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CHINA'S CO_2 EMISSION STRUCTURE 1957-2012

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ABSTRACT

This paper studies CO_2 emission structure of China from 1957 to 2012 by using newly compiled environmentally-extended historical input-output tables of China. These tables are the first environmentally-extended input-output tables covering the years in the early stage of People's Republic of China. The result shows that China's emission structure was stable for almost six decades. Heavy industries contributed about 80% of CO_2 emission in 1950s and 1960s, although China was a poor country at that time. Although after economic reform the share of CO_2 emitted directly from heavy industries has decreased and that from electricity has increased, a network analysis shows that a significant part of CO_2 emitted directly by electricity sector was induced by heavy industries. Therefore heavy industries are still the main contributor of CO_2 emission after economic reform. The independent and self-reliance ideology of China leads to stability of emission structure. Because the independent ideology will continue in the future, the only option for China is to increase energy efficiency for the current existing industries.

Keywords: Carbon emission; Historical; Industrial structure; Input-output analysis

1. INTRODUCTION

Because China promises to reduce CO_2 emissions after they peak around 2030, when and how can China achieve the objective raise many research interests (Liu et al., 2015; Tollefson, 2016). There is no new thing under the sun. Studying historical emission path of China can help us to forecast China's carbon mitigation procedure in the future. Especially, the historical facts help us to understand the behavior principles of Chinese government, because the carbon mitigation procedure relies on government intervention.

The government intervention does not only refer to the environmental protection policy but also refer to other economic policies that have environmental by-products. For instance China has an "independence and self-reliance" policy, which originated in the 1950s. "Independence and self-reliance" has been China's ideology regarding "maintaining independence and keeping initiatives in our own hands and relying on our own efforts" (Keith, 1985). Industrial policies, especially guidelines during a historical period, have remarkable significance in regard to economic structure for a powerful government (Johnson, 1982; Rodrik, 2004). Because of this policy, China can produce almost every category of industrial products. Furthermore, the "independent and self-reliance" policy actually has a strong effect on China's CO_2 emission structure. Because China tried to maintain all categories of industries, China's CO_2 emission structure is relatively stable, and the independence policy has led to an inertia in terms of the emission structure.

Some previous studies have investigated historical CO_2 emission. For example, Botzen et al. (2008) and Wei et al. (2012) analyzed the historical CO_2 emissions for the main emitters. However, due to limitations in term of data availability, they did not consider the sectoral structure of emissions. Without considering the emission structure, it is difficult to investigate the historical cause of China's CO_2 emission trends, although many studies have discussed the current structure of China's CO_2 emissions (Liu et al., 2012; Feng et al., 2013; Guan et al., 2014). A significant number of these studies utilized the input-output analysis (IOA). In addition, some studies focused on the spillover effects of emissions by using IOA. Meng et al. (2017) illustrated spatial spillover effects in China's regional CO_2 emissions growth from 2007 to 2010, while Mi et al. (2017) analyzed the emission flow pattern changes after the global financial crisis. Network analysis is another way to illustrate the economic and emission structure in greater details. The paper is organized as follows. Section 2 describes the methodology, Section 3 presents the results, and Section 4 offers conclusions.

2. MATERIAL AND METHOD

To characterize the sectoral contributors of CO_2 emission during the last half a century, we apply the environmental extended input-output (EEIO) model to calculate the sectoral CO_2 emission by means of consumer-based accounting (CBA) and producer-based accounting (PBA). To show more information on the emission structure, the IOA actually can disaggregate the emission data into an n×n matrix, if we utilize the following equation:

$$\boldsymbol{\Theta} = \hat{e}(\boldsymbol{I} - \boldsymbol{A})^{-1}\hat{\boldsymbol{f}}.$$

Here, we diagonalize both e and f. The ijth element of Θ, θ_{ij}, refers to the CO_2 emitted from sector i to satisfy the final demand of sector j. It represents the complete linkage between sector i and j. We call it "emission linkage from sector i to sector j". Meanwhile, the n×n matrix, Θ, also illustrates a network with regard to CO_2 emissions. By using the elements of Θ, we can define both self-effect and sectoral spillover effects. Self-effect are the elements on the main diagonal of the matrix Θ. Sectoral spillover effects are the non-diagonal elements of matrix Θ, and include the sending and receiving effects. The sending effect refers to the emissions from a sector that are induced by the final demand of the other sectors, which is defined by $\rho_i = \Sigma_{j \neq i}\theta_{ij}$. The sending effect is also referred to as forward linkage in the IOA literature. Meanwhile, the receiving effect is the impact of one sector's final demand on the emissions from all the other sectors. The receiving effect of sector i is defined by $\gamma_i = \Sigma_{j \neq i}\theta_{ji}$, and is referred to as backward linkage in the IOA literature. The network shown in Θ also reflects the size of final demand f. Additionally, we considered the pure technical linkage without considering the demand size.

Furthermore, following the tradition of network and block models, we divided the sectors into 4 types in terms of the directions of linkages.

We obtain IOTs for the years of 1957, 1963, 1968, and 1973 from the CHIOTs project (Lin and Chen, 2018). Additionally, we form time series IOTs since 1992 with CO_2 emission and analyze the change of emission structure of China during recent decades and attempt to determine the historical origin of current emission problems by using traditional IOA and network analysis.

3. RESULTS AND DISCUSSION

3.1 Sectoral CO2 structure analysis

We first show the sectoral CO_2 emissions from 1957 to 2012. Under the framework of PBA, from 1957 to 1973, China's CO_2 emissions increased from 54.03 million tonnes (Mt) to 322.74 Mt, with an average growth of 17.64% per year. From 1957 to 1973, CO_2 emissions from the mining, heavy industry and electric power sectors increased by 598.05%, 504.94%, and 567.39%, respectively. However, emissions from light industry were relatively stable, increased by only 66.85%. This is consistent with China's development strategy. "Five-year plans" in this period focus more attention on the heavy industry and military industry. In 1963, after China finished the second five-year plan, the CO2 emissions from heavy industry accounted for 82.90% of the total emissions. In this year, China's GDP per capita was only 181 RMB (1963 value), which is the equivalent of only 142.02 USD (2010 value) per capita. If we compare the situation of China in 1963 with the other low and middle income countries, the CO_2 emission structures are totally different. For example, the GDP per capita of India and Indonesia in 1995 were 622 and 2,219 dollar (2010 value), while the shares of CO_2 emissions from heavy industry were 24.08% and 33.03%, respectively. Those values were much lower than those for China in 1963. This means that the development model for China was totally differently from those two other countries. The difference in term of development model resulted in differences in the structure of CO_2 missions. According to the PBA, heavy industry was the most significant polluter, which contributed almost 80% of the emissions for the years before the economic reform. After the economic reform, the shares of emissions produced directly by heavy industries reduced and the share decreased to 40% by 2012. However, the reduction was replaced by emissions caused by electric power generation. About 42% of the emissions in 2012 were from the electric power, heat power. This is because in these three decades, China has achieved notable success in the construction of electricity generating capacity. The increase in the share of emissions from the electricity sector implies the technical progress in China because electrically powered machines have replaced the labor force. The increase in the share of emissions from electricity generation sector crowded out the share of emissions from heavy industry. However, this does not imply that there has been a decrease in the importance of heavy industry in CO_2 emission structure in China, because part of the electricity was generated to satisfy the demand from heavy industries. To illustrate this point, we show the share of emissions from heavy industries and the share of emissions from both heavy industries and electric power generation in Figure 2.

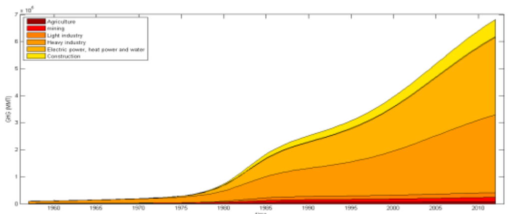


Fig 1 Sectoral CO2emissions 1957-2012 under the framework of PBA

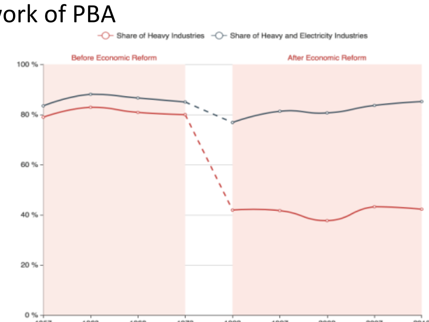


Fig 2 The shares of CO2emissions for heavy industry and electric power

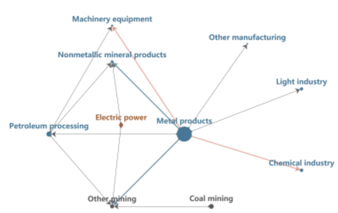
3.2 *Stability*

In order to prove the stability of emission structure, we calculate the Pearson correlation coefficients between the sectoral CO_2 emissions for different years, which was used to measure the linear correlation between two variables. In this analysis, we considered two kinds of sector classifications: the original 18 sector classification, as well as a 6 sector classification. In the 6 sector classification, heavy industries and electric power generation are considered as one sector. This is because emissions from electric power generation crowded out the direct emissions from the heavy industries. The 6 sectors are agriculture, mining sector, light industry, heavy industry and electric power, construction, and service. In the 18 sector classification, the correlation coefficients between the sectoral emission structures for 1957 and 1973 was 0.991. Its counterpart of the 6 sector classification was 0.999, and all of them were statistically significant with a confidence level of 99%. This implies that before the economic reform, the emission structure was stable even if heavy industries and electric power generation are separated. After the economic reform, in the 18 sector classification, the correlation coefficient between the sectoral emission structures of 1992 and 2012 was 0.980. Its counterpart of the 6 sector classification is 0.999. All of them are significantly positive with the confidence level of 99%. These results imply that if we study the two periods (before economic reform and after economic reform) separately, the emission structures would be stable for each period. However, if the two periods are considered together, then the situation is entirely different. In the 18 sector classification, the correlation coefficient between the sectoral emission structures for 1957 and 1973 is 0.365, which is non-significant. This means that the emission structure for 1957 was different than that of 2012 if heavy industries and electric power sector are separated. When the heavy industries and electric power sectors are aggregated in the 6 sector classification, the correlation coefficient between the sectoral emission structures of 1957 and 2012 becomes 0.984, which is significant with a confidence level of 99%. That is, if heavy industries and electric power generation are not separated, then the emission structure was stable for more than 50 years. In order to test whether the aggregation of the sectors other than heavy industries and electric power sector affects the significance of the correlation coefficients, a 7 sector classification was also tested, in which heavy industries and electric power sector were separated based on the 6 sector classification. In the 7 sector classification, the correlation coefficient between the sectoral emission structures of 1957 and 1973 is 0.631, which is non-significant. The conclusion is consistent with that of the 18 sector classification. The separation of heavy industries and electric power sector caused the instability during 1957 - 2012.

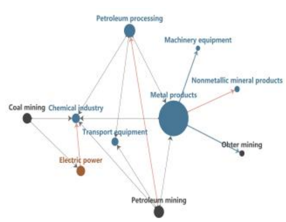
3.3 *Network analysis*

This part visualizes matrix Φ to show the inter-sectoral linkage density for the years of 1957, 1973, 2002, and 2012. From Figure 4(a) and 4(b) it is clear that the sector of metal products was an core sector, and the emission network dominated by heavy industry was gradually established. Metal products was the most important core sector of the networks for 1957 and

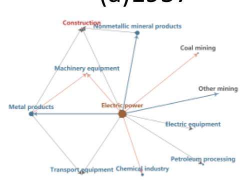
1973. On the one hand, the emissions from metal products was larger than for other sectors; on the other hand, most arrows-especially those representing core linkage density-were associated with metal products. Some sectors, such as the manufacture of electric equipment, transport equipment, and machinery equipment, are integrated into industrial chains and make contact with other sectors that are based on metal products. Mining sectors and electric power provide energy for other sectors, and in this period, mining sectors are more important than electric power. After economic reform, the network transformed from having one core to two cores, as the electric power sector gradually became the another key node. Heavy industries, such as metal products manufacturing, transport equipment manufacturing, and petroleum processing, surrounded the electric power sector. This implies that heavy industries were the main consumer of electricity. This finding confirms that the increase in CO_2 directly emitted from electric power generation was mainly caused by the demand of heavy industries. Therefore, the stability described by the 6 sector classification with aggregated heavy industries and electric power sector is robust. Heavy industries will always be the most important contributors to CO2emissions.



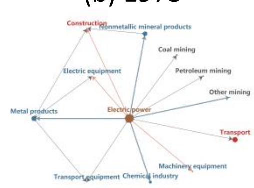
(a)1957



(b) 1973



(c) 2002



(d) 2012

Fig 3 Sectoral CO2 emissions links 1957-2012

4. CONCLUSIONS

This study compiled environmentally-extended historical input-output tables of China from 1957-2012. These tables, which made up of micro-level, industry-level, and macro-level statistical data, are the first environmentally-extended input-output tables covering the years in the early stage of People's Republic of China. Based on the tables, this paper studies CO_2 emission structure of China from 1957-2012. The results show that China's CO_2 emission structure is relatively stable, due to the stable economic structure associated with the independent economic policy. Because of this policy, China has had a stable economy for more than 60 years. Furthermore, this study visualized the inter-sectoral linkage of emissions and constructed the emission network dominated by heavy industry, which confirmed the increase in CO_2 directly emitted from electric power generation was mainly caused by the demand of heavy industries. The correlation coefficients are used to study the stability over time, which implied that if heavy industries and electric power generation are not separated, then the emission structure was stable for more than 50 years. Based on the above analysis, this study puts forward the following implications.

Firstly, the stable economic system and emission structure had historical origins. From the one hand, the emission structure was relatively stable for more than 50 years both from the 1 × n dimensional emissions and from the n × n dimensional emission network. From the other hand, compared with other countries, domestic inputs that leading to emissions are much higher in China. Secondly, China could change the spatial structure for heavy industries and the emissions but could not remove them from the economic system. As the core sectors in the economy, heavy industries transfer from the municipalities and the east provinces with high developed stage to the central and western provinces, but China could not transfer her industries to outside China. Although China's imports were huge after the economic reform, each industry still had a significant part of domestic share. Imports and domestic products coexisted in the market, because of the "independent policy and sefl-reliance" policy, which regulated the rate of domestic production. Meanwhile, both imported and domestic products were distributed in all industries well-balanced way.

Finally, as we discussed in the previous sections, the stability of economic structure leads to the stability of CO_2 emission structure. Due to the "independent and self-reliance" ideology, China could not adopt the carbon leakage policy to reduce China's CO_2 emission by transferring her industries to outside China. Under this background, to keep the promise of reducing CO_2 emissions after they peak around 2030, the only option for China is to increase energy efficiency for the current existing industries.

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