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Research on the Factors Influencing Carbon Emissions of Energy Consumption in Anhui Province

-- Based on LMDI Factor Decomposition and LEAR Model

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Abstract

As a province with coal-based energy structure, it becomes particularly important to balance the relationship between economy, energy and environment in Anhui Province. This study takes the energy sector of Anhui Province as the research object, takes the energy balance sheet of Anhui Province as the empirical data, calculates and analyzes the carbon emission of energy consumption and the change characteristics of Anhui Province from 2005 to 2022, uses LMDI factor analysis to quantify the contribution of economic development, energy consumption intensity, etc. to carbon emission, and introduces LEAP model to establish four scenarios for Anhui Province from 2025 to 2030 for energy consumption The trend of energy consumption and carbon emission in Anhui Province from 2025 to 2030 is forecasted, and the consumption of non-clean energy in Anhui Province is further analyzed to provide some political reference for the development strategy of energy conservation and emission reduction in Anhui Province.

Keywords

Carbon Emission; Factor Decomposition; LEAP Model; LMDI Model.

1. Introduction

Human activities emit a large amount of greenhouse gases, resulting in global temperature rise global warming, the consequences of global warming are extremely serious, such as sea level rise, glacier melting, uneven distribution of precipitation, frequent extreme weather, which will also threaten the survival and development of human beings. In order to cope with global warming, the international community generally agrees that actions to reduce emissions are needed to lower greenhouse gas emissions and at the same time strengthen the adaptive capacity to cope with climate change. The international community has been making efforts to this end. To address global warming, the international community has engaged in extensive cooperation to reduce emissions. The United Nations Framework Convention on Climate Change (UNFCCC) is an important mechanism for international cooperation on emission reduction, aiming to strengthen cooperation and coordination in reducing greenhouse gas emissions globally, and to achieve global CO2 emission reduction targets by promoting the formulation and implementation of national emission reduction targets.

In addition, countries also carry out emission reduction exchange and cooperation through various multilateral and bilateral cooperation mechanisms, such as the United Nations Emission Reduction Mechanism for Developed Countries, the United Nations Clean Development Mechanism, and the European Union Carbon Emission Trading System. At the

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same time, countries have also adopted domestic laws and policy regulations to promote the implementation of emission reduction actions. These emission reduction cooperation initiatives have provided important support for the global response to climate change issues and promoted the coordination and advancement of global emission reduction cooperation.

Anhui Province, as a central province in China, has a changing energy consumption profile. According to recent data, the composition of energy consumption in Anhui Province is complex and diverse, but coal is still the most dominant energy source in Anhui Province, accounting for more than half of the total energy consumption, which greatly affects the total carbon emissions in Anhui Province. In order to better adapt to the current development situation, Anhui Province must now balance the relationship between energy, development and carbon emissions, and change its original development thinking to energy conservation and emission reduction.

2. Current Status of Research

In terms of time dimension, China's carbon emission interval can be divided into three major phases: the low growth phase from 1978 to 2002, the high growth phase from 2002 to 2011, and the fluctuating peak phase after 2011 under the high quality economic development. In the accelerated transition scenario, China will reach the peak of carbon emissions around 2025, with a peak of about 10.4 billion tons (Liu, 2021); in the spatial dimension, the internal structural sources of carbon dioxide emissions at the provincial level in China from 2000 to 2019 are characterized by obvious changes, showing a spatial distribution pattern of "more in the east and less in the west, more in the north and less in the south " distribution pattern, as well as a shift of the distribution center of gravity to the west. The level of spatial variation of CO2 emissions in China is on the rise, and the characteristics of spatial imbalance are increasingly prominent (Liu, Huajun, 2023); analyzing the relationship between energy consumption and carbon emissions in its own dimension, carbon emissions are bound to continue to increase with economic development under the rapid development of the global economy. Studying and analyzing the influencing factors of energy consumption intensity changes and its relationship with carbon emissions is conducive to improving energy use efficiency and promoting the construction of an efficient low-carbon energy system (Zhang, Chi, 2019). These dimensions together require recognizing the contradiction between growing demand and limited resources, trying to solve the problem of dynamic balance between energy utilization, energy consumption and economic development, conforming to energy conservation and emission reduction, and achieving the goal of "double harmony".

Meanwhile, many scholars have already made predictions and recommendations on the trends of energy consumption and carbon emissions in different provinces and cities in different regions of China: the emission factor method was used to measure the carbon emissions in Shanxi Province, and it was concluded that the agriculture in Shanxi Province has already achieved the carbon peak, and with the further strengthening of low-carbon measures, it will help to accelerate the achievement of the carbon neutrality goal (Wang Shufen, 2023); the Kaya constant equation and the log-averaged Dirichlet decomposition (LMDI) method were used to estimate the carbon emissions in Shanxi Province from 1983 to 2005. method (LMDI) to systematically analyze the trend of carbon emissions in Hong Kong from 1983-2018, and concluded that Hong Kong should continue to implement a strong strategy to control total energy consumption and total carbon emissions to control carbon emissions, and pay attention to the potential impact of future energy price fluctuations (Lin, 2022); using the LEAP model to set up four scenarios to predict the industrial sector of Shanghai's carbon emission trends using the LEAP model, resulting in three feasible scenarios to provide viable means for the industrial sector in Shanghai (Cheng, Ningxi, 2022).

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These studies have already played a role in achieving the "double sum" goal of energy conservation and emission reduction in various regions, and the same regional research on energy and carbon emissions has also brought a certain basis for the study of this topic, but it is not difficult to find that most of the studies at this stage are limited to developed eastern regions or coastal cities or only exist in a certain category such as industry and agriculture, due to its This paper attempts to analyze Anhui Province, a provincial-level city in the central region, in a systematic and comprehensive manner, and to provide a basis for proposing energy saving and emission reduction strategies for the energy provinces in the central region, which is quite innovative.

3. Model Construction

The LMDI model (Logarithmic Mean Dichotomous Index) is a method of calculating the risk of a portfolio in a logarithmic mean manner. It combines the risk indicators of all items in the portfolio history according to the logarithmic mean method to obtain the overall risk indicator of the portfolio. First, the risk indicators of each investment in the portfolio are valued, and the risk indicators of each investment are combined in a logarithmic average manner.

$$(Di) = \exp(1/n * 2 \ln(Xi))$$

Where Xi denotes the risk indicator of an investment in the portfolio and n denotes the total number of investment items in the portfolio. Finally, it is possible to obtain the overall risk indicator of the portfolio by calculating the Di index (Di) for each investment in the portfolio.

The relationship between the energy consumption ET in the target year (year t) and the energy consumption E0 in the precise year (year 0) is given by the following equation:

$$E^T = E^0 + \Delta ES + \Delta EI + \Delta IS + \Delta ED + \Delta PS$$

Where the equation ΔES denotes the contribution of energy consumption structure, ΔEI the degree contribution of strong energy consumption, ΔIS the contribution of industrial structure, ΔED the contribution of industrial scale, and ΔPS the contribution of population scale.

In this section, according to the model, the study phases are divided into 2005-2010, 2010-2015 and 2015-2019 and the energy consumption and carbon emissions of Anhui Province from 2025 to 2045 under different scenarios are analyzed.

LEAP is specifically designed for energy planning, especially long-term energy planning. It has transparent data input and a relatively flexible process. The main module of the energy program consists of five parts: energy demand, energy conversion, biological resources, environmental impact assessment, and cost analysis, etc. The LEAP model is structured in a bottom-up manner, with three processes: "resource, conversion, and demand", realizing the complete process of energy development to meet demand. The LEAP model is a representative model with the following structure:

$$\mathrm{ED_K} = \sum_{\mathrm{i}} \sum_{\mathrm{j}} \mathrm{i\, AL_{k,i,j}} \times \mathrm{EI_{k,i,j}}$$

Energy demand is the product of activity level and activity intensity. Where ED is the total energy demand, AL is the activity level, and EI is the energy intensity; i, j, and k represent different sectors, equipment, and fuels, respectively.

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The model assumes that the energy consumption of each sector can be represented by the activity level and energy intensity, and the CO2 emissions of each sector are calculated according to its energy consumption, energy mix, and emission factors of energy:

$$E = ALO \times IE \quad ; \quad C = \sum Ei \times FE, i$$

E is the energy consumption; IE is the energy intensity; Ei is the consumption of the ith energy source; FE, i is the CO2 emission factor of the ith energy source; ALO is the activity level, which can be measured by physical indicators (e.g., product output) or economic indicators (e.g., industrial value added). Since the CO2 emission factors of different energy sources vary greatly, energy consumption needs to be further refined according to the energy consumption structure.

On the basis of LEAP model, the scenario analysis method is finally adopted by combining the consumption structure of energy and carbon emission factors in Anhui Province. Based on the first-hand information obtained from the real-life research and survey and the understanding of the current macro policy, four relevant scenarios were established in this study as follows:

Scenario 1 - Benchmark Scenario (BS): In this scenario, the core view is that there will be no new measures to reduce energy consumption and CO2 emissions. That is, the energy consumption intensity, industry size and population size of energy-intensive industries in Anhui Province are located in the period 2025-2045, and the trend is consistent with the trend of the last five years.

Scenario 2 - Energy-saving Scenario (ES): In this scenario, its economic and technical indicators are the change of GDP after energy saving, energy use intensity, etc.

Scenario 3 - Energy-saving and Low-Carbon Scenario (ELCS): This scenario is a further development of the energy-saving scenario, in which the internal indicators add clean energy to the energy-saving scenario indicators, and the economic approach moves toward low energy consumption and The internal indicators of this scenario add clean energy to the indicators of the energy saving scenario, and the economy develops in a low energy, high value-added way.

Scenario 4 - Low Carbon Scenario (LCS): This scenario is the full implementation of low-carbon economy, when the concept of low-carbon is deeply rooted in people's hearts, and Anhui Province implements sustainable economic and environmental development.

4. Empirical Analysis

Table 1. Parameters of the LEAP model for Anhui Province

	Baseline situation	High quality scenario	Green scenario	Green and low-carbon scenarios
population size	It will reach 43.18 million in 2018 and peak at 57.49 million in 2030	Coreference scenario	Coreference scenario	Coreference scenario
GDP	8% in 2020-2025, 5% in 2030-2040 and 3% in 2050-2060	Coreference scenario	Coreference scenario	Coreference scenario
urbanization rate	71.25% in 2030 and 78% in 2060	71.25% in 2030 and 78% in 2060	80% in 2060	82% in 2060
energy intensity	The proportion of energy intensity reduction in the primary industry is small; The energy intensity of the secondary industry decreased significantly. The tertiary industry energy intensity decreased	Compared with the benchmark scenario, the industrial intensity decreased significantly	Compared with the high quality scenario, the industrial intensity decreased more	Compared with the green scenario, the industrial intensity decreased significantly
energy structure	Fossil energy accounts for a large proportion	Improve coal technology and increase the conversion rate of thermal power generation	Increase the share of clean energy	Introduce advanced power generation technology and develop carbon technology

Based on the characteristics of the LEAP model and the availability of data, the LEAP model for Anhui Province was established and different scenarios were constructed to predict the future peak carbon time, total end-use energy consumption and total carbon emissions in Anhui.

Based on the economic development and energy level of Anhui Province during the 13th Five-Year Plan period, and taking into account the outline of the 14th Five-Year Plan and the actual development in the later period, a total of four scenarios, including the baseline scenario (BS), low carbon scenario (LS), enhanced low carbon scenario (ELS) and peak scenario in 2023 (2023S, a specific scenario), were developed for X city, based on different carbon emission drivers and potential paths of energy saving and emission reduction, In order to analyze the maximum emission reduction effect of different scenarios and the peak path of carbon emission reduction, four scenarios, including the baseline scenario (BS), the low carbon scenario (LS), the enhanced low carbon scenario (ELS), and the peak scenario in 2023 (2023S, a specific scenario), were developed.

The trend projections of total carbon emissions in Anhui Province under different scenarios are shown in Figure 1. Under the baseline scenario, the total carbon emissions in the city basically show an increasing trend and will not reach the peak before 2030; under the low-carbon scenario, with the green upgrading of industries, energy efficiency improvement and the shift of end-use energy consumption structure to electricity and natural gas, the total carbon emissions in the province will drop significantly compared with the baseline scenario. emissions will be around 178 million t. Under the enhanced low-carbon scenario, as electrification and energy cleanup are further strengthened, advanced energy-saving and emission reduction technologies are applied, energy consumption intensity decreases significantly, and the growth rate of total energy consumption is further reduced, the province's total carbon emissions will peak around 2025, with a peak carbon dioxide emission of about 157 million t.

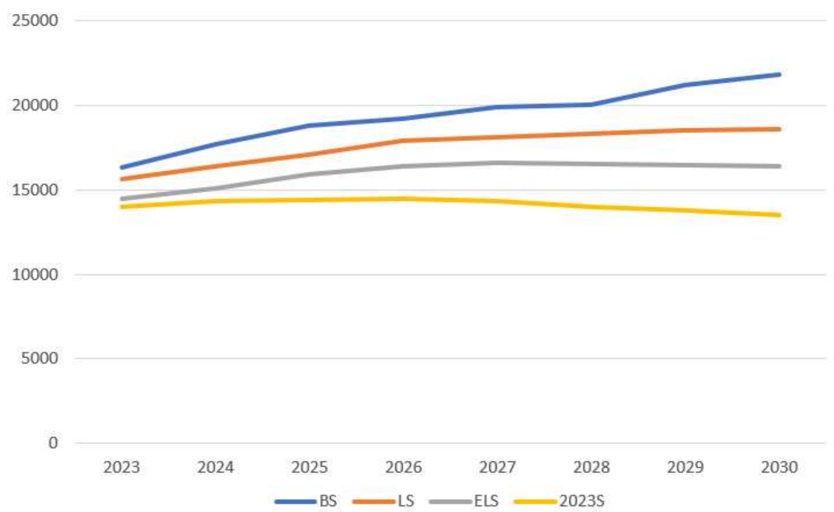

Figure 1. Total carbon emission and its trend forecast under different scenarios in Anhui Province

5. Conclusions and Recommendations

5.1. Research Conclusion

This paper takes Anhui Province as the study area, uses the scenario simulation method to measure the energy consumption CO2 emissions in Anhui Province from 2025 to 2045, analyzes the influencing factors of energy consumption carbon emissions in Anhui Province

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based on LEAP model and Ridge regression, and discusses the peak and peak time in Anhui Province from 2025 to 2045 under different scenarios, and draws the following conclusions:

(1) The CO2 emissions from energy consumption and per capita CO2 emissions in Anhui Province show an inverted U-shaped trend from 2025 to 2045, and the carbon emission intensity shows a continuous decreasing trend.

(2) At the same time, based on the current macroscopic planning of relevant policies and various practical factors, four relevant scenarios are designed, namely, the baseline scenario, the energy saving scenario, the energy saving low carbon scenario and the low carbon scenario. The future carbon peaks in Anhui province range from 182 to 191 million t, and the peaks occur in 2039. In the energy saving scenario, the peak is the lowest, about 182 million t. In the baseline scenario, the peak is the highest, about 191 million t. Combining the six scenarios, we find that the per capita GDP, urbanization rate and energy structure are growing at a low to medium rate, and the population size, energy intensity and industrial structure are developing at a medium to high rate, which can achieve the peak of carbon earlier.

(3) In terms of spatial autocorrelation, Anhui Province shows a trend of aggregation on the whole. In terms of localization, the high-low agglomeration area in Hefei City and the low agglomeration areas with low development level in Chihuahua Anqing and Tongling are mainly formed.

(4) From the analysis of influencing factors, population density, industrial structure and urbanization level all promote the increase of carbon emissions, so the emission reduction policies of cities should be improved by adjusting these aspects. As the economy continues to develop, carbon emissions will show a decreasing trend with economic development.

Taken together, the LEAP model can better predict the time of peak carbon emissions in Anhui Province under different scenarios, and also use the prediction results to adjust the energy conservation and emission reduction policies in Anhui Province and gradually increase the application of energy-saving technologies and the proportion of clean energy use. It is worth noting that there are still incomplete statistical information in the study, which will affect the accuracy of the prediction and needs to be improved in the future.

5.2. Policy Recommendations

5.2.1. Industrial Reform

On the one hand, it is necessary to optimize the industrial structure, develop high-tech industries, and increase the proportion of tertiary industries. On the other hand, we should accelerate technological innovation and give full play to the "knowledge spillover" effect to improve the utilization rate of energy, change the structure of energy use, increase the proportion of clean energy and renewable energy, and also increase the greening area of cities. For regions with a low level of economic development, industrial restructuring should be used to eliminate some low-technology enterprises with high energy consumption, accelerate the upgrading of traditional high-carbon industries, and develop a number of technology-intensive enterprises with low energy consumption, low pollution and high technology.

5.2.2. Promote Energy Conservation and Emission Reduction

Continue to promote energy conservation and reduce energy consumption. Although the total energy consumption in Anhui Province is expected to decrease during the 14th Five-Year Plan, the economic development level of Anhui Province is still at a low level, and the urbanization process still has a long way to go, so the level of energy consumption will still be at a high level, and the pressure to control energy consumption will remain in the future. Energy saving and emission reduction policy still needs to be implemented.

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5.2.3. Development of Clean Energy

Vigorously develop non-fossil energy projects to optimize the energy consumption structure. In view of the expected decrease in consumption of traditional fossil energy bodies such as coal and oil, Anhui Province can consider further promoting non-fossil energy projects such as wind and solar energy on the basis of meeting economic and social development goals, increasing the amount of non-fossil energy inputs in production activities, and achieving higher economic growth rates based on established target levels.

5.2.4. Implementation of Green Living Popularization

To promote green consumption preference, moderate consumption scale, non-material consumption structure, recyclable consumption resources, and shared consumption, we should focus on the unique advantages of NGOs and communities in promoting green and low-carbon consumption. The government and related institutions can increase the public's understanding and consciousness of green living, energy saving and emission reduction by increasing publicity, and then build a beautiful, harmonious and green social environment to accelerate the government-led and market-driven green low-carbon integration in key areas such as industry, energy, construction and transportation, build a green transportation network, and build a green low-carbon demonstration area together. In addition, it is necessary to fully mobilize the enthusiasm and participation of residents, promote the formation of a low-carbon society built by all people, and strengthen the control of carbon emissions and carbon intensity on the basis of controlling energy consumption and energy consumption intensity.

Finally, regarding the introduction of talents and the innovation of technology, a series of policies for green energy development carried out under the strong advocacy of the government are particularly important.

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