Structure Decomposition Analysis of The Carbon Footprint Differences Between Beijing and Tianjin

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Abstract: Carbon footprint is the total amount of CO2 emissions by particular product or service system in it full life cycle, or, it is the total amount of direct and indirect CO2 emissions by activity principals. There are significant differences of provincial total carbon footprint result from the different energy efficiency, final demand and input-output relationship of intermediate products. Based on the Structure Decomposition Analysis and input-output model, the differences of carbon footprint between Beijing and Tianjin are analyzed in this paper. The results show that the total carbon footprint is higher in Beijing than that in Tianjin. The effect of carbon emission intensity on carbon footprint in Beijing is lower than Tianjin by 0.008 billion tons CO2; according to the complicated relationship between industries in Beijing, there is 0.029 billion tons CO2 more the carbon footprint than Tianjin. The demand scale and structure is higher than Tianjin; So in the factors of final requirements on carbon footprint, the carbon footprint of Beijing is higher than Tianjin by 0.058 billion tons CO2.

Introduction

Beijing and Tianjin are all large modern cities and municipality cities, the rapid economic development and the growing intra - regional trade among these regions result in a increase of energy demands and CO2 emission. Final demand should be considered in the process of calculating the carbon footprint since the product will produce emissions during production and transportation, this calculation is generally called “carbon footprint”. The differences of carbon footprint between the two regions lie in three aspects: different emission intensity, different input-output relationship of intermediate products and different the final demand, the carbon footprint differences are evaluated with IO-SDA (Input-Output Structure Decomposition Analysis) in this paper.

Methods

As for IO-SDA theoretical and applied study, many scholars have done thorough researches[1]–[5]. Based RAS structure decomposition analysis, the carbon footprint differences among two regions are discussed, the functions are as follows:
\[ CF = C \times [I - A]^{-1} \times F \quad (1) \]

\[ B = [I - A]^{-1} \quad (2) \]

\[ \Delta Q = C_2B_2F_2 - C_1B_1F_1 = \Delta CB_1F_1 + C_2\Delta BF_1 + C_2B_2\Delta F \quad (3) \]

\[ \Delta Q = C_2B_2F_2 - C_1B_1F_1 = \Delta CB_2F_2 + C_1\Delta BF_2 + C_1B_1\Delta F \quad (4) \]

Then:

\[ \Delta Q = \frac{1}{2}(\Delta CB_1F_1 + C_2\Delta BF_1 + C_2B_2\Delta F) + \frac{1}{2}(\Delta CB_2F_2 + C_1\Delta BF_2 + C_1B_1\Delta F) \]

\[ = \frac{1}{2}(C_1B_1\Delta F + C_2B_2\Delta F) + \frac{1}{2}(\Delta CB_2F_2 + \Delta CB_1F_1) + \frac{1}{2}(C_1\Delta BF_2 + C_2\Delta BF) \quad (5) \]

where CF means the total amount of carbon footprint, \( \Delta C \) means change of direct emission intensity, \( \Delta B \) means change of Leontief inverse matrix, \( \Delta F \) change of means matrix of final demands.

**Data source** The data of home energy use and final energy use come from *China Energy Statistical Yearbook* (2007). The results of carbon footprint spelled out in author’s another paper (Wang Yan, 2012), Other data sources include 42 sector Input-output table of Beijing and Tianjin in 2007.

**The results**

**The Differences of CO2 Footprint between Beijing and Tianjin** The amount of CO2 footprint is 0.169 billion tons CO2 in Beijing, while it’s 0.091 billion tons in Tianjin, the CO2 footprint in Beijing is more than 0.078 billion tons that in Tianjin. The differences of CO2 footprint come from the diverse consumption and investment. The CO2 footprint by induced investment is 0.101 billion tons CO2 and the CO2 footprint by induced consumption is 0.068 billion tons CO2 in Beijing. The CO2 footprint by induced investment is 0.055 billion tons CO2 and the CO2 footprint by induced consumption is 0.068 billion tons CO2 in Tianjin. (Table 1).

**Table 1  The composition of carbon footprint in Beijing and Tianjin (Unit: 10^8 ton CO2)**

| Region  | Rural CFP | Urban CFP | Government CFP | Investment CFP | CFP  |
|---------|-----------|-----------|----------------|----------------|------|
| Beijing | 0.03      | 0.38      | 0.27           | 1.01           | 1.69 |
| Tianjin | 0.02      | 0.25      | 0.09           | 0.55           | 0.91 |
| Diversity | 0.01      | 0.14      | 0.18           | 0.46           | 0.78 |

The differences of CFP in all departments between Beijing and Tianjin The differences of carbon footprint between Beijing and Tianjin is carried out detailed and deep analysis on the departments. As it turned out, Beijing is more carbon footprint than Tianjin in the building and high quality consumption, such as construction, public administration and services, health and social security, educational services telecommunication and computer services, food processing, technical services, Geophysical prospecting services and water conservancy, transport equipment, metal products, accommodation and food serving services. One of the most remarkable department is construction, and the carbon footprint of construction in Beijing is more 0.0424 billion ton CO2 than in Tianjin. Meanwhile, Tianjin is more carbon footprint than Tianjin in the chemicals, general and special purpose machinery and electricity, steam and hot water production and supply.
### Table 2 The differences of CFP in all departments between Beijing and Tianjin (Unit: 10^8 ton CO2)

| sector                        | CFP  | sector                        | CFP  |
|-------------------------------|------|-------------------------------|------|
| Construction                  | 0.424| Accommodation and food serving services | 0.010|
| Public administration and services | 0.058| Handicraft and Other manufacturing products | 0.009|
| Health and Social security    | 0.056| Generators and Equipments     | 0.008|
| Real estate                   | 0.052| Telecommunication and electronic computer equipment | 0.007|
| Scientific research           | 0.040| Finance                       | 0.007|
| Educational services          | 0.036| Social services and Resident services | 0.006|
| Telecommunication and Computer services | 0.035| Cultural, media communication, sporting and recreational services | -0.004|
| Food processing               | 0.033| Chemicals                     | -0.005|
| Technical services, Geophysical prospecting services and Water conservancy | 0.028| General and special purpose machinery | -0.014|
| Transport equipment           | 0.013| Electricity, steam and hot water production and supply | -0.035|
| Metal products                | 0.012|                               |      |

**The Effect of the difference in emission intensity on carbon footprint**

Emission intensity is the amount of emissions of carbon dioxide of the unit of output, which is an important indicator of the measurement of energy technology level and energy utilization efficiency. The result has shown that even though the total carbon footprint of Beijing is higher than that of Tianjin, the carbon emission intensity of Beijing is lower than Tianjin by 0.008 billion tons of carbon dioxide, because of the higher energy utilization efficiency of Beijing.

The impact of the carbon emission intensity to the urban residents, rural residents, and government consumptions in Beijing is lower than that of Tianjin, among which the carbon footprint induced by the urban residents of Beijing is lower than Tianjin by 0.013 billion tons of carbon dioxide.

Because there are more infrastructure constructions in Beijing, although Beijing has some advantages in carbon emission intensity, it is not large enough to cancel out the increment of carbon emissions caused by new investments and constructions. Therefore, when measuring the impact of emission intensity on the carbon footprint caused by investments, the amount of carbon dioxide of Beijing is larger than Tianjin by 0.013 billion tons (Table 3).

### Table 3 The differences of carbon footprint between Beijing and Tianjin (Unit: 10^8 ton CO2)

| emission intensity | Rural CFP | Urban CFP | Government CFP | Investment CFP | CFP |
|-------------------|-----------|-----------|----------------|----------------|-----|
|                   | -0.01     | -0.13     | -0.07          | 0.13           | -0.0|
| economic system    | 0.01      | 0.09      | 0.08           | 0.10           | 0.29|
| requirement        | 0.01      | 0.18      | 0.16           | 0.22           | 0.58|

**The Effect of the differences in economic system on carbon footprint**

The effect of the economic system is mainly composed of the Leontief inverse matrix in the middle part of input-output table, means have indirect impact on the different part of carbon footprint, since each provinces have dissimilarities in Leontief inverse matrix, which attributing to the different effect of the economic system on the area of carbon footprint. In 2007, according to large intermediate inputs in consumption and the complicated relationship between industries in Beijing, the amount of carbon footprint is 0.029 billion ton CO2 more than Tianjin. The differences of carbon footprint between Beijing and Tianjin due to the economic system, mostly presented in the consumption attained to 0.019 billion tons CO2. At the same time, the economic system results in the carbon footprint induced by investment in Beijing is 0.01 billion tons CO2 more than Tianjin (Table 3).
The Effect of the difference in economic system on carbon footprint shows that direct emissions intensity has advantage in area, but the indirect effects from the strengthen of input-output relation between intermediate product department cannot be underestimated.

The Effect of the differences in final demand on carbon footprint Production is in order to meet the demand, the final demand made of consumption and investment is the main factor to induce the carbon footprint. The demand in Beijing is more large scale than Tianjin. So in the factors of final requirements on carbon footprint, the carbon footprint in Beijing is larger than Tianjin by 0.058 billion tons CO2. The carbon footprint in Beijing is higher than Tianjin by 0.035 billion tons CO2 caused by the difference of consumption. The carbon footprint in Beijing is higher than Tianjin by 0.022 billion tons CO2 because of the difference of investment requirements (Table 3).

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