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Decoupling and Decomposition Analysis of Carbon Emissions from the Power Sectors: A Comparative Study of China and the United States

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Abstract

The power industry accounts for more than 40% of global carbon emissions from power generation. The decoupling of carbon emissions and economic growth in the power industry has a great impact on the realization of global social and economic sustainable development. In this paper, Tapio decoupling model is used to explore the decoupling state between carbon emissions and economic growth in the power industry of China and the United States from 2000 to 2019. Then, combined with the logarithmic mean Divisia index (LMDI) model, the driving factors affecting the decoupling state of the power industry are analyzed. The results showed that: (1) From 2000 to 2019, China's carbon emissions from the power sector increased significantly, with an average annual growth rate of 8.3%, while those from the United States declined steadily at a rate of -1.2%. (2) During the study period, China's power sector carbon emissions experienced growth connection and weak decoupling in most years, while the United States experienced strong decoupling. (3) In general, power structure and power intensity are the main factors that promote the decoupling of carbon emissions in the power sector between China and the United States, while economic growth and population are the factors that inhibit the decoupling of carbon emissions.

Keywords

Power industry; Carbon emissions; Tapio elastic analysis; LMDI model; Comparative study.

1. INTRODUCTION

As the basic industry of economic development and human life, the power industry is the largest carbon emission sector in the world. The power sector accounts for 42% of global carbon emissions from electricity generation (IEA, 2018). Therefore, the low-carbon development of the power industry has an important impact on global climate mitigation [1].

In recent years, with the acceleration of industrialization and urbanization, China's power industry has developed rapidly, and the resulting carbon emissions have caused tremendous environmental pressure. From 1990 to 2018, China's power generation increased from 621.2 billion kWh to 7166.1 billion kWh, with an average annual growth rate of 14.6%, eight times (1.8%) that of the United States in the same period. At the same time, China's carbon emissions from the power sector grew at an average annual rate of 12%, and surpassed the United States in 2008 to become the world's largest carbon emitter from the power sector. In order to shoulder the responsibility of international emission reduction, China has formulated the strategic goal of achieving carbon peak by 2030 and carbon neutrality by 2060.The realization of this goal requires the joint efforts of all sectors, and the reduction of carbon emissions in other sectors, especially in the transportation and construction sectors, will inevitably require the development of electrification [2-3], which will lead to a further increase in the demand of

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the power industry and a further increase in the pressure on the power industry to reduce emissions. Therefore, the research of energy saving and emission reduction in the power industry is very important for the development of low-carbon in China and even in the world.

Globally, China and the United States are the two largest carbon emitters in the world's power sector. In 2018, the carbon emissions of China's power industry reached 4.896 billion tons, accounting for 35% of the total carbon emissions of the global power industry, ranking first in the world, followed by the United States, accounting for 13%. Therefore, the development of the power industry in China and the United States has an important impact on the global carbon emission trend of the power industry. In addition, although the carbon emissions of the power industry in China and the United States occupy an important position in the world, in recent years, the growth rate of carbon emissions in the power industry in the United States is very slow or even negative, which is in sharp contrast to the rapid growth of carbon emissions in China's power industry. Therefore, this paper chooses the United States as the comparative object of China, on the one hand, it is helpful to understand the current situation of carbon emissions in the international power industry; on the other hand, by comparing with the United States, we can find the gap in the development of China's power industry, and learn from the experience of the United States to achieve low-carbon development of the power industry.

Based on the above background, this paper intends to study the following issues: (1) To study the characteristics of carbon emissions changes in the power industry in China and the United States. The carbon emissions of electric power industry in China and the United States from 2000 to 2019 are calculated and their changing rules are analyzed. (2) To analyze the decoupling relationship between carbon emissions and economic growth in the power industry of China and the United States. From the short, medium and long term, this paper evaluates and compares the decoupling state between carbon emissions and economic growth in the power industry of China and the United States. (3) This paper compares the differences and similarities of the factors affecting the decoupling changes of carbon emissions in the power industry between China and the United States. It aims to provide policy basis for energy conservation and emission reduction in the global power industry, especially in developing countries.

This paper is organized as follows: Section 2 summarizes the existing literature on carbon emissions in the power industry. Section 3 introduces the research methods and data sources. Section 4 is the empirical analysis of the decoupling trend of carbon emissions and economic growth in the power industry in China and the United States, as well as the impact mechanism of carbon emissions decoupling in the power industry. Section 5 discusses policy implications and concludes the paper.

2. LITERATURE REVIEW

Due to the increasing pressure of mitigating global climate change, the influence of carbon emissions have always been a hot topic. There are three main methods for studying the factors that influence carbon emissions: econometric analysis (EA), structural decomposition analysis (SDA) and index decomposition analysis (IDA).

EA reveals the quantitative relationship between target variables and explanatory variables through mathematical equations. Scholars have studied carbon emissions based on different EA [4-6]. EA can accurately identify the degree of correlation between variables and the fitting degree of regression results, but the random trend of data and the endogeneity of variables will affect the analysis results, so a series of auxiliary tests are needed to ensure the accuracy and reliability of the results. Based on the input-output table, SDA decomposes the target variables carefully according to the economic links between the variables, and quantifies the relationship between the decomposition factors and the target variables [7-10]. SDA can describe the complex production links between regions and sectors, but the decomposition of SDA is based

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on input-output tables, which requires strict data. In addition, there is a "path dependence" problem in SDA.

IDA decomposes a target variable into the product of several important factors, and analyzes the contribution of each factor to the variable increment. There are three IDA methods in common use: Laspeyres Index Decomposition (LIDA), Divisia Index Decomposition (DIDA) and Logarithmic Mean Divisia Index (LMDI). The LIDA produces a residual term, and the DIDA hasa zero value problem. Ang (1997) proposed LMDI model overcomes the problems of residual term and zero value, and is the most widely used model in IDA. For example, Xu et al. [11] applied LMDI to study carbon emissions from energy consumption in China. Based on LMDI, Ma et al. [12] studied the change of global carbon emissions. Compared with EA and SDA, IDA requires simpler data, so this paper uses LMDI to study the driving factors of carbon emissions in the power industry in China and the United States.

So far, many scholars have applied various decomposition models to analyze the driving factors of carbon emission changes in the power industry from the perspective of a single country [13-16] or a single province [17]. However, there are few comparative studies on the power industry in multiple countries in the existing literature. China and the United States are major carbon emitters in the power industry, the development and emission reduction activities of the power industry in the two countries are particularly important for the realization of the global low-carbon sustainable development goals. Therefore, this paper uses Tapio decoupling model and LMDI model to study the decoupling trend between carbon emissions and economic growth in the power industry in China and the United States and the differences in driving factors. On the one hand, the results provide a basis for the formulation of energy saving and emission reduction policies in China's power industry; on the other hand, it provides a strategic reference for energy saving and emission reduction in other developing and developed countries similar to China and the United States.

3. METHODS AND DATA

3.1. Carbon Emission Calculation Method

Carbon emissions from the power sector in China and the United States are calculated according to the "top-down" approach outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, as shown in Eq. (1):

$$C = \sum_{i=1}^{5} C_i = \sum_{i=1}^{5} E_i \times e_i \tag{1}$$

Where, C represents the carbon emissions of the power industry; C_i represents the carbon emissions generated by energy i; E_i represents the energy i generation capacity; and e_i represents the carbon emission coefficient of each power generation (see Table 1), that is, the carbon emissions generated by unit energy generation capacity. Considering that the proportion of solar and wind power generation is small and the carbon emissions are very small, this paper only considers the carbon emissions generated by coal, oil, natural gas, water and nuclear energy.

Table 1. Carbon emission factors of various power generation modes

Type of energy sources	Coal	Petroleum	Natural gas	Water	Nuclear energy
Carbon Emission Factor (G/Kwh)	820	733	490	24	12

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3.2. Tapio Elastic Analysis

Decoupling model explains the internal relationship between economic development and environmental pressure through a simple quantitative relationship. Decoupling means breaking the dependence between economic development and environmental pressure (OECD, 2002). Decoupling models include the OECD decoupling index, the Velma decoupling index and the Tapio elastic index [18]. Tapio elastic index is further subdivided on the basis of OECD and Velma, and the decomposition results are more accurate. Therefore, this paper uses Tapio elastic index to study the decoupling state of carbon emissions and economic growth in China and the United States. Tapio's definition of decoupling index:

$$D = \frac{\left(C^t - C^0\right) / C^0}{\left(G^t - G^0\right) / G^0} = \frac{\Delta C / C^0}{\Delta G / G^0} \tag{2}$$

Where D is the decoupling index; C^0 and G^0 respectively represent carbon emissions and gross domestic product (GDP) of the power industry in the base period of 0 years; C^t and G^t respectively represent the carbon emission and GDP value of the power industry in the target period t; ΔC and ΔG represent the changes of carbon emission and GDP of power industry from base period to t period respectively; $\Delta C/C^0$ and $\Delta G/G^0$ represent the growth rate of carbon emission and GDP of power industry from base period to t period respectively. Figure 1 shows the classification criteria of eight decoupling states based on Eq.(2):

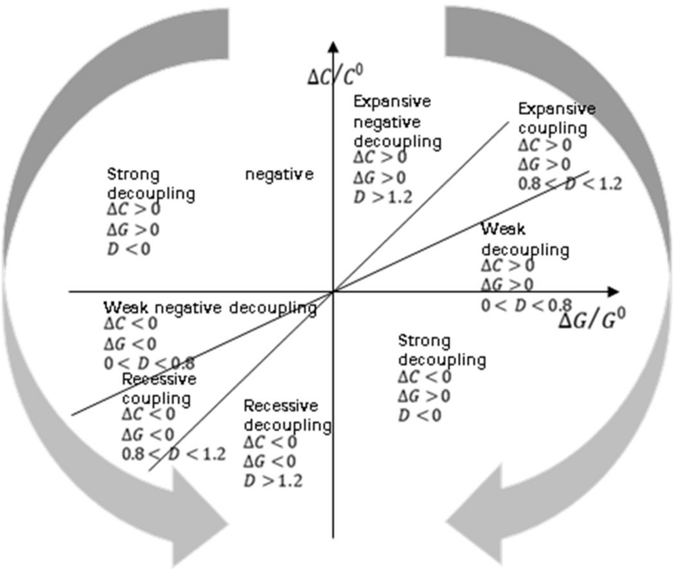

Figure 1. Decoupling analysis model of economic growth from carbon emissions

3.3. LMDI Decomposition Model

Kaya identity Eq. (3) was first proposed by Yoichi Kaya in 1989, and the model can be decomposed in different ways according to the research focus of scholars [19]. In this paper, five factors affecting the emissions of the power industry are considered, and the following extended kaya identity Eq. (4) is obtained:

Basic identity:

$$C = \frac{C}{E} \times \frac{E}{GDP} \times \frac{GDP}{P} \times P \tag{3}$$

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Extended Kaya identity:

$$C = \sum_{i=1}^{5} \frac{C_i}{E_i} \times \frac{E_i}{E} \times \frac{E}{G} \times \frac{G}{P} \times P = \sum_{i=1}^{5} CI \times ES \times EI \times A \times P \tag{4}$$

The footprints $i = 1, 2, 3, 4, 5$ represent the energy sources used to generate electricity: coal, oil, natural gas, water and nuclear energy. C is the total carbon emissions of the power industry; C_i is the carbon emissions generated by energy i; E_i is the power generation of energy i, that is, coal, oil, gas, hydropower and nuclear power; E is the total power generation; G is GDP expressed in constant US dollars in 2010; and P is total population. In addition, CI represents the carbon emission coefficient, i.e., the CO2 generated per unit of power generation; ES represents the power structure, i.e., the share of each power generation mode in the total power generation; EI represents the power intensity, namely, the power generation required for the development of per unit of GDP; A represents the level of economic development.

According to the LMDI model (Ang2004) [20], the carbon emission change of the power industry from the base period 0 to t is decomposed into five influencing factors, and the Eq. (5) is as follows:

$$\Delta C = \Delta C_{CI} + \Delta C_{ES} + \Delta C_{EI} + \Delta C_{A} + \Delta C_{P} \tag{5}$$

It is important to note that the carbon emission factors for various energy sources are constant (IPCC) with no change in technology, so in this study ΔC_{CI} will be taken as 0. Thus, the remaining determinants are calculated as Eqs. (6)- (9):

$$\Delta C_{ES} = \sum_{i=1}^{5} \frac{C_i^t - C_i^0}{\ln C_i^t - \ln C_i^0} \ln \frac{ES_i^t}{ES_i^0} \tag{6}$$

$$\Delta C_{EI} = \sum_{i=1}^{5} \frac{C_i^t - C_i^0}{\ln C_i^t - \ln C_i^0} \ln \frac{EI^t}{EI^0} \tag{7}$$

$$\Delta C_{A} = \sum_{i=1}^{5} \frac{C_i^t - C_i^0}{\ln C_i^t - \ln C_i^0} \ln \frac{A^t}{A^0} \tag{8}$$

$$\Delta C_{P} = \sum_{i=1}^{5} \frac{C_i^t - C_i^0}{\ln C_i^t - \ln C_i^0} \ln \frac{P^t}{P^0} \tag{9}$$

Among them, ΔC_{ES} represents the power structure effect, ΔC_{EI} represents the power intensity effect, ΔC_A represents the economic growth effect and ΔC_P represents the population size effect.

In addition to comparing the decoupling status of carbon emissions in the power industry between China and the United States, this paper also further analyzes the differences in driving factors behind decoupling. Therefore, this paper refers to the method of Wang [21] and combines Eq. (2) and Eq. (5) to further obtain Eq. (10):

$$D = \frac{\Delta C / C^0}{\Delta G / G^0} \tag{10}$$

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$$= \frac{\left(\Delta C_{ES} + \Delta C_{EI} + \Delta C_{A} + \Delta C_{P}\right) / C^{0}}{\Delta G / G^{0}}$$

$$= \frac{\Delta C_{ES} / C^{0}}{\Delta G / G^{0}} + \frac{\Delta C_{EI} / C^{0}}{\Delta G / G^{0}} + \frac{\Delta C_{A} / C^{0}}{\Delta G / G^{0}} + \frac{\Delta C_{P} / C^{0}}{\Delta G / G^{0}}$$

$$= D_{ES} + D_{EI} + D_{A} + D_{P}$$

Where, D_{ES}, D_{EI}, D_{A}, D_{P} respectively represent the contribution of power structure, power intensity, economic growth and population to the total decoupling index.

3.4. Data Sources

The research object of this paper is the carbon emissions of the power industry in China and the United States from 2000 to 2019. In order to avoid the error of data statistics and facilitate international comparison, the data of unified caliber are selected in this paper. Carbon emissions, total power generation, and power generation by energy source for China and the United States are from BP; gross domestic product (GDP) and population are from the World Bank. In addition, GDP in constant 2010 dollars is used to account for inflation.

4. RESULTS AND DISCUSSION

4.1. Comparison of Carbon Emission Trends of Power Industry Between China and The United States

From 2000 to 2019, the carbon emissions of China's power industry increased from 912 million tons to 4.13 billion tons, with an average annual growth rate of 8.3%, as shown in Figure 2. It can be seen that the carbon emissions of China's power industry and GDP maintain the same trend, indicating that economic growth is accompanied by an increase in carbon emissions from the power industry. Compared with China, the trend of carbon emissions in the power sector in the United States is relatively stable, from 2.1 to 1.729 billion tons in 2019, with an average annual growth rate of -1.2%. Although there are fluctuations in the carbon emissions of the power industry in the United States, the carbon emissions of the power industry in the United States generally show a downward trend during the study period, especially after 2007. The different emission trends of the power industry in China and the United States are due to the important impact of economic development on carbon emissions, and the two countries are at different stages of development. China is still in the middle stage of industrialization, while the United States achieved industrialization as early as the end of the 19th century and is now in the late stage of industrialization [22]. Therefore, this paper studies the relationship between carbon emissions and economic growth in the power industry.

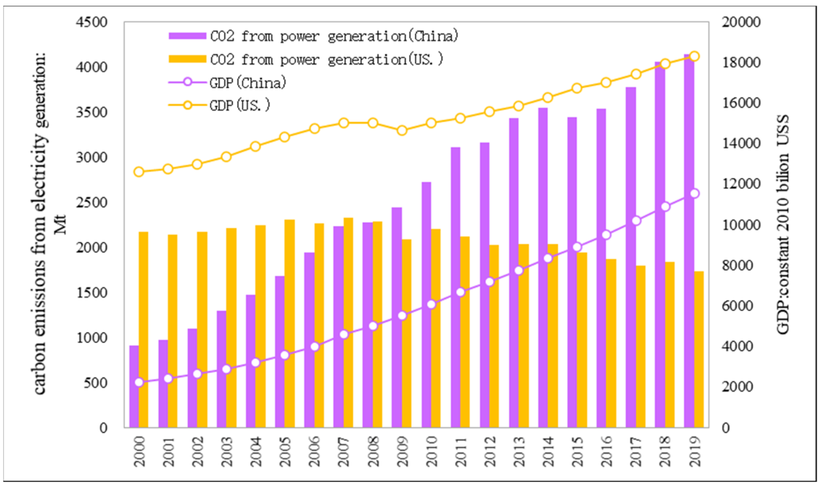

Figure 2. Carbon Emissions and GDP of Power Industry in China and the U.S.

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4.2. Comparative Study on Decoupling of Carbon Emissions in Power Industry between China and the United States

Table 2 shows the short-term (1-year) decoupling status of carbon emissions from the power sector in China and the United States from 2000 to 2019. It can be seen from the table that during the study period, there are four decoupling States of carbon emissions in China's power industry: growth negative decoupling, growth connection, weak decoupling and strong decoupling.

Table 2. Decoupling Status of Economic Growth from Carbon Emissions in China and the U.S.

Years	China		U.S.	
2001	0.77	Weak decoupling	-1.38	Strong decoupling
2002	1.44	Negative growth decoupling	0.88	Growth Connection
2003	1.80	Negativegrowth decoupling	0.60	Weak decoupling
2004	1.35	Negative growth decoupling	0.44	Weak decoupling
2005	1.21	Negative growth decoupling	0.72	Weak decoupling
2006	1.23	Negative growth decoupling	-0.53	Strong decoupling
2007	1.05	Growth Connection	1.53	Negative growth decoupling
2008	0.19	Weak decoupling	16	Decline decoupling
2009	0.8	Weak decoupling	3.27	Decline decoupling
2010	1.07	Growth Connection	2.14	Negative growth decoupling
2011	1.49	Negative growth decoupling	-2.65	Strong decoupling
2012	0.21	Weak decoupling	-1.85	Strong decoupling
2013	1.12	Growth Connection	0.27	Weak decoupling
2014	0.45	Weak decoupling	0.06	Weak decoupling
2015	-0.44	Strong decoupling	-1.59	Strong decoupling
2016	0.44	Weak decoupling	-2.49	Strong decoupling
2017	0.94	Growth Connection	-1.68	Strong decoupling
2018	1.11	Growth Connection	0.86	Growth Connection
2019	0.34	Weak decoupling	-2.71	Strong decoupling

In the short term, China's first and only strong decoupling occurred in 2015, which was attributed to the coal price increase policy implemented in China in 2014, resulting in a reduction in coal-fired power generation in 2014-2015, which led to a decline in carbon emissions. Growth connection and negative growth decoupling indicate that there is no obvious decoupling between carbon emissions from the power sector and economic growth. China has been in a state of negative growth decoupling and growth connection for most of the study period.Unlike China, the United States experienced recessionary decoupling in 2008-2009 as a result of the 2008 financial crisis, suggesting that carbon emissions from the power sector declined with the recession, but GDP contracted less than carbon emissions.In 2010, there was a negative decoupling in the growth of carbon emissions from the power sector in the United States.Since then, the United States has taken effective measures to reduce emissions, and there has been a widespread strong decoupling, that is, economic growth is accompanied by a decline in carbon emissions, which is the most ideal decoupling state.

In order to reduce the impact of macroeconomic and unexpected events (such as the US financial crisis in 2008 and the global COVID-19 in 2019) on the short-term decoupling index,

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this paper further evaluates the decoupling status of carbon emissions in the power industry between China and the United States in the medium term (5 years) and long term (10 years), as shown in Figure 3. Compared with the short-term decoupling index, the medium-term and long-term decoupling index more clearly reflects the changing trend of the decoupling state of carbon emissions in the power industry between China and the United States: China experienced a negative decoupling of growth, a connection of growth and then a weak decoupling; while the United States experienced a weak decoupling and then a strong decoupling.

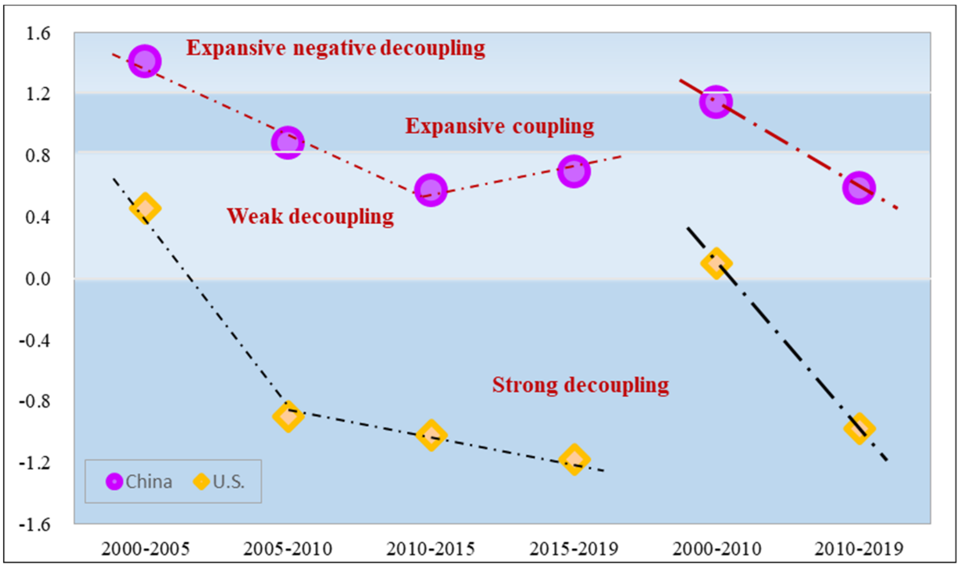

Figure 3. Medium-term and long-term decoupling of carbon emissions in China and the U.S.

4.3. Influencing Factors of Decoupling of Carbon Emissions in China and the U.S.

Decoupling index only quantitatively evaluates the state and trend of decoupling between carbon emissions and economic growth in the power industry.To achieve low-carbon development of the power industry, it is more important to explore the driving factors of decoupling between carbon emissions and economic growth. Figure 4 (a)- (b) shows the decomposition results of the decoupling index of carbon emissions in the power industry of China and the United States from 2000 to 2019.It can be seen from the figure that power structure and power intensity are the main factors to promote the decoupling of carbon emissions in the power industry between China and the United States, while economic growth and population development inhibit the decoupling of carbon emissions. However, unlike China, in the United States, the contribution of power structure and power intensity is greater than the effect of economic growth.

From the short-term, medium-term and long-term decoupling index, we can see that the decoupling state of carbon emissions from the power industry in the United States is much better than that in China. In order to analyze the reasons for this phenomenon, this paper uses the LMDI model to decompose the decoupling index of carbon emissions from the power industry in China and the United States into four factors: power structure, power intensity, economic growth and population size, in order to determine the mechanism of the decoupling status difference between China and the United States. Figure 4 (a)- (b) shows the decomposition results of the decoupling index of carbon emissions from the power sector in China and the United States from 2000 to 2019, respectively.

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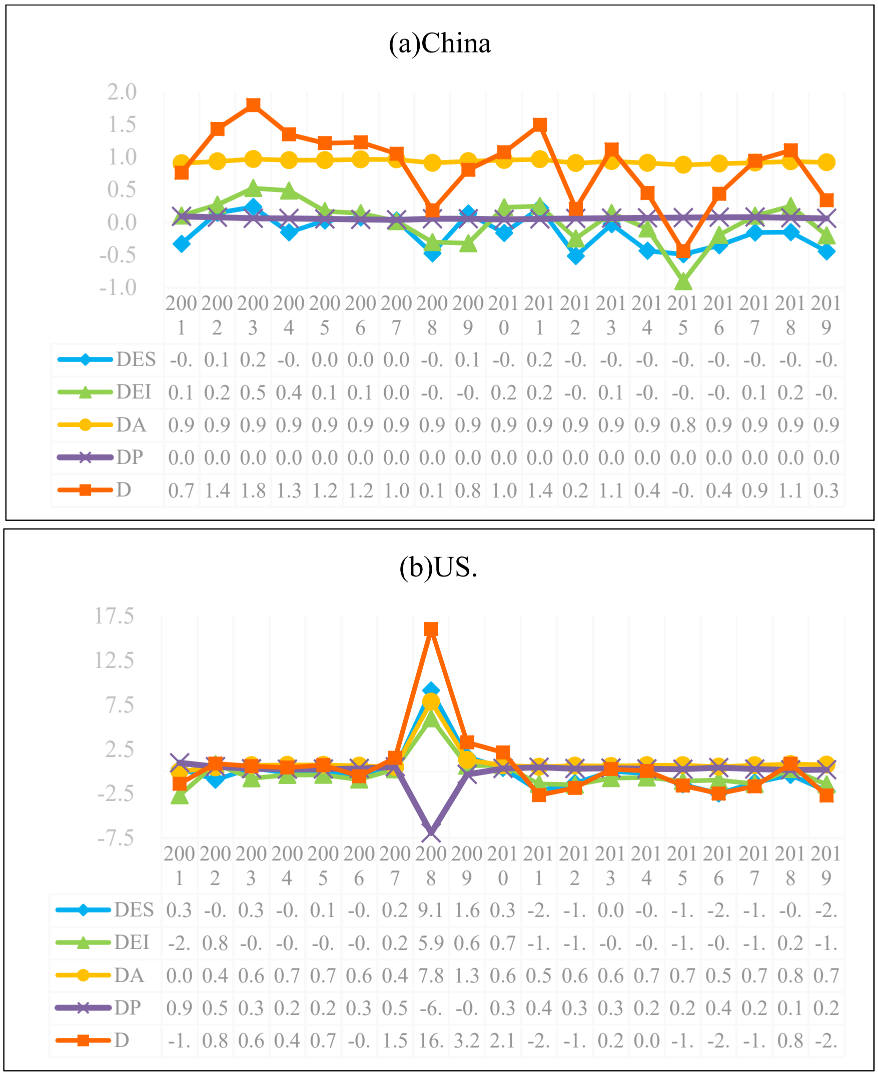

Figure 4. Decomposition of decoupling index of carbon emissions of China and the U.S. from 2000 to 2019

Power structure effect. According to Figure 4, the power structure is the most important factor to promote the decoupling of carbon emissions in the power industry between China and the United States, but numerically, the contribution of the power structure in the United States to the decoupling of carbon emissions is much greater than that in China: the contribution of the power structure in the United States is 142%, while that in China is only 21%. Figure 5 shows the power source structure of China and the United States in 1990 and 2019. From 1990 to 2019, the proportion of coal-fired power in China dropped from 71% to 64.The proportion of clean energy power generation increased from 0.01% to 9.9%, and the optimization of power structure led to a cumulative reduction of 666 million tons of carbon emissions in the power industry, accelerating the pace of decoupling carbon emissions from economic growth in the power industry. During the same period, the proportion of coal power in the United States dropped from 53.4% to 23.8%, and the proportion of gas power increased from 12.4% to 38.8%.At the same time, because the carbon emission of natural gas per kilowatt-hour of power generation is about half of that of coal [23], the replacement of coal by natural gas for power generation promotes the reduction of carbon emissions in the U.S. power industry, thus ensuring that the U.S. economy grows at a rate of 2% while carbon emissions decline at a rate of 1.6%.

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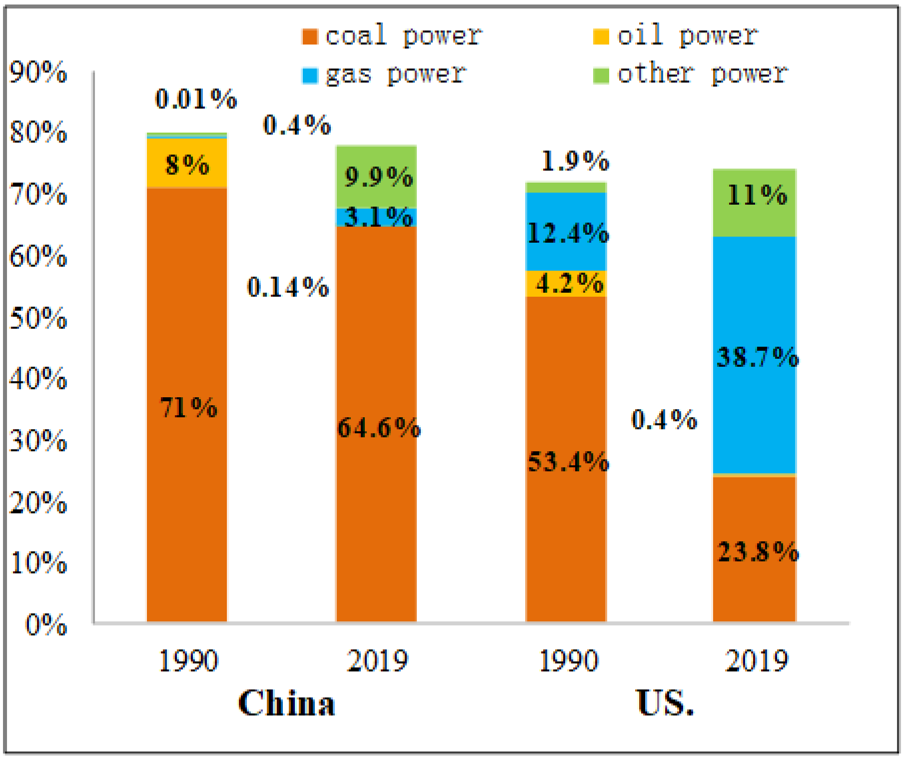

Figure 5. Power structure of China and the U.S. from 1990 to 2019

Through the comparison of power structure between China and the United States, it can be clearly found that the power structure effect of decoupling carbon emissions in the power industry in the United States is much greater than that in China, to a large extent, due to the fact that the proportion of coal-fired power in the United States is declining faster than that in China. Due to China's resource endowment of "more coal and less gas", China's coal-based power structure will still exist for a long time, but with the progress of low-emission coal technology and clean energy power generation technology, the power structure will further deepen the decoupling degree of carbon emissions.

Power intensity effect. It can be seen from Figure 4 that the change trend of electricity intensity effect is consistent with that of electricity structure effect, which also promotes the decoupling of carbon emissions in the electricity industry between China and the United States, but the contribution of electricity intensity effect to carbon emissions decoupling in the United States is 135%, while that in China is 2%. This indicates that the energy productivity of economic activities in China and the United States has been improved [24], which has led to a decline in carbon emissions in the power sector and a decoupling of carbon emissions from economic growth.At present, China's per capita power generation is 5,368 kWh, 40% of that of the United States; in addition, compared with the United States, China's industrialization and urbanization development is not yet perfect; meanwhile, in order to achieve low-carbon development, the National Development and Reform Commission (2016) implements the electrification policy. The above three reasons are likely to further increase China's power generation, so China urgently needs to improve power generation technology and energy productivity to enhance the impact of power intensity on carbon emissions decoupling.

Economic growth and population effect. Economic growth is the main factor that inhibits the decoupling of carbon emissions from the power industry between China and the United States, but numerically, the inhibitory effect of economic growth in China is stronger than that in the United States, accounting for 115% of the decoupling index, while that in the United States is 103%. During the study period, China's economy grew at a rate of 9.02%, which was maintained

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at 9.5% even during the financial crisis. Such extensive economic growth must be supported by electricity, resulting in a cumulative increase of 37.1.2 billion tons. However, the 19th National Congress of the Communist Party of China has put forward the goal of normalizing economic development, and in the future, this high-quality and low-speed development model is bound to weaken the inhibitory effect of economic growth on the decoupling of carbon emissions in the power industry. As the largest developed country, the average annual GDP growth rate of the United States is only 1.98%.However, through the comparative analysis of the speed of economic development between China and the United States and its degree of restraint on decoupling, we can see that carbon emissions decoupling can not be achieved only by changing the mode of economic development. The population effect also increases the carbon emissions of the power industry in China and the United States, which inhibits decoupling, but this effect is very small compared with the other three factors.

5. CONCLUSIONS AND POLICY IMPLICATIONS

5.1. Conclusions

This paper makes a comparative study on the influencing factors and decoupling status of carbon emissions in the power sector between China and the United States from 2000 to 2019.Firstly, the LMDI model is used to decompose the influencing factors of carbon emissions in the power industry of the two countries, and then the Tapio decoupling index is constructed to compare and analyze the decoupling state between carbon emissions and economic growth in the power industry of the two countries;Finally, the decoupling index of power industry carbon emissions in China and the United States is further decomposed to determine the determinants of the decoupling state of the two countries. The main conclusions of this study are as follows:

(1) During the study period, carbon emissions from the power sector in China increased significantly, with an average annual growth rate of 8.3%; compared with China, carbon emissions from the power sector in the United States declined steadily at a rate of -1.2%.

(2) During the study period, the decoupling status of carbon emissions from the power sector in the United States is better than that in China. In addition, economic growth is the most unfavorable factor restricting the strong decoupling of carbon emissions from the power industry in China and the United States, followed by population, while power structure and power intensity promote the decoupling between the two countries. However, compared with China, the promotion effect of power structure and power intensity on decoupling is greater than the inhibition effect of economic growth in the United States, so the decoupling state is more ideal.

5.2. Policy Implications

Based on the results of the comparative study of carbon emissions and economic growth in the power industry in China and the United States, this paper puts forward the following suggestions to promote the realization of emission reduction targets and the development of low-carbon economy.

(1)Maintain moderate economic growth and insist on promoting the normalization of economic development to weaken the positive impact of economic growth on the growth of carbon emissions in the power sector and the negative impact of decoupling. Economic growth is an important factor in restraining decoupling, especially for emerging economies such as China and India, which should seek an economic development model suitable for their national conditions within the scope of environmental affordability.

(2)Improve the technical level and optimize the power supply structure. The power structure plays a more prominent role in promoting decoupling in the United States than in China. In

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order to achieve the goal of carbon neutrality, the power structure of China and the United States, especially China, needs to be further optimized. It is necessary to use more low-carbon energy sources, such as natural gas and renewable energy sources (such as wind and solar energy);Non-clean energy-consuming technologies, such as carbon capture and storage (CCS), should also be encouraged.

(3)Implement the carbon emission trading system and promote the marketization of carbon emission costs. At present, the Regional Greenhouse Gas Emission Reduction Initiative (RGGI) promulgated and implemented by the United States and the National Carbon Emission Trading Market Construction Plan promulgated by the State Council of China are the only two carbon emission trading systems in the world in which only the power industry participates. In the future, other sectors and other countries in urgent need of low-carbon development should also adopt corresponding policies to actively respond to global climate change.

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