Economic Input-Output Analysis of China's CO_2 Emissions (2007)

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Abstract

China, as the biggest GHG emitter and the largest developing country, has been urged by international society to take responsibilities for reducing GHG, especially in the post-Kyoto commitment period. Currently, the United Nations Framework Convention on Climate Change (UNFCCC) assigns the responsibility to parties who produce the GHG, using the production-based GHG emissions inventories. However, some scholars argue that if consumption-based GHG emissions inventories were used, China would be less responsible for GHG emissions because GHG emissions embedded in exporting products directly contribute to its total emissions. This paper analyzes China's CO2 emissions in 2007 using Economic Input-Output (EIO) method, and finds that China's domestic emissions make up a large proportion of total emissions, and export-embodied emissions accounts for 15% of domestic emissions. What's more, results of production-based accounting method are different from results of consumption-based accounting method. These two different methods mainly impact the emissions from regions that belong to eastern China. If China attempts to implement environmental policies to achieve the emissions reduction target, different regional characteristics need to be considered.

Keywords: CO_2 emissions; economic input-output analysis; China

1. Introduction

Since global climate change has become an increasingly important issue, international participation is urged to reduce greenhouse gas (GHG) emissions. Under the guidance of "shared but differentiated responsibility" by the United Nations Framework Convention on Climate Change (UNFCCC), all countries should make a significant effort to establish effective environmental policies and take efficient actions for mitigating GHG emissions. Due to historical reasons, developed countries are required to take more responsibilities to reduce GHGs emissions. While in the post-Kyoto period, developing countries such as China and India are also urged to set a strict reduction target of GHG emissions. Thus, the debate of how to measure GHG emissions arises. Currently, there are two accounting methods for CO_2 inventory: production-based accounting and consumption-based accounting.

Production-based accounting method is used by the United Nations Framework Convention on Climate Change (UNFCCC), which defines a country's inventory should include "all greenhouse gas emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction" (IPCC, 1996, pp.5). However, Munksgaard and Pederson first questioned this accounting method, and they claimed that by using production-based accounting, producers were actually responsible for CO_2 emissions embodied in their production. Thus, they carried out a debate about whether producers or consumers of goods should be responsible for embodied emissions. Also, Peters and Hertwich (2008) claimed that two main problems may arise using the production-based inventory that is defined by territory boundary. First, emissions embodied in international trade are not allocated to countries because production-based inventories ignore where goods are consumed and where services occur due to the calculation of emissions only within the territory. Secondly, carbon leakage may occur "through imports from non-Annex I countries to Annex I countries" (Peters, 2008). Annex I countries are mostly developed countries such as the United States and European countries. Non-Annex I countries are developing countries such as China and India. Both

Annex I countries and non-Annex I countries are parties to the UNFCCC, while Annex I countries commit to legal bindings in the Kyoto Protocol. Therefore, Annex I countries face a more strict CO_2 emissions reduction target than non-Annex I countries. In order to meet the reduction target by generating less embodied CO_2 emissions within the territory boundary, Annex I countries could import goods and services from non-Annex I countries (Vringer, 2007).

In recent years, international society has urged China to take effective actions to reduce its CO_2emissions. Chinese government has committed to reduce CO_2 emissions per unit of GDP by 40-45% by 2020 compared to the 2005 level (Chen and Zhang, 2010). According to China's "12th five-Year Plan", China sets the CO_2 emissions reduction target at 17% decrease over 2011-2015. To achieve this target, all regions will get involved and reduce their CO_2 emissions. However, different regions may confront with different situations based on their specific characteristics, among which international trade could be a major impact.

Many scholars conducted studies about China's trade-embodied emissions. Peters (2007) carried out the calculation method for consumption-based emissions. Followed by this study, Peters and Hertwich (Peters & Hertwich, 2008) explored the emissions embodied in trade for 87countries and regions. The study claimed exported-oriented countries such as China and India needs to consider export-embodied emissions and promote consumption-based accounting. Also, Weber et al (2008) conducted an Economic Input-Output (EIO) analysis to explore CO2 emissions embodied in products of China's exports from 1987 to 2005. They concluded that nearly 33% of China's domestic emissions in 2005 came from the production of exports, increasing from 12% in 1987.

Using the EIO analysis, this paper uses the latest available data in 2007 to explore China's CO_2 emissions across 30 regions and 6 sectors. Inspired by a study *From Production-based to Consumption-based National Emissions Inventories* (Peters, 2007), this paper utilizes the similar methodology to calculate both China's production-and consumption-based CO_2 emissions. The rest of the paper is

organized as follows. Section 2 introduced the methodology and data used in this paper. Section 3 presents the results of China's CO_2 emissions, embodied emissions in exports and imports, and the different results from production-and consumption-based accounting methods. Also, it briefly discusses the potential impact on different regions in terms of carbon tax policy that is currently considered by Chinese government. Section 4 discusses and compares relevant previous studies. Section 5 concludes the findings and limitations.

2. Methodology and Data

2.1 Geographical Regions of China

China has altogether 34 regions, among which there are four municipalities (i.e. Beijing, Tianjin, Shanghai, Chongqing), five autonomous regions (i.e. Inner Mongolia, Ningxia, Xinjiang, Tibet, Guangxi), two special administrative regions (i.e. Hong Kong, Macau),and 22 provinces (Fig. 1). Data in this paper covers 30 regions excluding Tibet, Hong Kong, Macau, and Taiwan. Based on regional GDP per capita, these 30 regions are divided into three categories: western area, central area, and eastern area. Regions in western area include: Xinjiang, Gansu, Qinghai, Ningxia, Shaanxi, Sichuan, Chongqing, Guizhou, and Yunan; regions in central area include: Heilongjiang, Jilin, Liaoning, Inner Mongolia, Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi, and Guangxi; regions in eastern area include: Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan.

Fig. 1. Map of China

(Source: China Provinces Study Guide. http://chinageoquiz.blogspot.com/p/map-01-test.html)

2.2 Data Source

The data processed in this study is sourced from China Energy Statistical Yearbook (2008) and China's Economic Input and Output Table (2007). China Energy Statistical Yearbook provides CO_2 emissions intensities of 6 sectors across 30 provinces, while EIO table provides monetary transaction data of 42 sectors. This inconsistence is solved by aggregating 42 sectors into 6 sectors in EIO table (Table 1). Thus, some detailed information about sub-sectors may be missed. Also, Wiedmann (2009) analyzed errors caused by aggregation uncertainties, and claimed that significant errors occur when combining high and low impacting sectors into one sector; for example, post and telecommunication, cement and non-metallic minerals. But decomposing sectors in Energy Statistics Yearbook also has its disadvantages, as is hard to precisely allocate emissions among 42 sectors. At last, this paper analyzes the total emissions from each sector in each region, emissions are finally summed up; thus, even

decomposing 6 sectors into 42 sectors, it may not lead to a big difference comparing to results from aggregation.

<p align="center">Table 1   Sector Classification and Code</p>

Sector Code	Sector Classification
1	Agriculture, Forestry, Animal Husbandry & Fishery
2	Industry
3	Construction
4	Transport, Storage, Postal &Telecommunications Services
5	Wholesale and Retail Trades, Hotels and Catering Services
6	Others (Finance, education, tourism, public services, etc.)

2.3 Introduction to EIO Analysis

EIO was firstly proposed by Leontief (1936) and it employed sectoral monetary transactions data to reveal the interdependencies of industries (Munksgaard et al. 2005). In China's provincial input-output (IO) table, the row balance calculates the total output Y of sector i, which could be expressed as:

$$Y_i = Ax_i + TCF_i + E_i + TO_i - M_i - TI_i$$

Where Ax_i stands for intermediate inputs; A is a 6*6 matrix named direct consumption coefficients, which describes the relationship between sector i and sector j, and it is calculated by $A_{ij} = \frac{I_{ij}}{O_j}$. I_{ij} is the input from sector j to sector i, and O_j is the total output of sector j. TCF_i stands for total final consumption which includes residential consumption, government consumption, and gross capital formation; E_i is exports to other countries of sector i; TO_i is the transfers-out to other regions within China; M_i stands for imports to foreign countries and TI_i stands for transfers-in from domestic regions in China.

This IO table is used to calculate CO_2 emissions by $B=R*(I-A)^{-1}*Y$. The term of $(I-A)^{-1}*Y$ is processed using input-output table. R is a diagonal matrix and its diagonal factors are CO_2 emissions per unit of currency from each sector, calculated by $R=C_i/x_i$. C_i is CO_2 emissions intensity from China Energy

Statistical Yearbook (2008). x_i indicates the gross outputs from sector i. Y_p is the total demand of each sector. In order to explore how much amount of CO_2 emissions are embodied in products for domestic consumption and for exports separately, Y_c indicates the domestic consumption of each sector, which sums up TC, GCF, and TO. Y_e indicates the demand of each sector for export alone. The following equation describes $Y_p = Y_1 + Y_e$:

$$\begin{pmatrix} TC \\ GCF \\ TO \\ EX \end{pmatrix} = \begin{pmatrix} TC \\ GCF \\ TO \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \\ EX \end{pmatrix}$$

Therefore, B_1 represents domestic CO_2 emissions from each sector which is calculated by $B_1 = R*X = R*(I − A)^{-1} * Y_1$; while B_e represents CO_2 emissions embedded in exports from each sector, calculated by $B_e = R*X = R*(I − A)^{-1} * Y_e$.

According to Peters's study, the calculation $B_p = B_1 + B_e$ is the method to calculate production-based CO_2 emissions.

Similarly, the consumption-based CO_2 emissions can be calculated as

$$B_c = B_2 + B_m = R*(I − A)^{-1} * Y_2 + R*(I − A)^{-1} * Y_m$$

Where $Y_c = Y_2 + Y_m$, which is $\begin{pmatrix} TC \\ GCF \\ TI \\ M \end{pmatrix} = \begin{pmatrix} TC \\ GCF \\ TI \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \\ M \end{pmatrix}$

One thing worth mentioning is that in Peters's study the A matrix is decomposed into two parts. One is the matrix (A^{rr}) represents sector requirements of domestically produced products alone, and the other matrix (A^{rs}) represents sector requirements from imported products because imported products are either indirectly consumed in the processing production or directly consumed as final consumption. When calculating both domestic emissions and embodied emissions, Peters only use the A^{rr} matrix. However, in this paper A matrix is not decomposed as the data is not available to show the contribution of

imported products to domestic consumption. Therefore, the values in A matrices for each region are greater than what Peters used, which may lead to a greater domestic CO_2 emissions. This issue is to be discussed later in Section 4.

3. Results

3.1 Overview of Production-Based CO_2 emissions from sectors and provinces

Figure 2 shows a general relationship between production-based CO_2 emissions and GRP in China. The more GRP, the higher CO_2 emissions it produces. Guangdong, Jiangsu, Shandong, Zhejiang, and Hebei stand out among 30 regions. Although Hebei's GRP is not high, its large population contributes a significant amount of CO_2 emissions. However, when looking at Figure 3, which depicts the relationship between GRP per capita and CO_2 emissions per capita, we could see that Shanghai, Tianjin, and Beijing have the highest three CO_2 emissions per capita associated with highest GRP per capita. CO_2 emissions per capita of Guangdong, Jiangsu, and Zhejiang are moderate, while emissions of Shandong and Hebei are relatively low. In both Figure 2 and Figure 3 we could see regions with higher CO_2 emissions are belong to eastern area. Since China has pledged to reduce CO_2 emissions based on CO_2 emissions per unit of GDP, all provinces would be involved and bear certain responsibilities for emissions reduction. Thus, the measurement for each province may be based on per unit of GRP. Figure4 shows the relationship between GRP and CO_2 emissions per unit of GRP. The biggest change is that several regions in the central area of China have the highest level of emissions. Relatively poor regions such as Hebei, Jilin, Inner Mongolia, and Shanxi should be more responsible for high CO_2 emissions per unit of GRP. However, developed regions such as Guangdong, Zhejiang, Shanghai, and Beijing would bear less responsibility for emissions reduction.

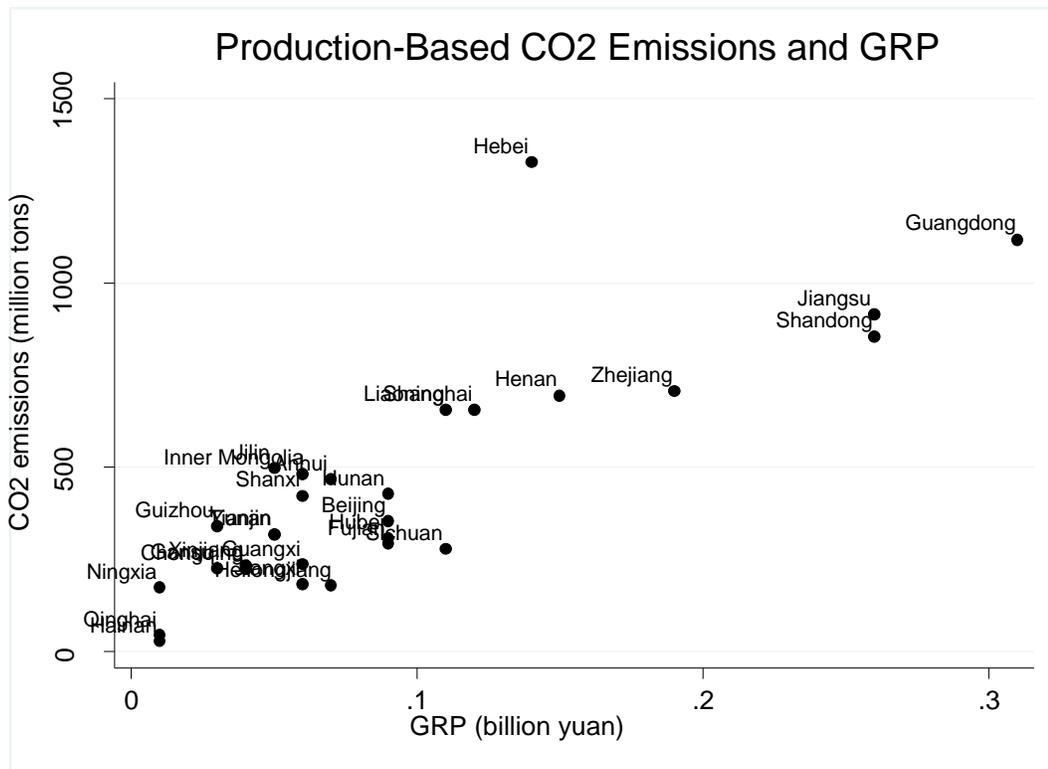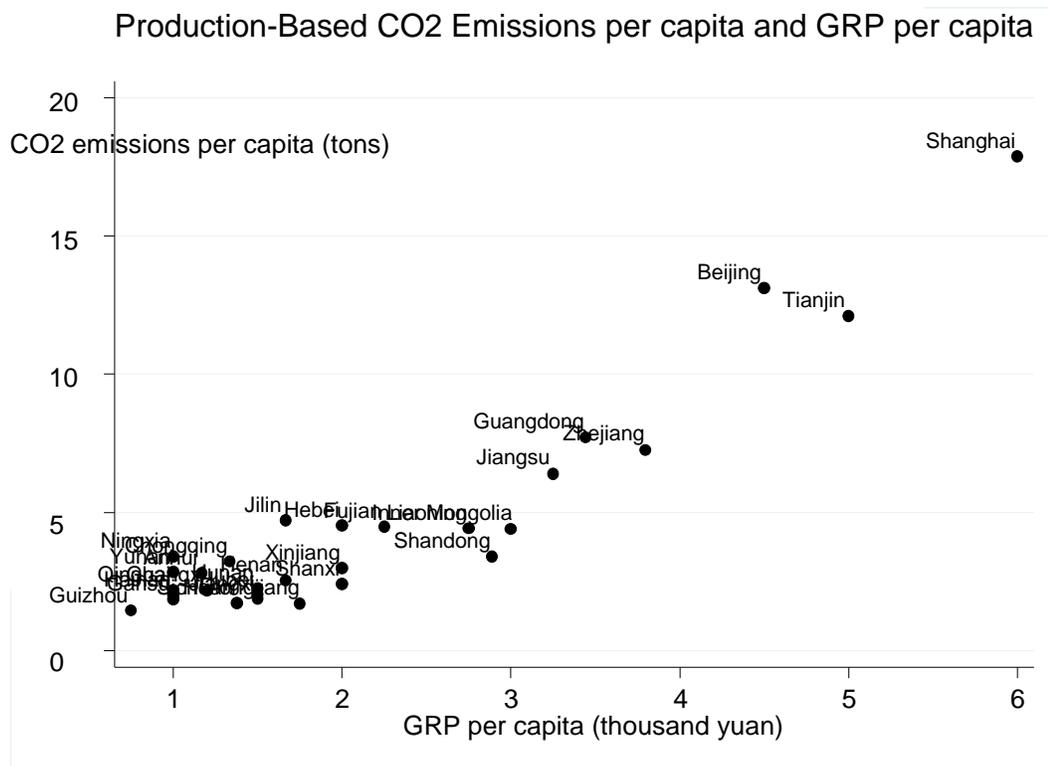Fig. 2 Production-Based CO_2 Emissions and GRP across 30 Regions in China

Fig. 3 Production-Based CO_2 Emissions per capita and GRP per capita across 30 Regions in China

Fig.4 Production-Based CO_2 Emissions per unit of GRP and GRP across 30 Regions in China

3.2 Production-based CO_2 emissions from domestic consumption and exports

CO_2 emissions in China vary from region to region. In order to see the provincial level CO_2 emissions, Figure 5 is presented, and regions or provinces in this figure and the remaining ones in the paper are in three geographical groups, which from left to right are eastern area, central area, and western area of China. Results show that regions in eastern area of China are responsible for most of embodied CO_2 emissions in exports as well as domestic CO_2 emissions. These regions include Guangdong, Jiangsu, Shanghai, Zhejiang, Shandong, Fujian, Beijing, Tianjin, and Hebei. Geographically, they lie on China's east coastal line and possess many harbors for exports. Economically, they have high GDP level and are well developed in China. Hebei has the highest level of domestic CO_2 emissions while Guangdong has the highest level of CO_2 emissions embodied in exports. Guangdong province is well-known for its exports of light industries such as machinery and electric equipment, textile materials and miscellaneous

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manufacturing articles (e.g. furniture, toys). With the ideal location on the shore of the South China Sea, its major export destinations include Hong Kong, United States, European Union and Japan. Its average export volume takes up nearly 30% of China's total exports (Harvard Business Review, 2012).

In addition, we could see provinces such as Guizhou, Ningxia, Qinghai, and Xinjiang have a relatively low emissions. These provinces are located in the north-western part of China, and are recognized as underdeveloped provinces. Because of limited resources and low productivity, these provinces are relatively poor and are not major power to drive China's economic growth. Thus, in order to speed up China's economy and improve people's livelihood, central government has implemented The Strategy for Development of Western Regions since 2001, mainly focusing on the infrastructure construction.

Fig. 5 CO_2 emissions from domestic consumption and exports across 30 regions
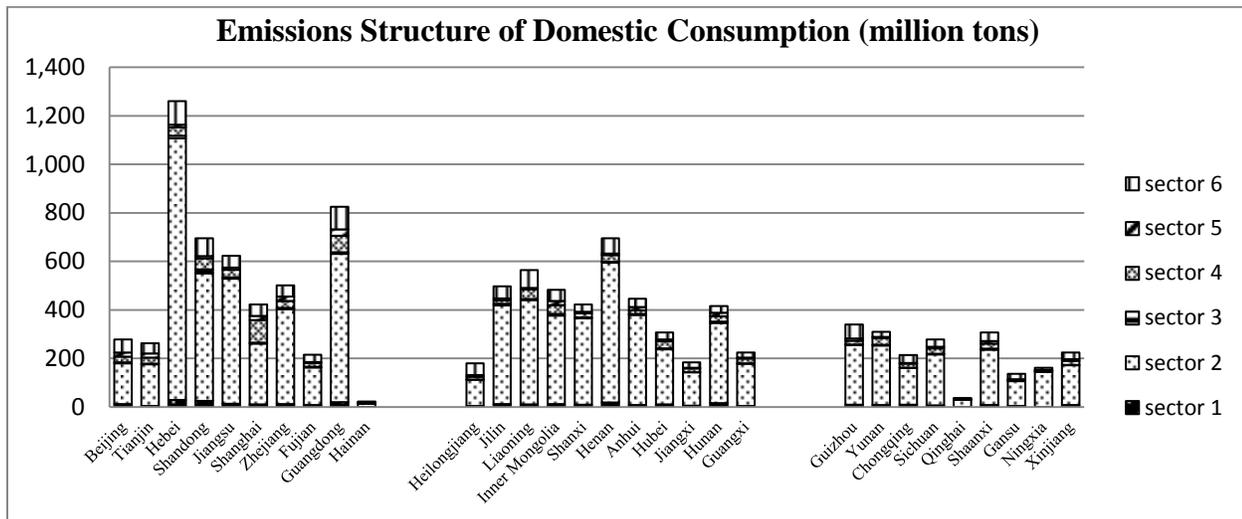

Figure 6 shows the structure of emissions from domestic consumption in 30 regions. Sector 2 in all regions makes up a significant proportion. In addition, Sector 6 and Sector 1 share certain amount of CO_2 emissions from domestic consumption.
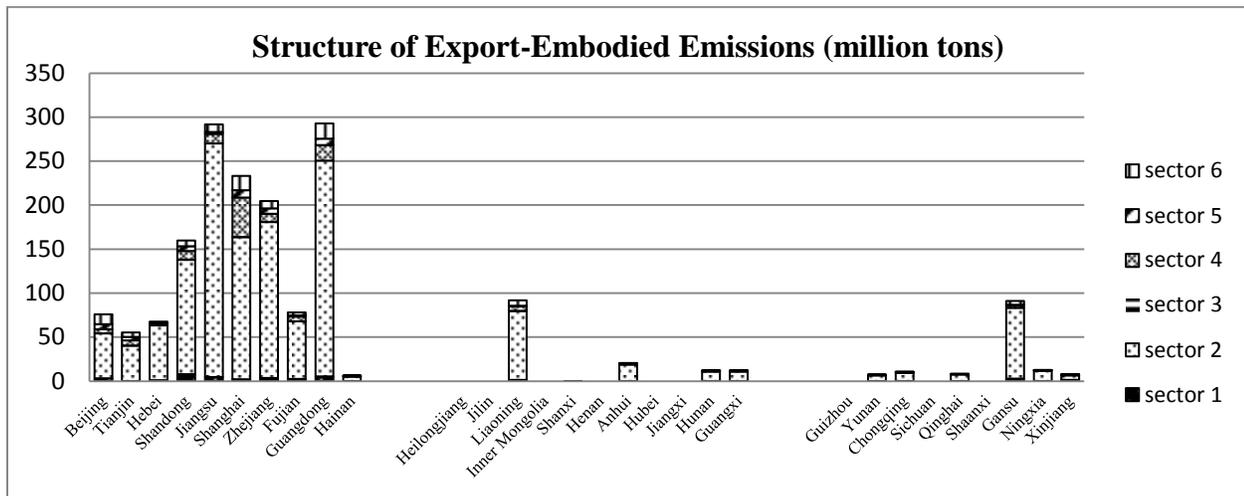
Fig. 6 Emissions Structure of Domestic Consumption

Emissions Structure of Domestic Consumption (million tons)

3.3 CO$_2$ emissions embodied in exports

The total CO$_2$ emissions embodied in exports in 2007 is 1,739 million tons, which is similar to the finding from Weber et al(2008). They found that in 2005 China's domestic CO$_2$ emissions were 1,700 million tons. However, they claimed that 1,700 million tons were 33% of China's domestic CO$_2$ emissions, while this paper finds that it only makes up 15% of China's domestic CO$_2$ emissions. This issue is to be discussed in Discussion Section.
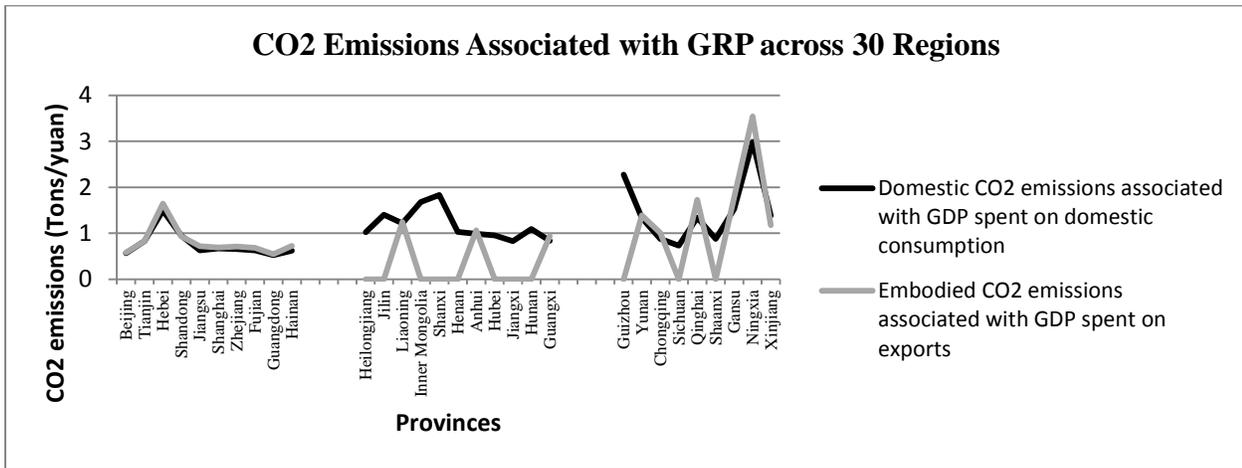
In addition, Figure 7 shows the structure of export-embodied emissions. Sector 2 is the largest contributor, which is not surprising from common sense. China as the "world factory" is well known for its cheap labor. Therefore, many companies outsource businesses to China. For example, China assemblies all ipods over the world, but only earns $4 per unit. With the retail price of $300, huge profits are earned by the US (Gereffi, 2013). However, to assembly all ipods, China inputs its energy and resources such as electricity and water while outputs many wastes that pollute the environment. Also, Sector 6 contributes to embodied emissions in some regions of eastern area. The possible reason is that these regions are relatively more developed, thus, technology and innovation, cultural services, and tourism would contribute more than those of underdeveloped regions.

Fig.7 Structures of Export-Embodied Emissions

Structure of Export-Embodied Emissions (million tons)

Legend: sector 6, sector 5, sector 4, sector 3, sector 2, sector 1

To produce goods for both domestic consumption and exports, capital investments are spent on the production. Figure 8 shows the amount of CO_2 emitted from one unit of GRP spent. We could see that regions in central area have the largest difference under these two scenarios. If one yuan of GRP is spent on domestic consumption, more CO_2 emissions would be emitted (i.e. an average of 1.2 tons) than the scenario of one yuan of GRP is spent on exports (i.e.an average of 0.3 tons). For regions in eastern area, one unit of GRP spent on exports would lead to an averaging CO_2 emission of 0.8 tons, which is quite similar with 0.76 tons if GRP is spent on domestic consumption. For regions in western area, per unit of GRP spent on export would lead to an average emission of 1.2 tons, while spent on domestic consumption it would lead to an average emission of 1.5 tons. Also, the highest emission levels for both domestic consumption (i.e. Ningxia and Guizhou) and exports (i.e. Ningxia and Qinghai) occur in western area. This may because of the lack of advanced environmentally-friendly technology and effective management.
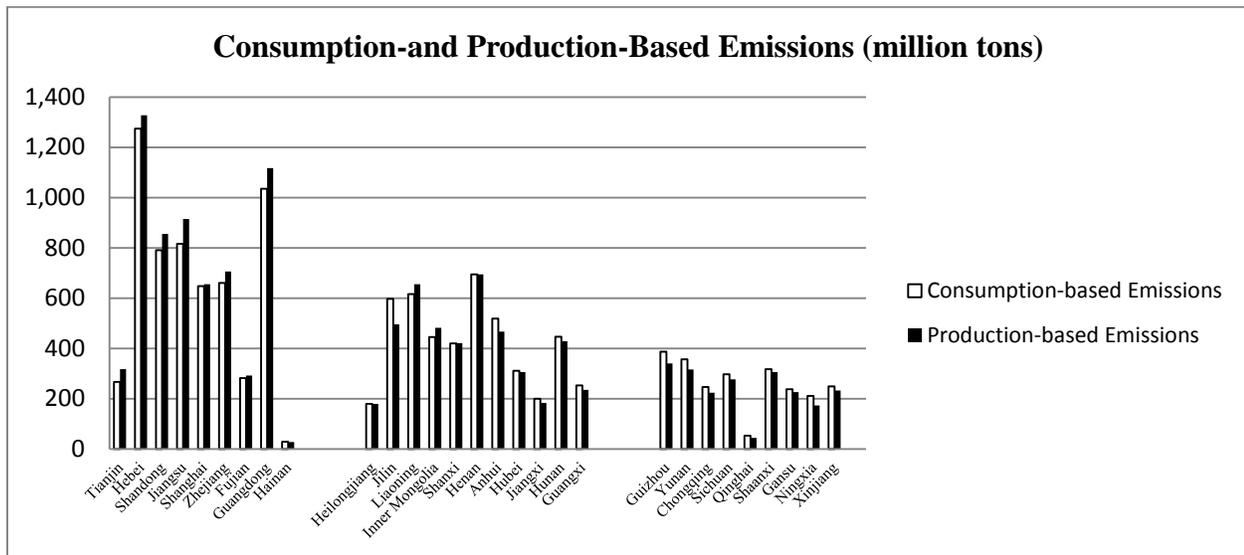
Fig.8 CO_2 emissions associated with GRP

3.4 Consumption-Based CO_2 Emissions

Consumption-based CO_2 emissions from domestic consumption and imports are also calculated. Compared with production-based CO_2 emissions (Fig. 9), total consumption-based emissions are 40 million tons less than total production-based emissions, and large differences occur in several regions such as Jiangsu, Guangdong, and Jilin. Generally speaking, export-embodied CO_2 emissions are nearly 384 million tons more than import-embodied CO_2 emissions. However, when simply looking at domestic consumption, consumption-based emissions are 340 million tons more than production-based emissions.

Fig.9. Consumption-and Production-Based CO$_2$ Emissions in 2007

In order to see the differences caused by two approaches in each region, Table 2 shows the detailed information by subtracting consumption-based emissions from production-based emissions.

In addition, since 2010 Chinese Central Government and its think-tanks have been discussing the formulation and implementation of carbon tax in China (2010, GESEP[1]). Carbon tax was expected to be carried out around the year 2012 at the price of 10-20 RMB Yuan/ton; however, with RMB appreciation this plan has been delayed several times. Assuming that the government would levy the tax at the price of 15 RMB yuan per ton, which is approximately $2.4/ton, each region needs to pay for their emissions. If emissions are calculated using production-based approach, From Table 2, when CO2 emissions are calculated using production-based approach, regions with negative changes in carbon tax would save some certain amount of taxes. However, regions with positive changes in carbon tax would get some losses. For example, Jilin Province would save 1.5 billion yuan if using production-based approach, while Guangdong Province would pay 1.2 billion yuan more.

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[1]GESEP, Global Energy Saving and Environmental Protection.

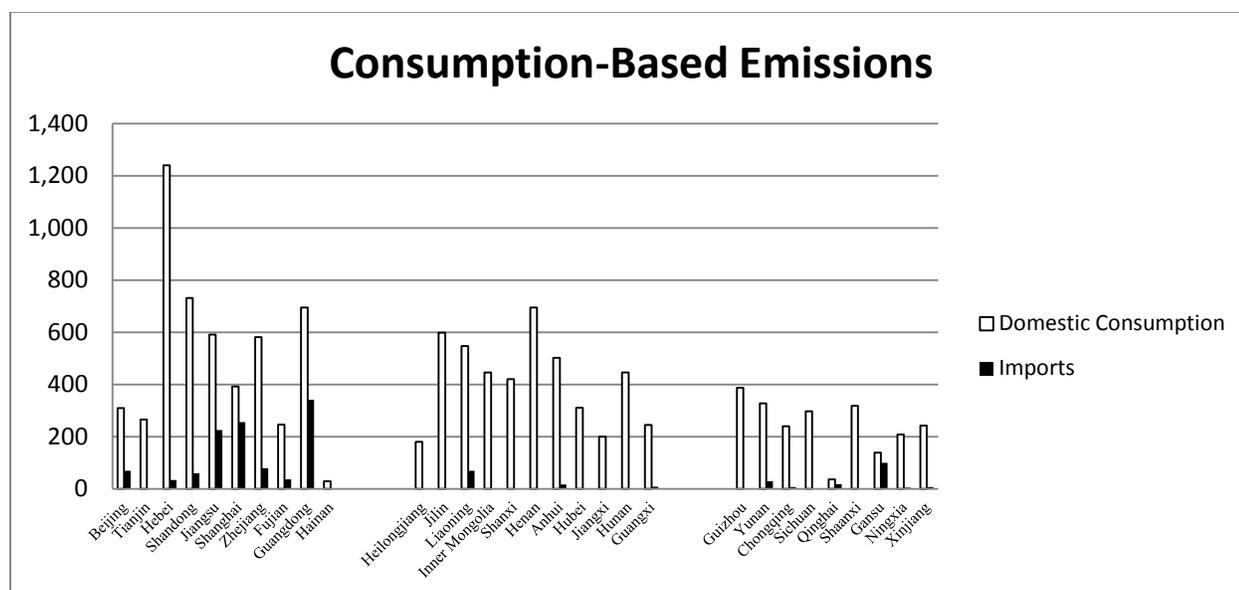Table2. Differences Caused by Different Accountings and Potential Change of Carbon Tax

(Note: difference is defined as production-based emissions minus consumption-based emissions)

Regions	Difference in Emissions (million tons)	Variation of Carbon Tax (million yuan)
Jilin	-101.3	-1,519.8
Anhui	-51.3	-769.5
Guizhou	-47.9	-718.1
Yunnan	-40.4	-605.8
Ningxia	-38.3	-574.3
Hunan	-29.9	-449.1
Beijing	-24.7	-369.8
Chongqing	-23.4	-350.4
Sichuan	-19.6	-293.6
Guangxi	-17.6	-263.9
Xinjiang	-16.7	-250.8
Jiangxi	-15.8	-237.0
Gansu	-11.4	-171.6
Shaanxi	-10.8	-161.3
Qinghai	-9.4	-140.6
Hubei	-4.3	-64.0
Hainan	-0.6	-9.4
Henan	-0.6	-9.4
Heilongjiang	0	0
Shanxi	1.3	18.8
Shanghai	7.9	118.2
Fujian	10.2	152.8
Tianjin	11.4	171.2
Inner Mongolia	36.9	554.1
Liaoning	39.6	594.0
Zhejiang	45.7	685.3
Hebei	53.7	805.0
Shandong	64.5	967.0
Guangdong	82.1	1,231.9
Jiangsu	98.5	1,478.0

However, we could see that CO_2 emissions in most regions of eastern area decrease when using the consumption-based accounting method. Thus, these regions could be less responsible for the emissions. This may lead to a controversial issue that developed regions with strong economy actually pay less, while relatively poor regions in central area or western area need to pay more. Chinese government has

frequently emphasized that diminishing the poverty gap between eastern area and western area will be a long-term strategic goal for China's development, therefore, the government may consider comprehensive conditions to choose proper method to regulate emissions across different regions. What's more, emissions embodied in imports are mainly concentrated in eastern area (Fig. 10), so import-embodied emissions could avoid some carbon leakage through exports. Therefore, although consumption-based approach leads to a lower level of total emissions, it may not be a good option if considering emissions from domestic consumption alone and specific regional characteristics.

Fig. 10.Consumption-Based Emissions from Domestic Consumption and Imports

4. Discussion

4.1 Discussion on Transfers-in and Transfers-out

In many studies on China's embodied emissions, inter-provincial transfers-in (TI) and transfers-out (TO) are not emphasized. However, during the calculation process, it turns out that TI and TO plays a significant role in embodied emissions. As mentioned above, this paper finds embodied emissions in exports in 2007 is 15% of domestic emissions, which is much smaller than 33% that is concluded in Weber's study. This may be because of the treatment of TI and TO in this paper is different. In Weber's paper, final domestic consumption include household consumption, government consumption, and gross

capital formation; while in this paper, beyond those three values, TO is added to calculate production-based domestic emissions, and TI is added to calculate consumption-based domestic emissions. Therefore, domestic emissions will be much larger, which will lead to a smaller proportion of embodied emissions in exports. For example, if subtracting TO from final domestic consumption, the embodied emissions in exports is 83% of domestic emissions; if adding TO into final domestic consumption, the embodied emissions in exports is only 35% of domestic emissions.

Zhang (2011) in the study of Determination of Each Province's CO_2 Reduction Target Based on Embodied CO_2 Emissions compared embodied emissions in TI and TO using the data of 2002 IO table, and indicated the importance of TI and TO in the determination of provincial reduction target. For further study, embodied emissions in TI and TO in 2007 could be analyzed.

4.2 Discussion on Direct Consumption Coefficients (A) Matrix

As mentioned in Section 2, Peters introduced the calculation methods which indicated that A matrix could be decomposed in to A^{rr} and A^{rs}. When calculating emissions, A^{rs} was removed because it stands for import contribution to intermediate inputs. However, due to the limited data, this study does not remove the contribution of imports to intermediate inputs, while in Weber's study he derived the matrix of A^{rs} and subtracted it from the A matrix.

Deriving A^{rr} matrix has some challenges. According to Su et al (2013), it is hard to disaggregate A matrix to A^{rs} and A^{rr} matrix since it involves many data sources that have inconsistencies. Also, it is hard to assume emissions intensities for processing trades that contributes to intermediate inputs. After they compared differences of these assumptions on A matrix and A^{rr} matrix, they concluded that using A matrix underestimated embodied emissions in normal trades while overestimated embodied emissions in processing trades that contributes to intermediate use. Therefore, this finding could be a possible explanation that why results of emissions from exports in this study is smaller than results in Weber's study.

5. Conclusions

This paper analyzes China's CO_2 emissions from domestic consumption and exports across 6 sectors and 30 regions in 2007. Geographically and sectorally, different regions present different CO_2 emissions. By comparing production- and consumption-based accounting methods, main conclusions are drawn as follows: First, CO_2 emissions in different measurements could lead to different emission levels across regions. For example, using CO_2 emissions per unit of GRP may cause relatively poorer regions to be more responsible for CO_2 emissions. Second, regions in eastern area of China contribute the most CO_2 emissions of domestic consumption and CO_2 emissions embodied in exports. Most of these regions lie on the costal line and possess many ports and harbors. Thus, international trades are active in these regions. Third, consumption- and production-based methods cause some differences among regions in terms of CO_2 emissions, however, when using consumption-based accounting method eastern regions are less responsible for CO_2 emissions, while regions in central area bear more responsibilities. That is to say, relatively developed regions need to pay less if nationwide carbon tax is levied based on consumption-based accounting method. Fourth, industrial sector makes up the largest proportion of emissions both in domestic consumption and exports. Chinese government has advocated adjusting industrial structures in its "12th five-Year Plan (2011-2015)", and addressed to innovate environmentally-friendly technologies, utilize renewable energies, close small businesses relied on high energy consumption, and promote clean-energy sector. Fifth, environmental policies need to take account provincial characteristics when implementing environmental policies. Regions in western area may need more financial and technological supports to control and reduce emissions, therefore, inter-provincial trade could play a significant role to balance the development of eastern and western areas.

In addition, it is difficult to say whether consumption-based accounting is better than production-based method, although consumption-based accounting seems to be reasonable that whoever consumes should

be responsible. According to Wei et al (2010), if using consumption-based emissions inventories, producers who produce the emissions embodied in the products may have less incentives and responsibilities, therefore, they may choose not to actively reduce emissions embodied in production, and not have the motivation to innovate technologies and develop clean energy. Lenzen et al (2007) suggested that "shared principle" is a better option, which means the responsibility should be allocated to both producer and consumer. From the analysis in this paper, using consumption-based accounting leads to a lower level of China's total CO_2 emissions as well as a lower level of embodied emissions in international trades. Therefore, China is in favor of consumption-based accounting when negotiating in international treaties such as the UNFCCC. But when looking at purely domestic emissions relatively poor regions in China take more responsibilities for emissions reduction. Therefore, China's government needs to consider specific regional characteristics, and implement policies that would compensate those poor regions.

6. Acknowledgement

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