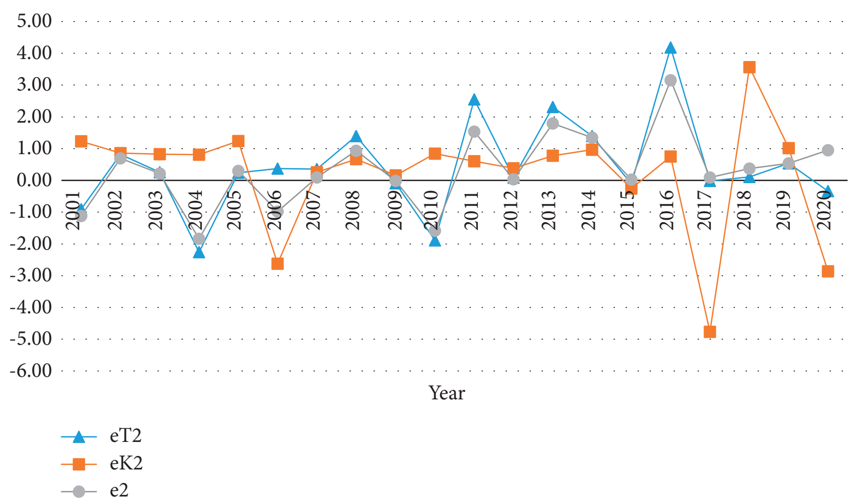

Figure 13: Relationship between carbon emission decoupling index and intermediate variables of the petroleum and natural gas sector from 2001 to 2020.

gas sector. The second stage is from 2010 to 2014, which is basically in the state of negative decoupling , except for recession decoupling in 2011; the output value has been decreasing or increasing slightly during this period. The third stage is 2015–2020. The negative decoupling state of carbon emissions fluctuates greatly in this period. The decoupling state and negative decoupling state appear alternately and are closely related to the increase in output value.

To further analyze the reasons for the decoupling between energy carbon emission and output value growth in the petroleum and natural gas sector, the carbon emission decoupling index e_2 is decomposed into energy efficiency decoupling index e_{T2} and energy structure decoupling index e_{K2}. The relationship between intermediate variables and carbon emission decoupling index is shown in Figure 13. According to Figures 12 and 13, it can be seen that the decoupling of carbon emissions in the petroleum and natural gas sector is mainly affected by energy efficiency, and the decoupling of carbon emissions by energy structure is small. From 2002 to 2009, energy efficiency basically inhibited carbon emissions, and from 2010 to 2014, energy efficiency basically promoted carbon emissions. From 2015 to 2020, the energy structure has an increasing impact on the decoupling of carbon emissions. In particular, the energy structure in 2016–2019 has an inhibitory effect on carbon emissions. The analysis of the energy structure data of subdivided sectors also confirms this conclusion, because the petroleum and natural gas sector has been increasing the consumption of natural gas in recent years; the consumption of natural gas accounts for nearly 60% in 2020, as shown in Figure 3.

4.3. Decoupling Analysis of Carbon Emission from the Ferrous Metal Sector. According to the collected data of the ferrous metal sector from 2000 to 2020, this part calculates the carbon emission change rate $\%\Delta C_3$, the energy consumption

Table 10: Decoupling index and decoupling relationship of the ferrous metal sector from 2001 to 2020.

Year	$\%\Delta E_3$	$\%\Delta G_3$	$\%\Delta C_3$	e_{T3}	e_{T3} state		e_{K3}	e_{K3} state		e_3	e_3 state	
2001	0.05	0.17	0.05	0.30	+II	2	1.09	+IV	0	0.33	+II	2
2002	0.59	0.18	0.18	3.18	−III	−1	0.31	+II	2	0.99	+IV	0
2003	0.05	0.45	0.32	0.12	+II	2	6.05	−III	−1	0.72	+II	2
2004	0.11	0.15	0.12	0.77	+II	2	1.01	+IV	0	0.78	+II	2
2005	0.31	0.49	0.35	0.62	+II	2	1.13	+IV	0	0.70	+II	2
2006	0.12	0.44	0.17	0.28	+II	2	1.40	−III	−1	0.39	+II	2
2007	0.16	0.36	0.18	0.45	+II	2	1.12	+IV	0	0.50	+II	2
2008	0.59	0.34	0.34	1.76	−III	−1	0.57	+II	2	1.01	+IV	0
2009	−0.31	0.34	−0.25	−0.93	+I	3	0.81	−IV	0	−0.76	+I	3
2010	0.24	0.45	0.28	0.55	+II	2	1.14	+IV	0	0.62	+II	2
2011	0.20	0.17	0.23	1.14	+IV	0	1.14	+IV	0	1.30	−III	−1
2012	0.24	0.21	0.15	1.11	+IV	0	0.62	+II	2	0.69	+II	2
2013	0.03	0.16	0.10	0.20	+II	2	3.07	−III	−1	0.63	+II	2
2014	−0.04	0.04	−0.02	−0.94	+I	3	0.56	−II	−2	−0.53	+I	3
2015	−0.22	−0.03	−0.23	6.81	+III	1	1.04	−IV	0	7.11	+III	1
2016	−0.17	−0.12	−0.12	1.39	+III	1	0.71	−II	−2	0.99	−IV	0
2017	0.03	−0.42	0.01	−0.07	−I	−3	0.52	+II	2	−0.04	−I	−3
2018	0.02	−0.19	0.03	−0.13	−I	−3	1.21	−III	−1	−0.15	−I	−3
2019	0.02	−0.05	0.07	−0.45	−I	−3	3.28	−III	−1	−1.49	−I	−3
2020	−0.05	0.02	0.08	−2.20	+I	3	−1.60	−I	−3	3.51	+I	3

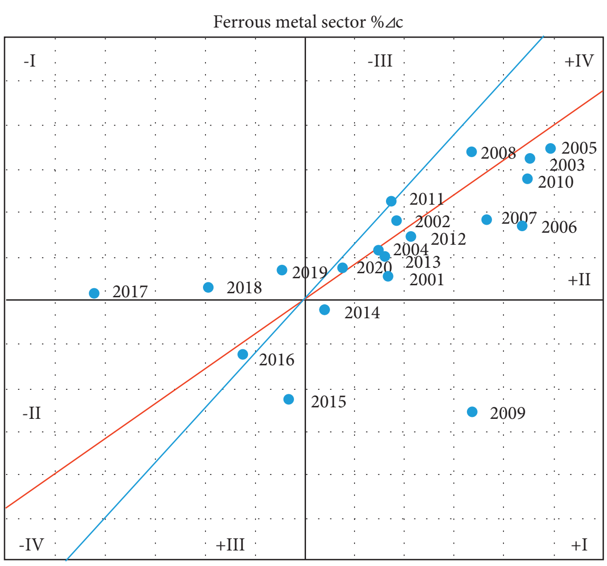

Figure 14: Carbon emission decoupling states of energy consumption in the ferrous metal sector from 2001 to 2020.

change rate $\%\Delta E_3$, and the industrial output value change rate $\%\Delta G_3$ and then calculates the carbon emission decoupling index e_3, the energy structure decoupling index e_{K3}, and the energy efficiency decoupling index e_{T3} using formulas (3), (7), and (9). The decoupling state of carbon emission is judged according to the decoupling model, as shown in Table 2; the decoupling state of energy structure is judged according to the decoupling model, as shown in Table 3; and the decoupling state of energy efficiency is judged according to the decoupling model, as shown in Table 4. All calculation results are shown in Table 10.

According to Figure 14, during 2001–2020, there are 13 decoupling states between carbon emission and output value growth of the ferrous metal sector, including 3 strong decoupling states, 9 weak decoupling states, and 1 recession decoupling. There are 4 times of negative decoupling, including 3 times of strong negative decoupling and 1 time of expansion negative decoupling. There are three connection states, including expansion connection twice and recession connection once. From the whole research period, most of the carbon emissions are decoupled from the growth of output value, which proves that the energy conservation and emission reduction effect of ferrous metal sector is very effective.

As shown in Figure 15, from the perspective of time evolution characteristics, the change in carbon emission decoupling state of the ferrous metal sector from 2001 to 2020 is stable, which can be basically divided into three stages. The first stage is from 2001 to 2016. The carbon emissions are decoupled. Except for the weak negative decoupled state in 2011, others are basically in the weak decoupled state and connected state. During this period, the output value has maintained a large increase. 2003–2010 is the stage of rapid development of the ferrous metal sector, reaching a growth rate of 49% in 2005, as shown in Table 8. The second stage is 2017–2019. The decoupling state of carbon emission is strong negative decoupling, which shows that the output value decreases, but the carbon emission keeps increasing. The third stage is 2020. The carbon emission is in a strong decoupling state. The strong negative decoupling state in the early stage is immediately reversed to a strong decoupling state, which shows that the output value increases, but the carbon emission decreases.

To further analyze the reasons for the decoupling between energy carbon emission and output value growth in the ferrous metal sector, the relationship between carbon emission decoupling index e_3 and energy efficiency decoupling index e_{T3} and energy structure decoupling index e_{K3} is shown

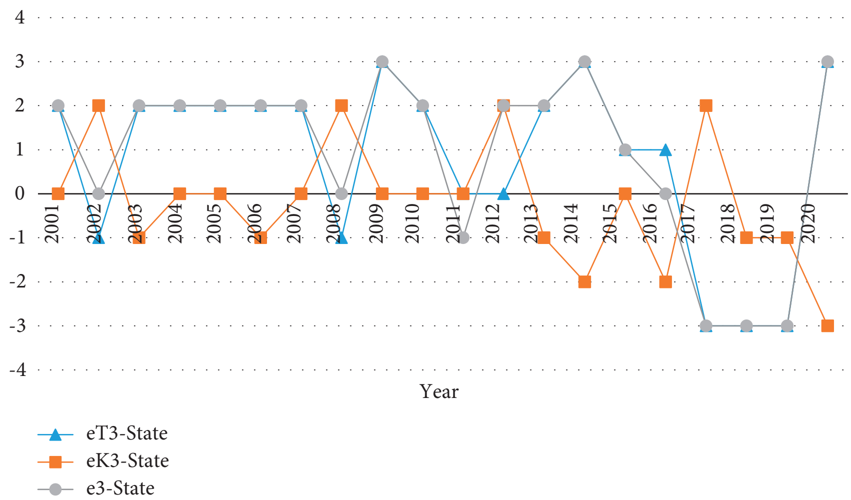

Figure 15: Decoupling of energy efficiency, energy structure, and carbon emission of the ferrous metal sector from 2001 to 2020.

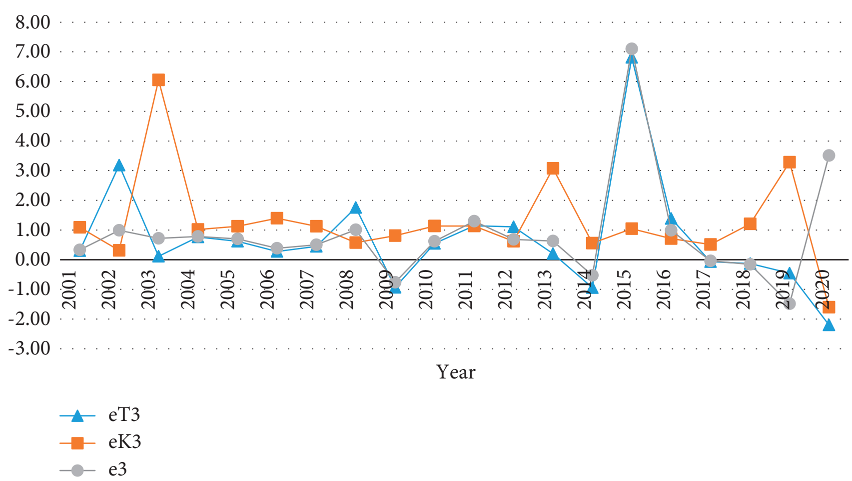

Figure 16: Relationship between carbon emission decoupling index and intermediate variables of the ferrous metal sector from 2001 to 2020.

in Figure 16. According to Figures 15 and 16, the fluctuation of carbon emission decoupling index of the ferrous metal sector is basically consistent with that of energy efficiency decoupling index, indicating that the decoupling state of carbon emission is determined by energy efficiency decoupling index. That is to say, the main driving factor of carbon emission of ferrous metal sector is energy efficiency. Energy efficiency is mainly affected by energy-saving measures and improving the level of energy utilization technology. Therefore, these two aspects are very important for carbon emission reduction in the ferrous metal sector. At the same time, the in-depth analysis found that the positive and substantial growth of output value has brought about the decoupling of carbon emissions. For example, the average increase rate of output value from 2003 to 2010 was more than 35%, which corresponds to the weak decoupling of carbon emissions and the weak decoupling of energy efficiency. When there is a negative change rate of output value from 2015 to 2019, the corresponding carbon emission is strongly negative decoupling. The energy structure of the sector cannot inhibit carbon emissions, as shown in Figure 15. To sum up, the energy efficiency and energy structure of the ferrous metal industry have great potential to curb carbon emissions. At present, the sector is heavily dependent on economic scale, and the fluctuation of output value has a great impact on the efficiency of production factors.

4.4. Decoupling Analysis of Carbon Emission from the Nonferrous Metal Sector. According to the collected data of the nonferrous metal from 2000 to 2020, this part calculates the carbon emission change rate $\%\Delta C_3$ the carbon emission change rate $\%\Delta C_4$, the energy consumption change rate $\%\Delta E_{4,}$ and the industrial output value change rate $\%\Delta G_4$ and then calculates the carbon emission decoupling index e_4, the energy structure decoupling index $e_{K4,}$ and the energy efficiency decoupling index e_{T4} using formulas (3), (7) and (9). The decoupling state of carbon emission is judged according to the decoupling model, as shown in Table 2; the decoupling state of energy structure is judged according to the

Table 11: Decoupling index and decoupling relationship of the nonferrous metal sector from 2001 to 2020.

Year	$\%\Delta E_4$	$\%\Delta G_4$	$\%\Delta C_4$	e_{T4}	e_{T4} state		e_{K4}	e_{K4} state		e_4	e_4 state	
2001	0.08	0.04	0.08	2.05	−III	−1	0.95	+IV	0	1.95	−III	−1
2002	0.19	0.08	0.07	2.39	−III	−1	0.36	+II	2	0.86	+IV	0
2003	0.10	0.13	0.29	0.73	+II	2	2.96	−III	−1	2.16	−III	−1
2004	0.03	0.14	−0.01	0.18	+II	2	−0.34	+I	3	−0.06	+I	3
2005	0.04	0.26	0.06	0.16	+II	2	1.54	−III	−1	0.25	+II	2
2006	0.06	0.24	0.08	0.25	+II	2	1.35	−III	−1	0.33	+II	2
2007	0.12	0.16	0.15	0.77	+II	2	1.20	+IV	0	0.92	+IV	0
2008	0.36	0.15	0.23	2.32	−III	−1	0.64	+II	2	1.49	−III	−1
2009	−0.19	0.19	−0.13	−0.99	+I	3	0.72	−II	−2	−0.71	+I	3
2010	0.13	0.13	0.15	1.01	+IV	0	1.18	+IV	0	1.19	+IV	0
2011	0.23	0.12	0.21	1.93	−III	−1	0.91	+IV	0	1.75	−III	−1
2012	0.11	0.18	0.09	0.64	+II	2	0.79	+II	2	0.51	+II	2
2013	0.02	0.15	0.04	0.14	+II	2	1.86	−III	−1	0.26	+II	2
2014	−0.00	0.05	0.00	−0.01	+I	3	7.37	+III	1	−0.06	+I	3
2015	−0.06	0.07	−0.07	−0.92	+I	3	1.16	+IV	0	−1.06	+I	3
2016	−0.08	−0.03	−0.07	2.38	+III	1	0.93	+IV	0	2.20	+III	1
2017	0.01	−0.27	0.03	−0.03	−I	−3	3.17	−III	−1	−0.11	−I	−3
2018	0.10	−0.30	0.13	−0.35	−I	−3	1.23	−III	−1	−0.43	−I	−3
2019	−0.01	−0.27	+0.00	0.02	−II	−2	−0.50	−I	−3	−0.01	−I	−3
2020	−0.02	−0.08	−0.05	0.29	−II	−2	2.08	+III	−2	0.61	−II	−2

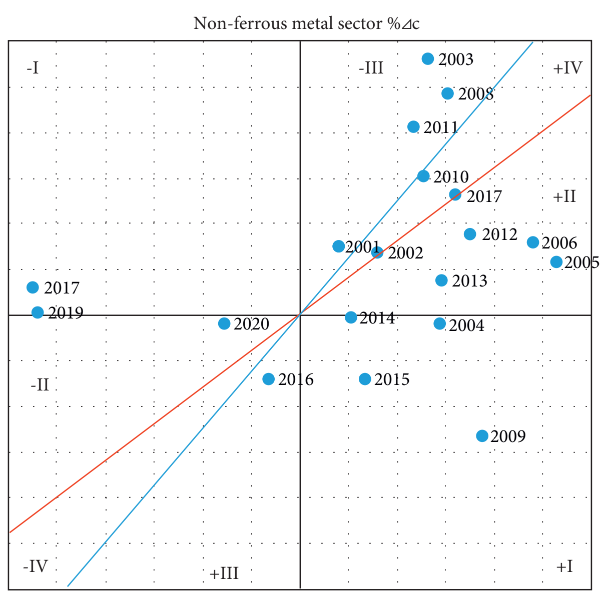

Figure 17: Carbon emission decoupling states of energy consumption in the nonferrous metal sector from 2001 to 2020.

decoupling model, as shown in Table 3; and the decoupling state of energy efficiency is judged according to the decoupling model, as shown in Table 4. All calculation results are shown in Table 11.

According to Figure 17, there are 9 times of decoupling between carbon emission and output value growth of the nonferrous metal sector during 2001–2020, including 4 times of strong decoupling, 4 times of weak decoupling, and 1 time of recession decoupling. There are 8 times of negative decoupling, including 3 times of strong negative decoupling, 1 time of weak negative decoupling, and 4 times of expansion negative decoupling. There are 3 times of expansion connection. From the whole research period, most of the carbon emissions are decoupled from the growth of output value, which proves that the energy conservation and emission reduction in the nonferrous metal sector are effective, but it is not particularly prominent, especially in recent years.

As shown in Figure 18, from the perspective of time evolution characteristics, the change in decoupling state of carbon emission of the nonferrous metal sector from 2001 to 2020 is unstable, which is divided into five stages. The first stage is from 2001 to 2003. The carbon emissions are basically in the state of expansion negative decoupling, and the output value has maintained a small growth, which can be regarded as the adjustment stage. According to the data from 1999 to 2000, it should be the continuation of the previous state. The second stage is from 2004 to 2007. The carbon emissions are basically decoupled. During this period, the output value increased the most. For example, in 2005 and 2006, the output value increased by 26% and 24%, respectively. The third stage is from 2008 to 2011. The decoupling state of carbon emissions is very unstable, but during this period, the output value growth is stable and the carbon emission changes greatly. The fourth stage is from 2012 to 2016. The carbon emissions are basically decoupled, with two strong decouples, which shows that the output value has been increasing, accompanied by a small increase or even decrease in carbon emissions. The nonferrous metal sector has the best emission reduction effect at this stage. The fifth stage is 2017–2020. The carbon emissions are in a strong negative decoupling state, which shows that the output value has decreased significantly, but the carbon emissions have increased.

To further analyze the reasons for the decoupling between energy carbon emission and output value growth in the nonferrous metal sector, the relationship between carbon

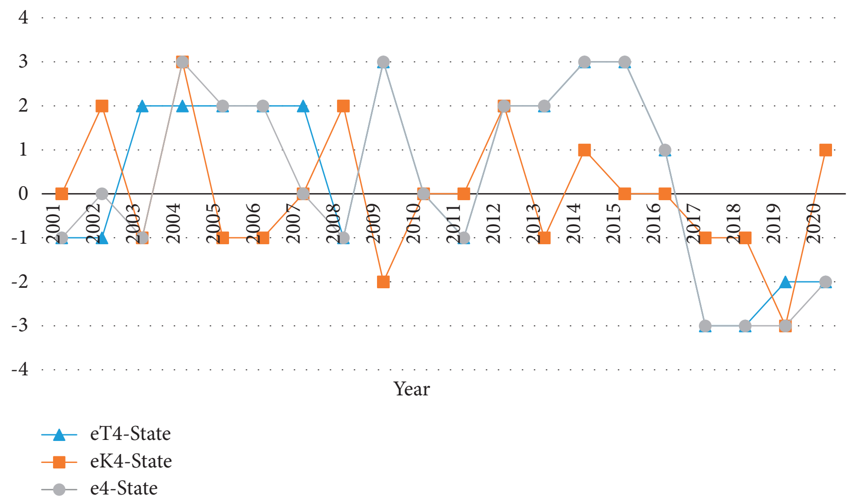

Figure 18: Decoupling of energy efficiency, energy structure, and carbon emission of the nonferrous metal sector from 2001 to 2020.

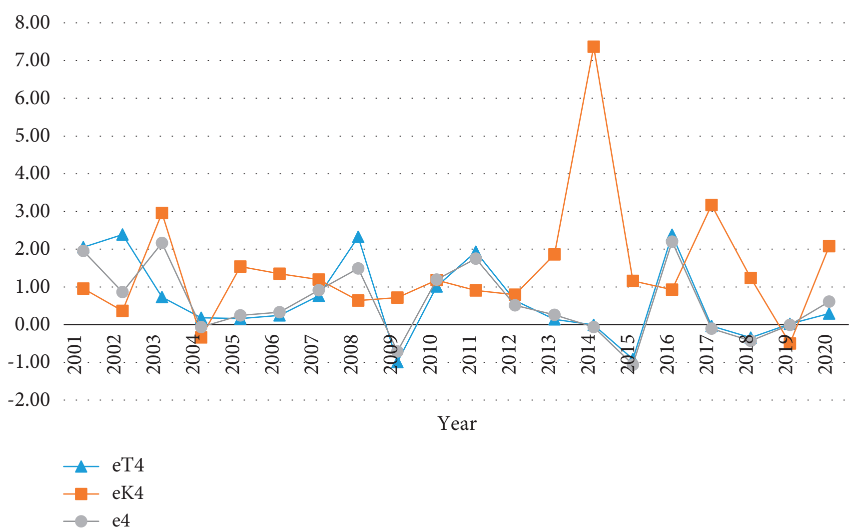

Figure 19: Relationship between carbon emission decoupling index and intermediate variables of the nonferrous metal sector from 2001 to 2020.

emission decoupling index e_4 and energy efficiency decoupling index e_{T4} and energy structure decoupling index e_{K4} is shown in Figure 19. According to Figure 19, the carbon emission decoupling index of the nonferrous metal sector before 2008 was jointly affected by energy efficiency and energy structure, and the fluctuation of the carbon emission decoupling index after 2008 was basically consistent with that of the energy efficiency decoupling index, indicating that the carbon emission decoupling state was determined by the energy efficiency decoupling index in this period. That is to say, the main driving factor of carbon emission reduction in the nonferrous metal sector is the energy consumption per unit output value. Therefore, energy-saving measures and improving the level of energy-saving technology are very important for carbon emission reduction in nonferrous metal sector. At the same time, it is also found that the substantial growth of output value has brought about the decoupling state of carbon emissions. Once the output value decreases, it would lead to the negative decoupling state of carbon emissions. It can be seen that the industrial economic scale has a great impact on the efficiency of industrial production factors. Before 2016, the energy consumption per unit output value of the nonferrous metal sector as a whole showed a downward trend. From the decline of energy efficiency after 2017, it can be seen that the potential of energy efficiency to inhibit carbon emissions in the future is limited, as shown in Figure 18. The energy structure does not play a great role in carbon emission of nonferrous metals, but it has great potential to curb carbon emission through the use of new energy.

4.5. Decoupling Analysis of Carbon Emission from the Nonmetallic Sector. According to the collected data of the nonmetallic sector from 2000 to 2020, this part calculates the carbon emission change rate $\%\Delta C_5$, the energy consumption

Table 12: Decoupling index and decoupling relationship of the nonmetallic sector from 2001 to 2020.

Year	$\%\Delta E_5$	$\%\Delta G_5$	$\%\Delta C_5$	e_{T5}	e_{T5} state		e_{K5}	e_{K5} state		e_5	e_5 state	
2001	0.09	0.06	0.09	1.43	−III	−1	1.03	+IV	0	1.48	−III	−1
2002	0.16	0.12	0.07	1.30	−III	−1	0.43	+II	2	0.55	+II	2
2003	0.12	0.03	0.17	3.87	−III	−1	1.43	−III	−1	5.55	−III	−1
2004	−0.11	0.22	−0.10	−0.49	+I	3	0.92	−IV	0	−0.46	+I	3
2005	0.08	0.13	0.04	0.62	+II	2	0.55	+II	2	0.34	+II	2
2006	0.02	0.32	0.04	0.06	+II	2	1.93	−III	−1	0.11	+II	2
2007	0.04	0.27	0.06	0.16	+II	2	1.38	−III	−1	0.22	+II	2
2008	0.49	0.27	0.38	1.84	−III	−1	0.78	+II	2	1.44	−III	−1
2009	−0.18	0.26	−0.14	−0.71	+I	3	0.79	−II	−2	−0.56	+I	3
2010	−0.03	0.26	0.00	−0.10	+I	3	−0.19	−I	−3	0.02	+II	2
2011	0.01	0.14	0.06	0.09	+II	2	4.56	−III	−1	0.40	−III	−1
2012	0.33	0.09	0.31	3.75	−III	−1	0.93	+IV	0	3.48	−III	−1
2013	−0.10	0.16	−0.10	−0.61	+I	3	1.02	−IV	0	−0.63	+I	3
2014	0.03	0.08	0.03	0.38	+II	2	0.82	+IV	0	0.31	+II	2
2015	−0.05	0.05	−0.06	−1.03	+I	3	1.12	−IV	0	−1.15	+I	3
2016	−0.05	0.01	−0.04	−3.68	+I	3	0.73	−II	−2	−2.67	+I	3
2017	−0.10	−0.26	−0.07	0.39	−II	−2	0.73	−II	−2	0.28	−II	−2
2018	0.14	−0.25	0.12	−0.55	−I	−3	0.87	+IV	0	−0.48	−I	−3
2019	−0.00	−0.01	+0.00	0.58	−II	−2	−0.02	−I	−3	−0.01	−I	−3
2020	−0.02	−0.03	0.01	0.78	−II	−2	−0.59	−I	−3	−0.45	−I	−3

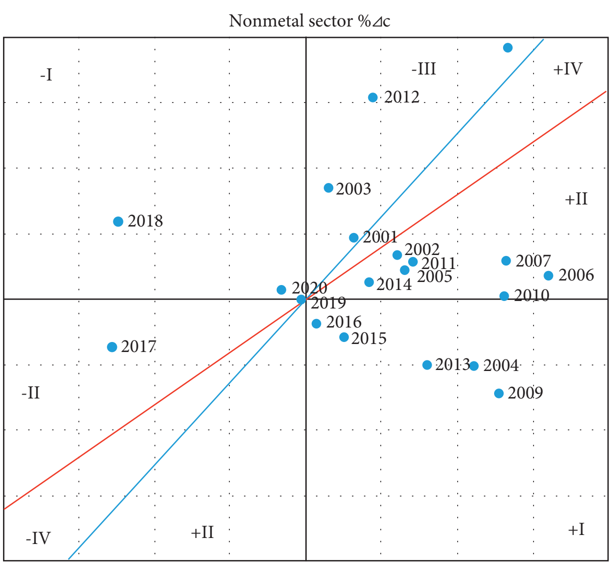

Figure 20: Carbon emission decoupling states of energy consumption in the nonmetallic sector from 2001 to 2020.

change rate $\%\Delta E_5$, and the industrial output value change rate $\%\Delta G_5$ and then calculates the carbon emission decoupling index e_5, the energy structure decoupling index e_{K5}, and the energy efficiency decoupling index e_{T5} of the nonmetallic mining industry using formulas (3), (7), and (9). The decoupling state of carbon emission is judged according to the decoupling model, as shown in Table 2; the decoupling state of energy structure is judged according to the decoupling model, as shown in Table 3; and the decoupling state of energy efficiency is judged according to the decoupling model, as shown in Table 4. All calculation results are shown in Table 12.

According to Figure 20, during 2001–2020, there are 11 times of decoupling between carbon emission and output value growth of nonmetallic sector, including 5 times of strong decoupling and 6 times of weak decoupling. There are 9 times of negative decoupling, including 3 times of strong negative decoupling, 1 time of weak negative decoupling, and 5 times of expansion negative decoupling. From the whole research period, most of the carbon emissions are decoupled from the output value growth, but there are not many advantages, which proves that the effect of energy conservation and emission reduction in the nonmetallic sector is very limited, especially the negative decoupling in recent four years.

As shown in Figure 21, from the perspective of time evolution characteristics, the annual carbon emission decoupling state of nonmetallic sector from 2001 to 2020 can be divided into three stages. The first stage is from 2001 to 2003. The carbon emissions are basically in the state of expansion negative decoupling, and the output value has maintained growth. During this period, there is a weak decoupling state. With the significant growth of output value, it can be regarded as the adjustment stage. The second stage is from 2004 to 2016. The carbon emissions are basically decoupled. In 2008 and 2011-2012, there is an expansion negative decoupling. During this period, the output value has been increasing significantly, accompanied by a small increase in carbon emissions, or even negative growth. The third stage is 2017–2020. Carbon emissions are in a strong negative decoupling state, which shows that the output value has decreased significantly, but the carbon emissions have increased.

To further analyze the reasons for the decoupling between energy carbon emission and output value growth in the nonmetallic sector, the relationship between carbon emission decoupling index e_5 and energy efficiency decoupling index e_{T5} and energy structure decoupling index e_{K5} is shown in Figure 22. According to Figure 22, the change

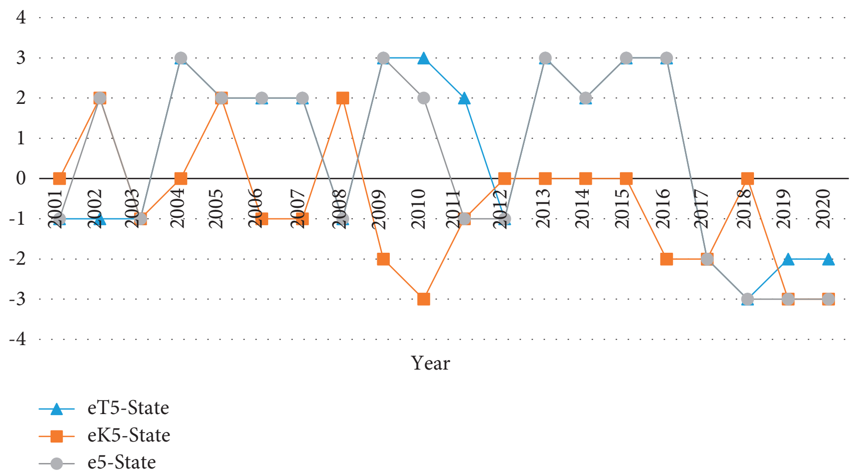

FIGURE 21: Decoupling of energy efficiency, energy structure, and carbon emission of the nonmetallic sector from 2001 to 2020.

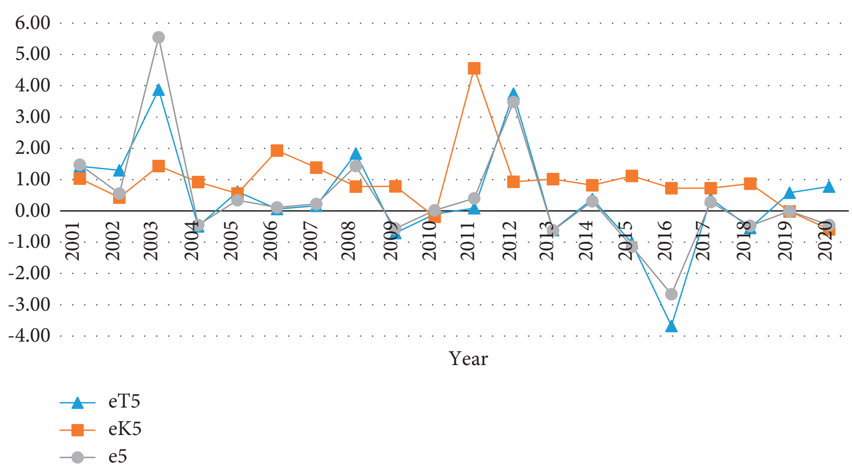

FIGURE 22: Relationship between carbon emission decoupling index and intermediate variables of the nonmetallic sector from 2001 to 2020.

trend of carbon emission decoupling index of the nonmetallic sector is basically consistent with that of energy efficiency index, except that it is affected by energy structure in individual time periods. From 2003 to 2009, the fluctuation of carbon emission decoupling index and energy efficiency decoupling index is consistent, which shows that the decoupling state of carbon emission is determined by the energy efficiency decoupling index; that is to say, the main driving factor of carbon emission reduction in the nonmetallic industry is to reduce energy consumption. In 2010–2012 and 2018–2020, the decoupling index of energy structure has a great impact on carbon emission decoupling, and energy efficiency has a greater impact on carbon decoupling index in 2013–2017. Therefore, in 2003–2009 and 2013–2017, the carbon emission reduction in the nonmetallic sector is mainly affected by energy-saving measures and energy-saving technologies. In other times, the optimization of energy structure plays a decisive role in the carbon emission reduction of the nonmetallic sector. According to the development of the nonmetallic sector, it is also found that the significant growth of output value has brought about the decoupling state of carbon emissions. Once the output value decreases, it will lead to the negative decoupling state of carbon emissions. It can be seen that the relative carbon emission reduction effect of the whole industry is not ideal. Once the output value decreases, the energy consumption per unit output value will increase. Before 2016, the overall energy intensity of the nonmetallic sector showed a downward trend. After 2017, the energy efficiency decreased significantly. It can be seen that the potential of energy efficiency to inhibit carbon emissions is limited, as shown in Figure 21. The energy structure has not been able to well curb carbon emissions, which shows that the adjustment of energy structure is not ideal, but it may have great potential to curb carbon emissions in the future through the use of new energy.

4.6. Decoupling Analysis of Carbon Emission in Mining Industry. According to the collected data of the mining industry from 2000 to 2020, this part calculates the carbon emission change rate $\%\Delta C$, the energy consumption change rate $\%\Delta E$, and the industrial output value change rate $\%\Delta G$ and then calculates the carbon emission decoupling index e, the

Table 13: Decoupling index and decoupling relationship of mining industry from 2001 to 2020.

Year	%ΔE	%ΔG	%ΔC	e_T	e_T state		e_K	e_K state		e	e state	
2001	0.07	0.01	0.03	13.06	−III	−1	0.49	+II	2	6.40	−III	−1
2002	0.09	0.09	0.08	0.95	+IV	0	0.87	+IV	0	0.83	+IV	0
2003	0.12	0.14	0.11	0.84	+IV	0	0.93	+IV	0	0.78	+II	2
2004	0.03	0.17	0.08	0.19	+II	2	2.52	−III	−1	0.48	+II	2
2005	0.03	0.19	0.09	0.15	+II	2	3.21	−III	−1	0.49	+II	2
2006	+0.00	0.16	0.07	0.03	+II	2	16.28	−III	−1	0.47	+II	2
2007	0.08	0.18	0.12	0.42	+II	2	1.58	−III	−1	0.67	+II	2
2008	0.05	0.18	0.11	0.26	+II	2	2.41	−III	−1	0.62	+II	2
2009	0.17	0.14	0.14	1.15	+IV	0	0.85	+IV	0	0.97	+IV	0
2010	0.02	0.18	0.10	0.10	+II	2	5.83	−III	−1	0.59	+II	2
2011	0.03	0.13	0.09	0.23	+II	2	2.94	−III	−1	0.67	+II	2
2012	0.06	0.09	0.08	0.68	+II	2	1.23	−III	−1	0.84	+IV	0
2013	+0.00	0.10	0.06	0.01	+II	2	87.96	−III	−1	0.63	+II	2
2014	−0.22	0.04	−0.04	−5.44	+I	3	0.18	−II	−2	−1.00	+I	3
2015	0.02	−0.02	0.00	−1.57	−I	−3	−0.20	+I	3	0.31	+II	2
2016	−0.13	−0.05	−0.06	2.79	+III	1	0.50	−II	−2	1.40	+III	1
2017	0.06	−0.20	−0.13	−0.30	−I	−3	−2.13	−I	−3	0.64	−II	−3
2018	−0.02	−0.12	−0.08	0.18	−II	−2	3.81	+III	1	0.70	−II	−2
2019	0.03	−0.08	−0.04	−0.33	−I	−3	−1.57	+I	3	0.52	−II	−2
2020	−0.02	0.02	0.12	−1.21	+I	3	−4.74	−I	−3	5.74	−III	−1

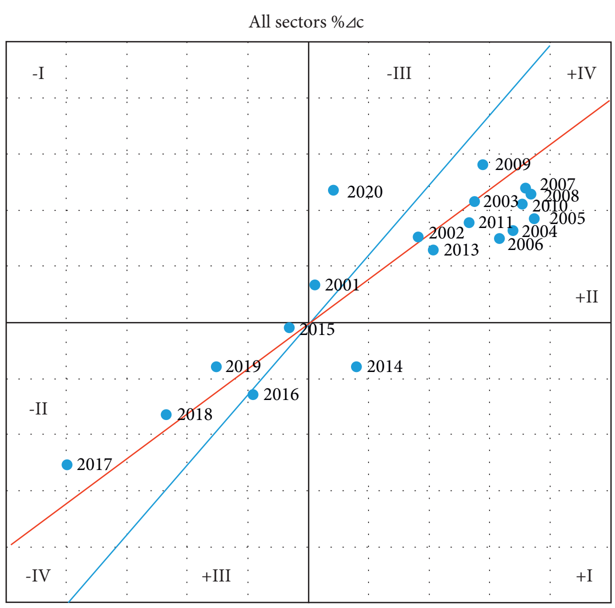

Figure 23: Carbon emission decoupling states of energy consumption in mining industry from 2001 to 2020.

energy structure decoupling index e_K and the energy efficiency decoupling index e_T using formulas (3), (7), and (9). The decoupling state of carbon emission is judged according to the decoupling model, as shown in Table 2; the decoupling state of energy structure is judged according to the decoupling model, as shown in Table 3; and the decoupling state of energy efficiency is judged according to the decoupling model, as shown in Table 4. All calculation results are shown in Table 13.

According to Figure 23, there are 12 decoupling states between carbon emission and output value growth of mining industry during 2001–2020, including 1 strong decoupling state, 10 weak decoupling states, and 1 recession decoupling state. There are 5 times of negative decoupling, including 3 times of weak negative decoupling and 2 times of expansion negative decoupling. Expansion connection occurred 3 times. From the whole research period, most of the carbon emissions are decoupled from the output value growth, which proves that the carbon emission reduction in the mining industry is very effective, but there has been a continuous negative decoupling in recent years.

As shown in Figure 24, from the perspective of time evolution characteristics, the decoupling state of carbon emission of mining industry from 2001 to 2020 is relatively stable, which can be basically divided into two stages. The first stage is from 2001 to 2016, and carbon emissions are basically decoupled or linked, except for weak negative decoupling in 2001. The output value has been increasing significantly during this period, accompanied by a small increase in carbon emissions. 2002–2012 is the golden decade of China's mining industry. Because of the strong market demand, the scale and output value of the industry have increased significantly. At the same time, under the guidance of energy conservation and emission reduction policies, the industry pays attention to reducing energy consumption, which has formed a decoupling state of carbon emissions for more than a decade. The second stage is from 2017 to 2020. The decoupling state of carbon emissions is basically negative decoupling. During this period, the output value has been negative growth, especially the output value decreased by 20% in 2017, but the decline of carbon emissions is small, resulting in negative decoupling. At the same time, China proposed the policy of supply-side reform, the market demand decreased, and the mining industry carried out the elimination reform of backward production capacity. The period is also a few difficult years for the development of the mining industry. After 2019, the market demand gradually recovered.

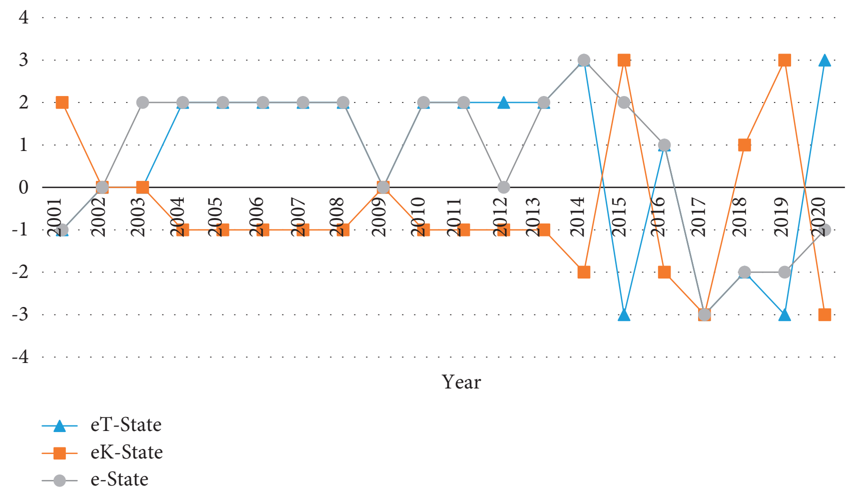

Figure 24: Decoupling of energy efficiency, energy structure, and carbon emission of mining industry from 2001 to 2020.

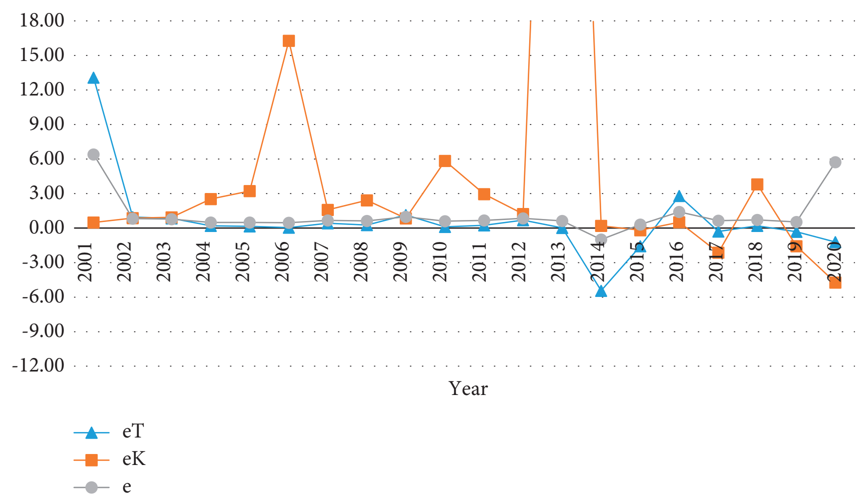

Figure 25: Relationship between carbon emission decoupling index of the mining industry and intermediate variables. *Note.* In Figure 25, the value of e_K in 2013 is 87.96, because it is too large than other values, so it is not shown in the figure.

To further analyze the reasons for the decoupling between energy carbon emission and output value growth in the mining industry, the relationship between carbon emission decoupling index e and energy efficiency decoupling index e_T and energy structure decoupling index e_K is shown in Figure 25. According to Figures 24 and 25, the fluctuation of carbon emission decoupling index of mining industry is basically consistent with that of energy efficiency decoupling index from 2001 to 2014, indicating that the decoupling state of carbon emission is mainly determined by energy efficiency decoupling index; that is to say, the main driving factor of carbon emission reduction in mining industry is energy efficiency. Therefore, energy-saving measures and energy utilization technology are very important for carbon emission reduction in mining industry. At the same time, in-depth analysis found that the positive and substantial growth of output value will lead to the decoupling state of carbon emissions. For example, the output value has maintained growth from 2002 to 2014, corresponding to the weak decoupling state of carbon emissions. On the contrary, the output value decreased sharply from 2017 to 2019, corresponding to the negative decoupling state of carbon emissions. Through the above analysis, this study believes that the adjustable range of production capacity of the mining industry is very limited, the supply is inelastic, and the industry is still in the stage of economies of scale. Economic scale can improve the efficiency of production factors, including energy efficiency. Therefore, the increase in industrial output value corresponds to the improvement of energy efficiency. When the output value of mining industry decreases, the corresponding energy consumption and operating costs cannot be reduced accordingly. Since 2015, the energy structure index has a great impact on the carbon emission decoupling index and inhibits carbon emission, as shown in Figure 25. In general, the energy efficiency of mining industry is the main driving factor of carbon emission reduction, while the energy structure has a little inhibitory effect on carbon emission.

The energy efficiency of the mining industry basically showed an upward trend and was relatively stable before

2014. During this period, the improvement of energy efficiency is the main driving force of the industry's emission reduction, as shown in Figure 25. After 2015, the energy efficiency is mainly in the state of negative decoupling and fluctuates greatly. It can be seen that the resistance to the improvement of energy efficiency after 2015 is very large and cannot maintain high-energy efficiency, which also shows that the space for the continuous improvement of the energy efficiency is very limited. Therefore, the inhibitory effect of energy efficiency on carbon emissions from mining industry will be very limited in the future.

From 2001 to 2014, the energy structure of the mining industry was basically in a state of negative decoupling, which failed to inhibit carbon emissions, as shown in Figure 25. From 2015 to 2020, the decoupling state of energy structure was unstable and showed W-shaped fluctuation, but the inhibition effect of energy structure on carbon emission increased. Therefore, increasing the proportion of new energy consumption in the future will greatly curb carbon emissions, and the inhibitory effect of energy structure adjustment on carbon emissions in the future has great room for improvement.

As shown in Figure 25, the carbon emissions of the mining industry from 2002 to 2016 were decoupled and very stable. The emission reduction effect during the period is relatively prominent. It can be seen that the emission reduction measures of the whole industry are reasonable. Carbon emissions from 2017 to 2020 are in a negative decoupling state, which shows that the industrial emission reduction measures during this period are unreasonable. From 2017 to 2020, the output value decreased significantly, resulting in negative decoupling of carbon emissions. It can be seen that the whole mining industry is highly dependent on economic scale.

5. Conclusions

Through the above research, the following conclusions are drawn:

(1) From 2002 to 2016, the carbon emission of the mining industry was basically decoupled and very stable. During the whole period, energy efficiency was the main driving factor of carbon emission reduction and had a great impact on carbon emission decoupling. During this period, the impact of energy structure on carbon emission decoupling is very small, and it cannot inhibit carbon emission. From 2017 to 2020, the carbon emission of the mining industry is basically in the state of negative decoupling. During this period, the energy structure has become the main factor to curb carbon emission.

(2) The energy efficiency of the mining industry basically showed an upward trend from 2004 to 2014 and was relatively stable. After 2015, the energy efficiency was mainly in the state of negative decoupling and fluctuated greatly. This study believes that there is great resistance to the improvement of energy efficiency, which also shows that the space for the continuous improvement of energy efficiency is very limited, and its inhibition effect on carbon emission in the future will also be very limited. From 2003 to 2014, the energy structure of mining industry was basically in the state of negative decoupling, which could not inhibit carbon emission and had little impact; from 2015 to 2020, the decoupling state of energy structure is unstable, but it has an inhibitory effect on carbon emissions and the impact is increasing. Therefore, this study believes that by increasing the proportion of new energy consumption, the inhibition effect of energy structure adjustment on carbon emissions will have great room for improvement in the future.

(3) Among all subsectors, the decoupling state of carbon emissions in the coal sector is the best ideal. The energy conservation and emission reduction effect of the coal sector is the most stable, the ferrous metal mining industry is the second, and the nonferrous metal sector is the most unstable. The effect of energy conservation and emission reduction in the petroleum and natural gas sector is the least ideal. The energy efficiency is the main driving factor of emission reduction in coal sector. The decoupling of carbon emissions in other industries is mainly affected by the energy efficiency index, but in some periods, the energy structure has a great impact on the decoupling of carbon emissions.

(4) The decoupling state of carbon emissions in the whole mining industry is closely related to the growth of output value. When the output value increases significantly, the energy efficiency is in a strong decoupling state, and the energy efficiency decreases when the output value decreases. It can be seen that economic scale and capacity concentration have a great impact on the energy efficiency of the mining industry.

Data Availability

The datasets used or analyzed during this study are available from the corresponding author on reasonable request. The original data in this study are obtained from China Energy Statistical Yearbook (2000–2020) and China Statistical Yearbook (2000–2021). For a detailed introduction, refer to "2.3 data source and data processing" and Reference [24, 25] in the paper.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Guangyu Jia and Lili Wei conceptualized the study and wrote, reviewed, and edited the manuscript; Lili Wei designed methodology, validated the study, and wrote the original draft preparation; Xiaohui Xu provided software; Lingyun Zhao provided resources; Lili Wei and Xiaohui Xu curated the data; and Guangyu Jia supervised the study.

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