Analysis of Carbon Emission Factors in China and Japan Based on LMDI

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Abstract. From 2000 to 2015, China's industry and economy developed rapidly, while at the same time, it became the world's largest carbon emitter. China's development trajectory in the 15 years since 2000 is similar to Japan's in the 1960s and 1980s. This paper used the Logarithmic mean Divisia index (LMDI) method to estimate the impact factors of carbon emissions in China from 2000-2015 and in Japan from 1971-1986. The differences and commonalities of carbon emissions between the two countries in the two periods were discussed by comparing the driving factors of carbon emissions. On this basis, corresponding policies were provided in this paper.

1. Introduction
In the past 20 years, China's economy has ushered in a period of rapid growth. Prosperous industrial and economic development, rapid urban expansion, and investment in transportation infrastructure has brought vitality to the country but also produced a large amount of greenhouse gas emissions. There is no lack of research on China's carbon emissions factors, many of which have been analyzed with the LMDI method. In 2019, Zhang[1] pointed out in his analysis of China's carbon emissions from 2000 to 2015 that economic effects are the most significant positive driving force for carbon emissions. However, there are only a few comparative studies on carbon emissions between China and other countries[2][3]. This paper estimates the effects of energy structure, energy intensity, population size, and economic output on China's CO2 emissions from 2000 to 2015 and Japan's from 1971 to 1986 with the LMDI decomposition model. It displays figures and discusses the results of the analysis. By comparing and analyzing the data of the two countries, this paper puts forward policy recommendations on how to reduce China's carbon emissions.

2. Methodology

2.1 LMDI Approach[4][5]:
LMDI is an index decomposition method often used in carbon emissions analysis. Its basic principle is as follows. Assuming that V is the total amount of object decomposed, there are n factors that affect it, in additive decomposition:

\[ V_t = x_{t,1}x_{t,2}x_{t,3} \cdots x_{t,n} \]  (1)

\[ \Delta V = V_t - V_0 = \sum_{i=1}^{n} \Delta V_{xi} \]  (2)

In the above LMDI method, the effect of the ith factor can be expressed as:

\[ \Delta V_{xi} = \frac{V_t - V_0}{\ln V_t - \ln V_0} \cdot \ln \frac{x_{t,i}}{x_{0,i}} \]  (3)

2.2 Kaya Identity:
According to Kaya identity developed by Yoichi Kaya, national CO2 emissions from human sources can be expressed in the form[6]:

\[ C = P \cdot G \cdot E \cdot F \]  (4)

Where C stands for the CO2 emissions of a country, P stands for the national population, G stands for the GDP, and E stands for the national energy consumption.

2.3 Additive LMDI Decomposition:
In additive LMDI decomposition, the difference of the CO2 emission difference between two years can be decomposed as the following equation, based on the Kaya Identity:

\[ \Delta C = C_t - C_o = \Delta p + \Delta g + \Delta e \]  (5)

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In which

\[
\Delta p = \frac{C_t - C_0}{\ln C_t - \ln C_0} \cdot \frac{p_t}{p_0}
\]  
(6)

\[
\Delta g = \frac{C_t - C_0}{\ln C_t - \ln C_0} \cdot \frac{g_t}{g_0}
\]  
(7)

\[
\Delta e = \frac{C_t - C_0}{\ln C_t - \ln C_0} \cdot \frac{e_t}{e_0}
\]  
(8)

\[
\Delta c = \frac{C_t - C_0}{\ln C_t - \ln C_0} \cdot \frac{c_t}{c_0}
\]  
(9)

\(\Delta p\) represents the difference of CO2 emission caused by population effect. \(\Delta g\) stands for the difference in CO2 emission caused by the economic growth effect. \(\Delta e\) is the technology effect on the difference in CO2 emission. \(\Delta c\) stands for the difference in CO2 emission due to structure effect.

3. Variable description and analysis

3.1 Overall LMDI results

The economic and population effects of the two countries play a positive role in the growth of carbon emissions, while the technology effect has a significant inhibitory effect on the increase of carbon emissions. The impact of structural effects on carbon emissions is not easy to see directly from the Figure 1 and Figure 2. Judging from the accumulated data over the years, the overall contribution of structural effects to the increase in carbon emissions is negative. Comparing the carbon emission change data obtained after LMDI decomposition, it can be found that the economic effect has the greatest impact on the CO2 emission change of the two countries, followed by the economic effect. The technology effect generally reduces carbon emissions, while the economic effect increases carbon emissions. Among them, China's economic effect is particularly obvious. Taking 2006 as an example, China's carbon emissions increase by 698.81 million tons, of which 79.7% is due to economic effects. While in the same year, only 12.8% of the increase in carbon emissions come from technology effects. The difference between Japan's technology effect and economic effects is not obvious. In the selected fifteen years, Japan's average annual reduction of carbon emissions due to technology factors is 23.54 million tons, and the increase in carbon emissions due to economic factors is 30.88 million tons.

Figure 1. This figure shows the carbon emission of China from 2000 to 2015, by four effects.
3.2 Structure effect

Until 2008, China's structural effects had no significant impact on the increase in carbon emissions. This can be understood as China's energy structure has not changed significantly during this period. The data shows that the proportion of coal in energy consumption in China peaked around 2008, after which the proportion of energy consumption of natural gas, sustainable energy, and nuclear energy gradually increased, which is reflected in the chart as a structural effect with an overall downward trend.

Compared with China, Japan's structural effect has a relatively obvious impact on carbon emissions in the early stages of the selected years. Before 1973, Japan's carbon emissions and primary energy consumption both increased rapidly, so there was no clear trend in the changes in carbon emissions reflected in structural effects. After 1973, Japan's carbon emissions entered a plateau period, fluctuating around 10 million tons of CO2. During the same period, Japan's primary energy consumption rose slowly and fluctuated, which led to a gradually decreasing emission intensity and a gradually strengthening structural effect in Japan.

3.3 Technology effect

Similar to the structural effect, in the first few years of the 21st century, China's carbon emissions have not been significantly reduced due to the technology effect. In the two periods of 2003-2005 and 2009-2012, when the GDP growth rate was stable, due to the relatively rapid increase of China's primary energy consumption, it led to an increase in energy intensity and reduced the help of technical effects in reducing carbon emissions. The possible reason is that during these two time periods, China's increased production capacity was low in added value and high in energy consumption. This phenomenon can also be explained from the perspective of urbanization which is closely related to industries with high carbon emissions, such as steel and cement. According to the urban population growth rate data provided by the World Bank[7], although China's urbanization rate has gradually slowed down in the past 15 years, China's urban population growth rate rebounded relatively quickly around 2003. 2009-2010 corresponds to the recovery of the real estate market after the 2008 economic crisis.

Before 1973, because Japan's carbon emissions and primary energy consumption both had a rapid growth rate, the technical effect at this stage fluctuated. When the growth rate of primary energy consumption slows down and enters the plateau period due to the steady growth of GDP in Japan, the contribution of technology effects to the reduction of carbon emissions becomes more evident. To explore its internal factors, we must pay attention to the growth of Japan's tertiary industry in the selected years. After 1975, the number of employees in Japan's secondary industry changed from an increase to a decrease, corresponding to a substantial increase in the number of employees in the tertiary industry.

3.4 Economic effect

From 2000 to 2008, China's economic growth rate gradually accelerated and remained stable in the following years. This trend can be seen from the GDP per Capita figure and the changes in the economic effects figure. The annual increase in carbon emissions caused by economic growth gradually increased in the first eight years and remained stable in the region. It is worth noting that thanks to the government's stimulating macro-control policies, the 2008 financial crisis did not have a severe blow to China's economic growth. Taking 2008 as a node, the rapid development of high-value-added industries such as photovoltaics in China has reduced the contribution of economic factors to carbon emissions to a certain extent. The changing trend of Japan's economic effect is also highly consistent with the change in GDP per capita. The figure of economic effects primarily reflects the problems Japan faced and the policies proposed at the time. In 1974, Japan's GDP and carbon emission data ushered in a trough closely related to the First Oil Crisis[12]. The soaring energy prices in the early 1970s challenged Japan's original import-processing heavy industry system. In
response, the Japanese government introduced policies to restrict the development of high-energy-consuming raw material industries, accelerated the transfer of labor-intensive industries to developing countries, and encouraged the development of knowledge-intensive industries. Thanks to this, Japan's economy also quickly recovered from the shadow of the oil crisis while maintaining a lower carbon emission from economic effect than before 1974.

Comparing the development trajectories of the two countries, both have introduced policies to upgrade their industries after facing the crisis.

3.5 Population effect

The impact of the population effect on the carbon emissions of the two countries is straightforward. As Japan's population growth rate continues to decrease at a relatively high speed, the corresponding increase in carbon emissions is also gradually decreasing. In the selected year, China's population growth rate decreased relatively slowly and even ushered in a rebound in population growth rate in 2012.

Considering the perspective of major consumer groups, babies born in 1980-1995 gradually became the labor force and had stronger consumption power within the following 20 years. Therefore, although China's population growth rate decreased slightly from 2000 to 2015, the increase in the growth rate of the labor force and significant consumption groups during this period led to a corresponding increase in the population effect.

4. Conclusion and Policy Suggestion

The analysis above points out that in China and Japan, structure and technology effects have the greatest impact on the reduction of carbon emission. Therefore, this article cuts in from these two angles to give policy recommendations with reference to Japan’s policies and changes in industrial structure in the selected years. First, it is feasible to replace coal with more efficient fossil energy. From 1971 to 1986, Japan made a transition in the field of fossil energy. Consumption of natural gas has grown nearly 30-fold and has become the dominant source of electricity. Despite China's rapid development in industries such as wind power and photovoltaics, policymakers need to realize that it is challenging to replace China's fossil energy consumption with sustainable energy to meet power generation and heating needs. The coal-to-gas reform can be implemented on a large scale to achieve remarkable results in pollution control and people’s quality of life[11]. In addition, the use of nuclear power can also be further promoted. Recently, China has had more discussions about inland nuclear power plants, which is a very positive sign. If the relevant supporting policies can be implemented, it will undoubtedly bring more choices for the energy transition in inland areas. As for the relocation of high-energy-consuming and high-polluting industrial sectors, finding a balance between employment, economic development and industrial upgrading is a problem that the government needs to solve in the future. Under the premise of ensuring the integrity of the existing industrial chain, the problem of overcapacity in high-energy-consuming industries such as steel and coal should be solved first. For industries that cannot be transferred in short time, the government should start from the energy aspect to reduce energy consumption and carbon emissions per unit of energy. Meanwhile, China should increase its policy preference for emerging industries and rely on technology and innovation to promote the elimination of technically outdated production capacity.

References


