A Review Research on the correlations among Carbon Emissions, Industrial Structure, and Economic Growth

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Abstract. The current situation of industrial structure and economic growth in China is analyzed first, and then collects, sorts, classifies and summarizes relevant studies on the correlations among economic growth, industrial structure, and carbon emissions, and reviews and summarizes the research methods.

1 Introduction

As one of the most serious challenges facing mankind in the 21st century, the issue of climate change has received widespread attention and importance from the international community. The rising CO2 concentration in the atmosphere as a result of human activity's rising energy consumption is most likely what is causing the world's climate to change [1]. On the one hand, economic growth and industrial development are dependent on fossil fuels directly or indirectly, and because different industries are dependent on energy to varying degrees and because different economic growth patterns exist, economic growth, industrial structure, and carbon emissions are all interconnected.

2 Analysis of carbon emissions, industrial structure and economic growth in China

2.1 Carbon emissions

China's carbon emissions are generally increasing in overall volume. An almost 6.5-fold increase between 14.62 million tons in 1978 and 10.838 billion tons in 2017. Due to China's first-ever energy development strategy, which was introduced in 1996, which vigorously adjusted the structure of energy production and consumption, promoted advanced energy-saving technologies, increased the efficiency of energy production, and implemented other policies, it showed a slight downward trend from 1996 to 1999. Some businesses with outdated technology and production capacity as well as serious environmental pollution were forcibly shut down during this time. Additionally, China's carbon emissions during this period were somewhat impacted by the Asian financial crisis. China has experienced a sharp rise in carbon emissions in the new century, particularly since 2002. This is because China's economic development entered a new cycle, and the ongoing growth of domestic demand and investment caused the rapid increase in energy consumption. China's per capita carbon emissions are still growing at a considerably slower rate than the global average. Despite the size and annual growth of China's carbon emissions, the intensity of those emissions is generally declining. In 1978, China's carbon emission intensity was as high as 3.97 tons per 10,000 yuan, which dropped to 0.14 tons per 10,000 yuan in 2017, a drop of 3.8 times. This indicates that as China's economy grows, the same amount of GDP growth brings a decreasing trend of carbon emission increment year by year.[2]

2.2 China's current industrial structure

In China, the share of the primary industry's output value has been declining for a while, while the share of the secondary one has been relatively stable, varying between 40% and 50%, and the share of the tertiary industry's output value has been rising. The progression from "two one three" to "two three one" and finally to "three two one" is visible in the overall industrial structure. In 2017, the three industries had a structure of 7.9, 40.5, and 51.6, and the tertiary industry made up half of China's national GDP.[3]

2.3 Analysis of the current situation of China's economic growth

China's national economy has experienced glorious achievements of continuous and rapid growth over the past 40 years and has exited an economic development path with Chinese characteristics through impressive advancement in terms of economic development level and social structure. In addition to greatly raising people's living conditions and bolstering overall national power, a new historical starting point for the country's future development is also established.

1978 China's GDP ranked 10th in the world, jumped to 6th in 2000, overtook Japan to rank second in the world in 2010, and remained until 2017, becoming an

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economic power with a GDP level second only to that of the United States. In 1978, our GNI per capita ranked 175th among 188 countries counted, rising to 141st in 2000 and 87th among 187 countries counted in 2017, moving from a low-income economy to a middle- to a high-income economy. Total import and export trade ranked 29th in 1978 and 8th in 2000, and ranked first in the world for the first time and again in 2015 and 2017, respectively. Foreign exchange reserves ranked 38th in 1978, jumped to 7th in 1990, and ranked 1st in 2017. Correspondingly, except for the indicator of the total population, which has declined, the share of China's other major economic indicators in the world has increased rapidly. Among them, the share of GDP in the world rose from 1.75% ± in 1978 to 15.17% in 2017. The share of total import and export trade in the world rose from 0.79% in 1978 to 10.22% in 2017. The share of foreign direct investment in the world rose from 0.11% in 1980 to 9.53% in 2017.[3]

3 Correlations among economic growth, industrial structure, and carbon emissions

3.1 Correlation between carbon emission and industrial structure

Foreign academics' research on this topic has a fairly broad scope and generally discusses the connection between carbon emissions and a variety of factors, including the internal organization of enterprises, the relationship between input and output, and the effectiveness of energy usage. For instance, Li et al. [4] found that although China's industrial structure has gradually improved, it still needs to be optimized because the industrial network density is still high when compared to the characteristics of Japan's and other developed nations' industrial structures.

Decomposition analysis and econometric analysis can be used to categorize the domestic literature on industrial structure and carbon emissions. Gu Alun et al. [5] evaluated each sector of the national economy by building carbon emission impact coefficients and carbon emission inductance coefficients, and the results showed that the majority of the basic industries in the national economy are high-energy-consuming industries. The focus of future energy conservation and emission reduction needs to gradually shift from these high-energy-consumption industries. He Yonggui et al. [6] studied carbon emissions, their changing trends, and the relationship between the industrial structure of China using the improved STIRPAT model.

3.2 Correlation between carbon emission and economic growth

This research may be loosely classified into two categories: a qualitative analysis and a quantitative analysis. Multiple regression analysis, correlation testing, and the Kuznets curve for the environment are the key tools used to conduct qualitative analysis investigations. For instance, Tucker [7] built quadratic multiple regression equations with GDP and carbon emissions per capita as indicators of economic growth and carbon emissions to study the relationship between carbon emissions and GDP. Tucker used data from 137 countries for more than 20 years as a sample. For 100 countries and regions, Azomahou [8] built a panel data model for GDP per capita and carbon emissions per capita. He then conducted an analysis and found a positive link between the two. After performing an EKC test for 30 years starting in 1980, Abid [9] concluded that there is a cointegration relationship between Tunisia's GDP and carbon emissions, but the Kuznets condition is not met. According to Yang et al. [10], the decoupling of carbon emissions and GDP in China is weak, with a strong decoupling beginning in 2014. In China, the United States, India, and Japan, the effects of economic growth and energy intensity are more significant in influencing the decoupling of carbon emissions from GDP. Additionally, in India and Japan, respectively, the population impact and the energy structure effect play significant roles in the decoupling of GDP from carbon emissions.

By using structural equations and panel models, some academics have proved and connected the Kuznets curve between economic growth and the environment in China or other regions. Some academics contend that the correlation between China's carbon emissions and economic growth is compatible with an inverted U-shaped trend, while others contest the existence of such a correlation between China's carbon emissions per capita and GDP per capita. Scholars gradually apply the decoupling theory to environmental, energy, economic, and specific regional studies to reflect the decoupling relationship between variables dynamically because the classical environmental Kuznets curve method can only identify the relationship between economic development and environmental pressure, making it difficult to identify the specific stage of the dilemma between economic development and environmental pollution.

3.3 Correlation between industrial structure and economic growth

Earlier studies on the connection between industrial structure and economic growth were conducted elsewhere. The American researcher Kuznets [11] then looked at the pattern of changes in gross output and identified the main direction of changes in industrial structure. After examining American economic growth from 1929 to 1957, Denison [12] concluded that 12% of it was due to industry reorganization. Since then, researchers from many nations have used the theory of industrial structure and economic growth to perform empirical investigations on the connection between industrial structure and economic growth. To investigate the impact of industry structure and changes in industrial structure on aggregate growth and income, Peneder [13] built a dynamic cross-sectional econometric model using time series data from 28 OECD nations between 1990 and 1998. The findings indicate that, on average, the value-added share of services and the respective shares of imports and exports in labor-intensive and technology-driven industries contribute 63% of economic growth in the 28 OECD nations. Through econometric modeling and analysis of panel data on the service sector and economic growth for 37 OECD countries from 1980 to 2005, Maroto-Sanchez [14] concludes that aggregate output increases by 1.9% for every 1% increase in the share of employment in the service sector. The Granger test reveals that, while economic output growth is not the Granger cause of service sector growth, it is the Granger cause of growth in the service sector. To examine the association between industrial structure indicators and economic growth in a 55-year panel data of 47 Japanese prefectures, Xueling Guan et al. [15] created two measures of industrial structure advancement and rationalization. It was determined that sophisticated and rationalized industrial structures both boosted economic growth, however, the impacts vary depending on the stage of economic development.

3.4 Research on the relationship between carbon emission, industrial structure, and economic growth

Using econometric techniques, Halicioglu [16] investigated the causal relationship between carbon dioxide emissions, energy consumption, income, and foreign trade in Turkey. To study the relationship between economic growth, industrial structure, and carbon emissions in 2015, Tao Changqi et al. [17] used a panel vector autoregressive (PVAR) model. They discovered that there is a long-term equilibrium relationship between these three variables. Economic growth has a significant impact on carbon emissions, but economic growth is not a driver of carbon emissions. Carbon emissions and industrial structure are dynamically linked in two directions. The Granger causality test and the VEC model were then used by Qiao Zhenzhi [18] to examine the dynamic relationship between carbon emissions and economic growth, industrial structure, and urbanization level in China. He concluded that over the long term, GDP per capita, the share of secondary industry, and urbanization level have an impact on emissions while the share of tertiary industry has an impact on emissions reduction. Short-term reductions in carbon emissions are mutually influenced by the degree of urbanization and the proportion of tertiary industries. The Granger cause of the increase in the share of secondary industries is the rise in carbon emissions.

4 Research methodology

4.1 Calculation and decomposition of carbon emissions

The Guidelines for National Greenhouse Gas Inventories, which provide a standardized algorithm and reference standard for carbon emission estimation, were first published by the IPCC in 1996. The 2006 National Greenhouse Gas Inventory Guidelines amended the original inventory and became the latest standard for carbon emission measurement in each region. The IPCC inventory was studied in the context of developed countries, and there was no objective estimation of the emission status of fossil fuel combustion and industrial development in developing countries. China's National Climate Change Countermeasures Coordination Group (NCCCCCG) has established five separate sections to measure GHG inventories for energy activities, industrial processes, agricultural activities, urban waste, land use change, and forestry. In addition to creating an inventory of gas emissions, different carbon sources are measured using real measurement techniques, material balance techniques, emission factor techniques, model simulation techniques, system simulation techniques, decision tree techniques, and so forth.

4.2 Carbon emission analysis based on scenario analysis and model simulation

By setting different development scenarios and carbon emission scenarios, the scenario analysis method can effectively get rid of the limitation of the researcher's cognitive ability and research model, measure the response state of economic development, industrial structure, and carbon emission, and make long-term quantitative planning. The Sustainable Development Strategy Research Group of the Chinese Academy of Sciences used scenario analysis and decoupling theory to study China's future low-carbon development scenarios [19]. The research team of Liu Weidong et al. set two industrial structure change scenarios according to industrial structure as the main emission reduction factor and proposed a basic framework for low-carbon economic development [20]. With the aid of the MARKAL-MACRO model, Wenying Chen described the temporal pattern of the influence of emission reduction on GDP growth under various scenarios and contrasted the total loss of undiscounted GDP for various emission reduction scenarios [21]. The model simulation method calculates and simulates the energy consumption trends and carbon emission levels under economic growth scenarios by constructing models of urban economic systems and socio-economic energy systems.

4.3 Carbon emission study based on input-output and carbon footprint

The input-output model-based analysis, which has been extensively utilized in the disciplines of economy, energy, and environment, is a potent tool for determining how the interrelated components of an economic system affect the economic growth-industrial structure-carbon emission system. Input-output techniques were used by Tang et al. to develop an AECPC model, introduce the idea of average energy consumption, and identify the nine production chains that had the greatest average energy consumption of various energy products [22]. Liu

Hongguang et al. created a structural analysis model of regional carbon emissions and a CO2 reduction model of regional industrial restructuring based on the non-competitive input-output analysis framework and inter-regional input-output tables to research the emission sensitivity of economic restructuring [23].

5 Conclusion

Although the correlations among carbon emissions, industrial structure, and economic growth in China have been systematically and comprehensively analyzed in this paper and some results have been obtained, the conclusions are still not entirely accurate due to data availability, technical level, and my research capacity. We can broaden and advance in the future by looking at these problems from the following two angles.

First, when analyzing the influencing factors of carbon emissions, we can consider adding more influencing factors into it and decompose the research from the perspective of internal causes.

Second, the industrial structure needs to be measured using a more reasonable and scientific measurement of the advanced level of industrial structure.

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