

The Effects of China-EU Trade on CO₂ Emissions

Hui Zhou, Jie Cao, Jichuan Sheng

School of Economics and Management, Nanjing University of Information Science & Technology, Nanjing, China.
Email: zhouhui966@163.com, cj@amss.ac.cn, shengjichuan@gmail.com

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ABSTRACT

Production for international trade has played an important role in driving the rapid increase of Chinese CO₂ emissions. This paper uses input-output analysis to quantitatively estimate the effect of the bilateral trade between China and its present largest trading partner, the European Union (EU), on both national and global CO₂ emissions. The results show that under the bilateral trade, China's emissions from 2002 to 2008 increased by 2458 MMT (6.64%), and the EU's emissions decreased by 539 MMT (1.81%). From a global perspective, the trade led to an increase of 1919 MMT CO₂ in the world's total emissions. The trading pattern is not dominated by pollution haven effect but by the comparative advantages in factor endowments. It is suggested that a consumer responsibility-based accounting system of national CO₂ inventory should be introduced in replace of the present producer responsibility-based one. In order to achieve cost efficiency in emissions reduction in the new accounting system, more CDM programs could be established.

Keywords: Carbon Dioxide Emissions; Trade between China and EU; Pollution Haven Hypothesis; Factor Endowments

1. Introduction

During the past ten years the total CO₂ emissions of China through consumption of energy have almost tripled. China surpassed the United States and became the world's largest CO₂ emitter beginning in 2007. Among the main forces of driving Chinese CO₂ emissions, international trade plays an especially important role.

The bilateral trade between China and the EU almost quadrupled, from 100 billion euros in 2000 to 395 billion euros in 2010. In 2006 China took the place of the USA and became EU's largest import partner.

However, the impacts of the bilateral trade between the EU and China on CO₂ emissions have not been studied extensively. Therefore, the first motivation of this paper is trying to figure out the impacts of China-EU trade on national and global CO₂ emissions quantitatively. Following the Shui and Harriss (2006) framework [1], we want to answer the following three questions: 1) How much the CO₂ emissions for China changed because of the China-EU trade? 2) What amount of CO₂ emissions changed for the EU due to the bilateral trade? 3) What is the impact of the bilateral trade between China and the EU on global CO₂ emissions?

In addition to analyzing the effects of EU-China trade

on CO₂ emissions, we want to further explore the reasons behind the trade pattern. There are two major competing theories concerning competitive advantages. The pollution haven hypothesis (PHH) predicts that countries with relatively weak environmental policy, which are often low-income countries, will specialize in dirty-industry production. The major alternative to the pollution haven hypothesis is that the direction of trade in dirty goods is primarily determined by conventional determinants of comparative advantage-factor endowments and differences in technology. This hypothesis can be called factor endowments hypothesis and under it, the pollution-haven effect is swamped by other motives for trade [2].

In the global warming case, as Annex I countries, the EU was required by the Kyoto Protocol to achieve greenhouse gas emissions reduction targets, which could represent an environmental competitive disadvantage. The EU launched European Union Emissions Trading Scheme (EU ETS) in 2005 which now covers more than 10,000 installations with a net heat excess of 20 MW in the energy and industrial sectors which are collectively responsible for close to half of the EU's emissions of CO₂ and 40% of its total greenhouse gas emissions. On the other side, China is a non-Annex I country without a binding target for CO₂ emissions reduction. If PHH holds,

the EU has incentives to transfer energy-intensive industries to China, or to directly import energy-intensively produced goods from China in order to reduce domestic carbon emissions. Therefore, has China become the “CO₂ pollution haven” for the EU, or was the trade mainly driven by endowment factors? This is the second motivation of this paper and in order to answer this question, we will: 1) identify the pattern of the bilateral trade between China and EU; and 2) testify the pollution haven hypothesis for the carbon intensive sectors.

According to the above research aims, the rest of the paper is organized as follows: Section two reviews recent literatures on the topic; section three introduces the methodologies, including input-output analysis and the indicator for PPH; sector four presents the data sources; section five proposes the main results; section six makes discussions on carbon leakage and the trade driving forces; and section seven concludes the paper.

2. Literature Review

Many studies show that China is a net exporter of energy, and the energy embodied in exports tends to increase over time, which is driven by the consumptions in the developed world. Wang and Watson (2007) make an initial assessment of the emissions from the goods and services that China exported in 2004, concluding that the net exports from China accounted for 23% of its total CO₂ emissions. It supports the argument that the steep rise in China’s emissions has been fueled by exports of cheap goods from its factories to western consumers [3]. Weber, *et al.* (2008) find that in 2005, around one-third of Chinese CO₂ emissions (1700 Million Metric Tons, MMT) were due to production of exports, and this proportion has risen from 12% (230 MMT) in 1987 and only 21% (760 MMT) as recently as 2002 [4]. According to the estimation of Guan, *et al.* (2009), half of China’s recent increase in carbon emissions has been driven by its production of goods for export—60% of which went to wealthy OECD states [5]. Lin and Sun (2010) show that about 3357 MMT CO₂ emissions were embodied in the exports of China while the emissions avoided by imports were only 2333 MMT in 2005, implying that China was a net exporter of CO₂ emissions [6].

There are other studies focusing on the carbon emissions embodied in bilateral trade between China and its top trading partners. The most relevant one is Yang *et al.* (2011) which also study the impact of China-EU trade on climate change. They find out that the EU has outsourced its own emissions to an extent of ca 13.6% of its total energy-related CO₂ emissions (2006/7) and the emissions embodied in China-EU trade were very imbalanced [7]. As for China and the US, about 7% - 14% of China’s CO₂ emissions were a result of producing exports for US consumers during 1997-2003. US CO₂ emissions would

have increased from 3% to 6% if the goods imported from China had been produced in the US [1]. The decomposition analysis of embodied CO₂ emissions in the trade between China and Japan reveals that the growth of exports (or activity change) had a large influence on the growth of embodied CO₂ emissions during 1990-2000 [8]. Liu, *et al.* (2010) point out that the exported CO₂ emissions from China to Japan greatly increased in the first half of the 1990s and had reduced from 1995 levels by 2000 [9]. It is estimated that through trade with China, the UK reduced its CO₂ emissions by approximately 11% in 2004, compared with a non-trade scenario in which the same type and volume of goods were produced in the UK [10].

On the PPH, empirical evidences are mixed. Some studies prove the existence of pollution havens. A study on Italy verifies that as a Kyoto and European Emissions Allowance Trading Scheme (EATS) complying country, evidence of a change in the trade patterns occurred on the basis of the PPH does exist [11]. Cole (2004) finds evidence of pollution haven effects, using detailed data on North-South trade flows for pollution intensive products, but such effects do not appear to be widespread and appear to be relatively small compared to the roles played other explanatory variables [12]. Using a new dataset on the stringency and enforcement of environmental policy, Kellenberg (2009) is the first to find robust confirmation of a pollution haven effect in a cross-country context by accounting for strategically determined environment, trade, and intellectual property right policies [13].

However, some studies reject an association between environmental regulation and trade in dirty industries. Liddle (2001) find that the benefits of trade can be either positive or negative depending on country endowments, but their results do not support the pollution haven hypothesis [14]. Kearsley and Riddel (2010) reject the PPH because they find only very weak statistical evidence that dirty imports are correlated with higher emissions [15]. Dietzenbacher and Mukhopadhyay (2007) find out that the gains from trade have increased comparing 1996/1997 with 1991/1992, indicating that India has moved further away from being a pollution haven [16].

3. Methodologies

3.1. The Input-Output Framework

This paper first seeks to calculate the CO₂ emissions embodied in imports and exports. The embodied CO₂ emission of a product is an accounting methodology which aims to find the sum total of the carbon emissions in an entire product lifecycle. This lifecycle includes raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and/or decomposition.

The input-output analysis (IOA), which was first developed by Wassily Leontief in 1936, is adopted in this paper for the purpose of estimating embodied emissions. Since the IO table is able to capture indirect environmental impacts caused by upstream production, it has frequently been used to analyze the emissions embodied in goods during the last few decades.

Assuming that an economy includes n industries, the equation can be represented as:

$$x = Ax + y. \quad (1)$$

Where x is a column vector representing the total output of the entire economy. x is decomposed into two parts, the intermediate input for producing the total output, which is Ax , and the final demand, which is y . A is the direct requirement coefficients matrix, whose element a_{ij} ($i, j = 1, \dots, n$) represents the amount of input from industry i required directly in order to produce one unit of output from industry j . The final demand y in the IO model includes household consumption, government consumption, investment and net export.

The relationship between the final demand y and the total output x can be represented as:

$$x = (I - A)^{-1} y. \quad (2)$$

Where $(I - A)^{-1}$ is called the Leontief inverse matrix, which is also called the cumulative demand coefficients matrix. Its element represents the amount of demand from industry i required directly and indirectly to produce one unit final demand from industry j .

The emissions C embodied in the final demand y is:

$$C = E(I - A)^{-1} y. \quad (3)$$

Where E is a row vector representing the coefficients of direct CO₂ emissions per unit output by sector. $E(I - A)^{-1}$ represents the coefficients matrix of cumulative CO₂ emissions per unit output by sector.

According to this framework, the amount of the avoided CO₂ emissions in the EU by importing goods from China is:

$$C_1 = E_{EU} (I - A)_{EU}^{-1} y_{CE} = R_{EU} y_{CE}. \quad (4)$$

Where: E_{EU} is the coefficients vector of the EU's direct CO₂ emissions per unit output and $R_{EU} = E_{EU} (I - A)_{EU}^{-1}$ represents the coefficients matrix of cumulative emissions per unit output in the EU. y_{CE} is the vector of the Chinese exports to the EU.

The CO₂ emissions embodied in the production of the exports from China to the EU are:

$$C_2 = E_C (I - A)_C^{-1} y_{CE} = R_C y_{CE}. \quad (5)$$

Where: E_C is the coefficients vector of the China's direct CO₂ emissions per unit output and $R_C = E_C (I - A)_C^{-1}$

represents the accordingly coefficients matrix of cumulative emissions per unit output in China.

On the other hand, the amount of avoided CO₂ emissions in China by importing from the EU is:

$$C_3 = E_C (I - A)_C^{-1} y_{EUE} = R_C y_{EUE}. \quad (6)$$

Where: y_{EUE} is the vector of the EU exports to China.

The CO₂ emissions embodied in the production of the exports from the EU to China are:

$$C_4 = E_{EU} (I - A)_{EU}^{-1} y_{EUE} = R_{EU} y_{EUE}. \quad (7)$$

In summary, the amount of CO₂ emission change of China compared to a non-trade scenario is the difference between the emissions embodied in the exports to the EU and the avoided emissions embodied in the imports from EU, which is represented as:

$$\Delta C_1 = C_2 - C_3. \quad (8)$$

Similarly, the amount of CO₂ emission change of EU because of bilateral trade is the difference between the emissions embodied in the exports to China and the avoided emissions embodied in the imports from China, which is shown as:

$$\Delta C_2 = C_4 - C_1. \quad (9)$$

The world's total CO₂ emissions changes due to the bilateral trade between China and the EU compared to the non-trade scenario is:

$$\Delta C = \Delta C_1 - \Delta C_2. \quad (10)$$

For the results of (8)-(10), a positive value means an increase of the emissions while the negative value implies a decrease of the emissions.

3.2. Indications about the Pollution Haven Hypothesis

In this paper, the indicator of net export-domestic consumption ratio is used to testify whether the pollution haven hypothesis is true [11]. The indicator is defined as the following:

$$N^{(k)} = \left(y_{CE}^{(k)} - y_{EUE}^{(k)} \right) / C^{(k)}. \quad (11)$$

Where $y_{CE}^{(k)}$ and $y_{EUE}^{(k)}$, following the definition in the preceding section, represent respectively Chinese exports and imports of sector k toward or from the EU. $C^{(k)}$ represents the domestic apparent consumption of the products of sector k in China, which is obtained through:

$$C^{(k)} = P^{(k)} + I^{(k)} - E^{(k)}. \quad (12)$$

Where $P^{(k)}$ is the domestic total production of sector k in China. $I^{(k)}$ and $E^{(k)}$ are total import and export of sector k .

If the indicator shows an increasing trend, the PHH may occur. On the converse, the PHH is rejected.

4. Data Sources

4.1. CO₂ Emission factor for Chinese Industry

We follow the method proposed by [17] to construct E_C : the direct CO₂ emissions coefficients vector in China. The data of final energy consumption by sector were collected from China Energy Statistical Yearbook (CESY) 2008. In this database, the entire economy is categorized into 44 sectors.

In addition, we use the latest-available version of the Chinese input-output table of 2007 to acquire the basic matrix. There are two categorizations in the input-output table, which are 42 sectors and 135 sectors. However, neither of them is in accordance with the 44-sector categorization in the CESY. So we made a match between the 42-sector of input-output table and the 44-sector of energy consumption, and re-categorized the entire economy into 29 sectors, listed in the **Appendix 1**.

4.2. CO₂ Emission Factor for EU Industry

E_{EU} , the direct CO₂ emissions coefficients vector in the EU, is obtained through the E3IOT database, and the avoided CO₂ emissions in the EU and the embodied CO₂ emissions for EU exports are calculated using the Chain Management by Life Cycle Assessment (CMLCA) software. Both the database and the software were developed by the Institute of Environmental Sciences of Leiden University, the Netherlands. The CMLCA is a software tool that supports the calculation of input-output analysis (IOA), including environmental input-output analysis (EIOA). The E3IOT database contains a high resolution, environmentally extended input-output table for Europe which covers production, consumption and waste management sectors. It can be assumed to give a good estimate of total emissions and resource use (mostly fossil energy) related to final consumption in the EU-25 [18]. Because of lack of officially released input-output table of the EU, E3IOT database can serve as the best alternative for the purpose of environmental extended input-output analysis of the EU in this paper.

4.3. Trade Data and Aggregation

Because the E3IOT database was developed based on the area of EU-25, we focused on the trading between China and the EU-25. Because of data availability, we chose the study period to be 2002-2008. The data of bilateral trade between China and EU-25 during this period were obtained from the eurostat website of the European Commission.

All the original trading data are in the form of a Har-

monized System (HS) which divides the trading goods into 98 categories. In order to calculate the CO₂ embodied in Chinese exports to the EU, we made a match of the HS category with the 44-sector categorization in the Chinese input-output table, according to Appendix 4 of the Input-Output Tables of China 2007, and then aggregated them into the 29-sector category.

On the other hand, in E3IOT datas *et al* most 500 production sectors are distinguished, based on the input-output table of the US. Therefore, in order to calculate the CO₂ embodied in EU exports to China, we matched the EU exporting data in the HS category into the E3IOT category according to the Table of Concordance Between 2002 Input-Output Commodity Codes and Foreign Trade Harmonized Codes, which is available in the Bureau of Economic Analysis website in the US.

4.4. Data for Calculating PHH Indicator

The data of total imports and exports of China from 2002 to 2008 were collected from the International Trade Center website. The data of sector productions and investments of China were collected from the China Statistical Yearbook 2003-2009. We used the exchange rates and the consumer price index (CPI) to convert the trading values, the productions and investments between years into a 2007 constant price RMB value.

5. Results

5.1. The CO₂ Emissions Embodied in Chinese Exports to the EU

In 2002, China exported goods to the EU for about 90 billion euros. This number increased steadily to 245 billion euros in 2008. In order to produce the goods exported to the EU, China emitted large amount of CO₂. The carbon emission embodied in the Chinese exports to the EU was 250 MMT in 2002 (7.21% of the total Chinese emissions in that year) and reached 769 MMT (12.30%) in 2007 (shown in **Figure 1**). The emission went down to 758 MMT in 2008. However, the percentage of the CO₂ emissions produced due to exports to the EU (referred to as EEE) to the total Chinese emissions decreased more rapidly than that of the EEE itself. This is because although the exports to the EU from China declined in 2008 due to the global economic downturn, the total Chinese emissions kept going upward during the same period. From 2002 to 2008 the accumulated CO₂ emissions in China attributed to producing exports to the EU were 3736 MMT, about 10.09% of the Chinese total emissions.

5.2. The Avoided CO₂ Emissions in the EU through Importing from China

According to our estimation, through importing from

China, the avoided CO₂ emissions in the EU increased from 69 MMT in 2002 (1.67% of the EU total emissions in that year), to 185 MMT (4.41%) in 2008 (shown in **Figure 2**). During the period 2002-2008, the total avoided CO₂ emissions in the EU added up to 889 MMT. This means that if all the imported goods had been produced in the EU instead of in China, the total CO₂ emissions of the EU would have increased by 889 MMT, about 2.99% of the EU emissions in that period.

5.3. The CO₂ Emissions Embodied in EU Exports to China

The exports of EU to China more than doubled from 35 billion euros in 2002 to 78 billion euros in 2008. The CO₂ emissions embodied in these exports increased accordingly. In 2002 the CO₂ emissions embodied in the exports from EU to China were 31 MMT, accounting for 0.75% of the total EU emissions. It climbed to 67 MMT, which was 1.60% of the total in 2008 (shown in **Figure 3**).

5.4. The Avoided CO₂ Emissions in China through Importing from EU

China avoided CO₂ emissions through importing goods from the EU. The amount increased steadily from 99

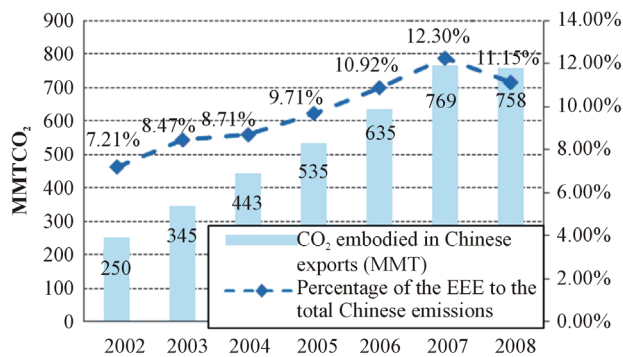


Figure 1. The CO₂ emissions embodied in Chinese exports to the EU, 2002-2008.

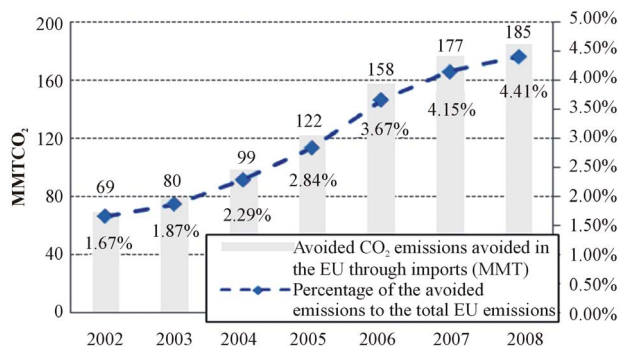


Figure 2. Avoided CO₂ emissions in the EU for imports from China, 2002-2008.

MMT in 2002 to 241 MMT in 2008. The percentage of the avoided to the total Chinese CO₂ emissions fluctuated around 3.5% most of the time in this period (shown in **Figure 4**). If China had produced these goods instead of importing them from the EU, the total emissions in 2002-2008 would increase by 1277 MMT, about 3.45% of the Chinese emissions in that period.

5.5. The Impact of Bilateral China-EU Trade on National and Global CO₂ Emissions

Through bilateral trade between China and the EU, China had a trade surplus increasing from 55 billion euros in 2002 to 167 billion euros in 2008. The CO₂ emissions embodied in Chinese exports to the EU are much larger than those embodied in Chinese imports from the EU, which makes China a net CO₂ exporter. If we call the difference of these two amounts the “CO₂ trade surplus”, the EU had a considerable CO₂ trade surplus from trading with China, increasing from 219 MMT in 2002 to 708 MMT in 2007 and decreasing to 691 MMT in 2008 (shown in **Figure 5**).

Chinese CO₂ emissions kept increasing during the recent decade, in which international trade played an important role. If China had not produced exports for the EU from 2002-2008, the total CO₂ emissions would have

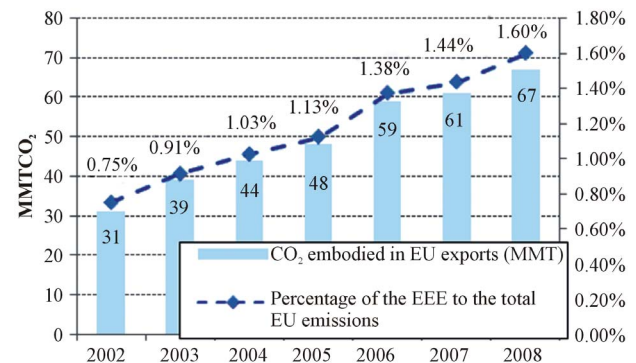


Figure 3. The CO₂ emissions embodied in EU exports to China, 2002-2008.

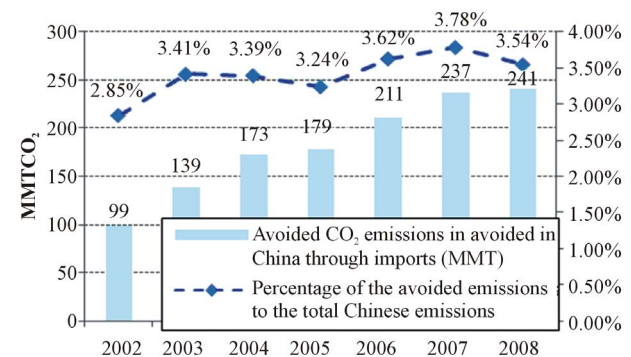


Figure 4. Avoided CO₂ emissions in China for imports from the EU, 2002-2008.

decreased by 3736 MMT, about 10.09% of the Chinese total emissions. If China had not imported goods from the EU, the total CO₂ emissions would have increased by 1277 MMT, about 3.45% of the total emissions during this period. Therefore, trading with the EU increased Chinese total CO₂ emissions (as **Figure 6** shows) by 2458 MMT, which was 6.64%, from 2002 to 2008.

On the other hand, if the EU had produced the same amount of products domestically, instead of importing from China, the total emissions of the EU would have increased by 889 MMT, about 2.99% of the EU emissions from 2002 to 2008. Producing goods for exporting to China resulted in an increase of CO₂ emissions of 350 MMT, or 1.18% of the EU emissions. Thus trading with China decreased EU total CO₂ emissions (as **Figure 7** shows) by 539 MMT, which was 1.81%, from 2002 to 2008.

Therefore the bilateral trade between China and the EU had an obvious impact upon national CO₂ emissions, increasing China's emissions and decreasing the EU's emissions. From a global point of view, China-EU trade increases global CO₂ emissions. According to our estimation, the bilateral trade between China and the EU actually increased the global CO₂ emissions by 1919 MMT from 2002-2008.

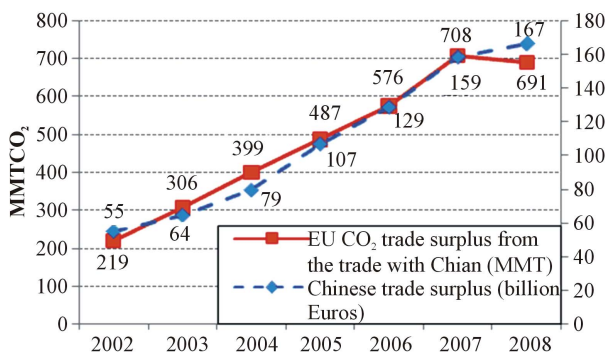


Figure 5. Commodity and CO₂ trade surplus of China and the EU, 2002-2008.

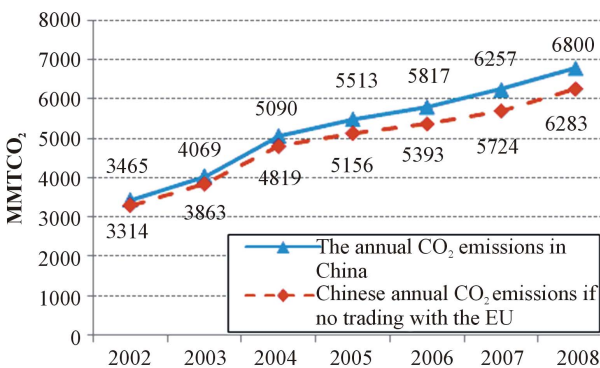


Figure 6. The influence of EU-China trade on China's emission.

5.6. Identification of Carbon Intensive Sectors

First, the direct CO₂ emissions coefficients of the 29 sectors of China are calculated following the way proposed by [17]. Then the accordingly coefficients of the cumulative emissions per unit output in China are obtained using the Chinese Input-Output Table 2007. The carbon intensive sectors are identified as the ten sectors with highest cumulative CO₂ emission factor (which are shown in **Table 1**), excluding those that have not been involved in the bilateral trade with the EU.

5.7. Trade Pattern of the Carbon Intensive Products

The values of exports of the ten carbon intensive sectors to the EU kept increasing from 28 billion euros in 2002 to 84 billion euros in 2008, at an average annual increas-

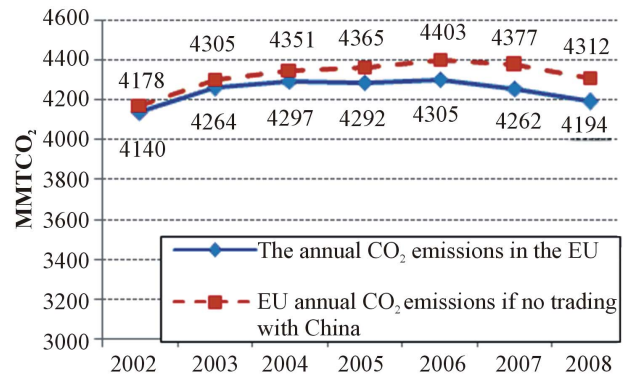


Figure 7. The influence of EU-China trade on EU's emissions.

Table 1. The most carbon intensive sectors and their cumulative CO₂ emission factors.

Rank	Sector (Code)	CO ₂ emission factor (kgCO ₂ /yuan)
1	Manufacture of Non-metallic Mineral Products (13)	0.6404
2	Mining and Processing of Metal Ores (04)	0.5440
3	Smelting and Pressing of Metals (14)	0.4886
4	Mining and Washing of Coal (02)	0.4812
5	Chemical Industry (12)	0.4542
6	Manufacture of Metal Products (15)	0.4332
7	Mining and Processing of Nonmetal Ores and Other Ores (05)	0.3920
8	Processing of Petroleum, Coking, Processing of Nuclear Fuel (11)	0.3894
9	Manufacture of Electrical Machinery and Equipment (18)	0.3477
10	Manufacture of General Purpose and Special Purpose Machinery (16)	0.3463

ing rate of 20%. The carbon intensive exports from China accounted for 31.27% of the total exports to the EU in 2002, and this ratio decreased to 29.76% in 2005. It climbed to the peak of 34.19% in 2007 and stayed almost unchanged in 2008 (shown in **Figure 8**).

In order to further show the trade pattern of the carbon intensive sectors, export-import ratio of the 10 carbon intensive sectors from 2002 to 2008 are calculated (listed in **Table 2**). If the export-import ratio of a sector is larger than one, *i.e.*, the exports of this product are larger than the imports, it means that this country is a net-exporter in this product. On the contrary, a less-than-one export-import ratio implies that the country is net-importer in this product.

In general, China has been a net-exporter to the EU in carbon intensive products. From **Table 2** we can see that the export-import ratios of the total carbon intensive sectors from 2002 to 2008 were larger than one. Concretely speaking, eight sectors out of ten have larger-than-one export-import ratios during the study period, meaning

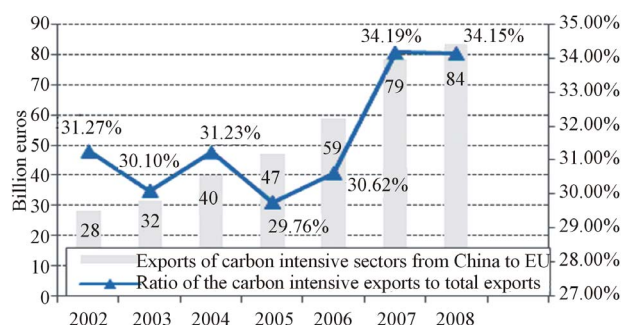


Figure 8. Exports of the carbon intensive sectors from China to EU.

Table 2. The export-import ratio of the carbon intensive sectors.

Sector code	2002	2003	2004	2005	2006	2007	2008
13	4.08	4.62	4.99	8.17	8.17	8.60	7.90
04	16.21	18.01	21.25	8.20	4.81	2.80	4.61
14	0.54	0.42	0.63	0.65	1.31	2.52	2.18
02	385	273	173	103	49	33	33
12	2.13	2.05	1.95	2.10	2.10	2.11	2.07
15	5.87	5.14	5.66	6.36	6.42	6.79	7.05
05	1.07	1.03	1.09	1.06	1.01	1.09	1.31
11	2.62	4.75	8.88	7.79	2.51	3.29	2.44
18	3.27	3.05	3.44	3.52	3.22	3.37	3.06
16	0.42	0.41	0.41	0.53	0.61	0.81	0.79
Total carbon intensive sectors	1.43	1.36	1.42	1.61	1.69	1.97	1.85

larger exports than imports. This trading pattern plays an important role in explaining the huge gap between the CO₂ emissions embodied in the Chinese exports and those in the EU exports, which is clearly shown in section 5.1 - 5.5. However, we would like to further ask how this trading pattern is determined? Is it dominated by the difference in the stringency of climate change policies, *i.e.*, PHH effect, or by the difference in factor endowments?

5.8. Tendency of the PHH Indicator of Carbon Intensive Sectors

The purpose of this section is to testify whether there exist some changes in the production of the carbon intensive sectors, on the basis of PHH. The values of the net export-domestic consumption ratio for the carbon intensive sectors in China from 2001 to 2009 are calculated. The changing tendencies of their PPH indicators are shown in **Figure 9**.

Among the ten carbon intensive sectors, there are six

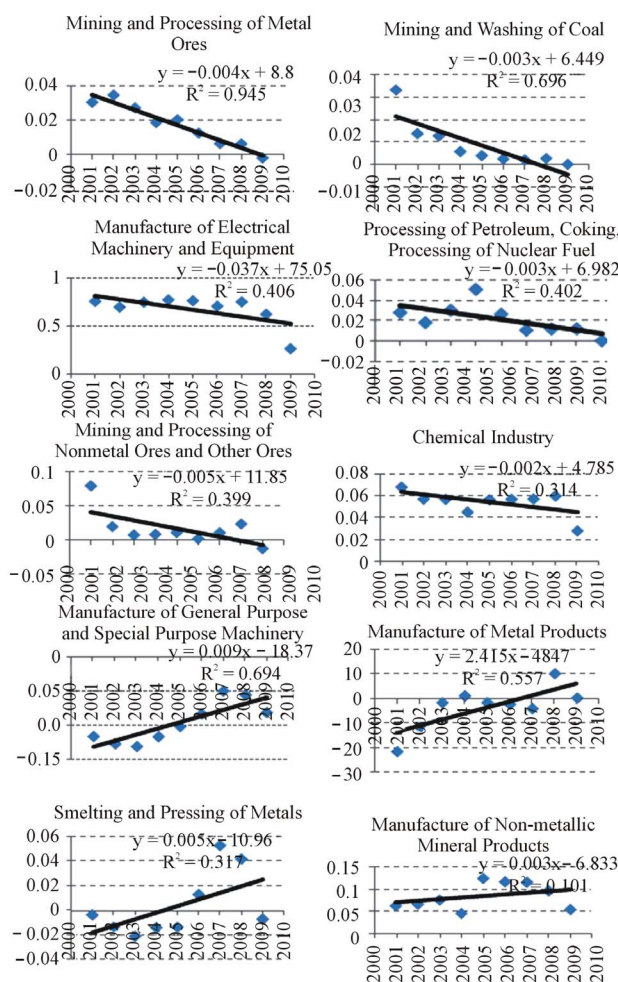


Figure 9. Tendency of the PHH indicator of carbon intensive sectors.

sectors, *Mining and Processing of Metal ores, Mining and Washing of Coal, Manufacture of Electric Machinery and Equipment, Processing of Petroleum, Coking, Processing of Nuclear Fuel, Manufacture of Non-metallic Mineral Products and Chemical Industry*, showing decreasing trend of a regression line. So for these sectors, PHH is excluded.

The other four sectors show an increasing trend. We further calculate their t-statistic values of the trend coefficients, which are 3.985, 2.972, 1.805 and 0.890 respectively. The critical values of one-side hypothesis testing for 1%, 5%, and 10% significance level are 4.297, 3.250 and 2.821 (for $n = 9$). Therefore, we can only reject the null hypothesis “There is no PHH” at 5% significance level for one sector, *Manufacture of General Purpose and Special Purpose Machinery*, and reject the null hypothesis at 10% level for the sector of *Manufacture of Metal Products*. For these two sectors, the PHH is verified. However, for the other two sectors, the increasing trend is not significant enough to provide reliable indications to support PHH.

In a word, according to **Figure 9**, we can only find evidence supporting the existence of PHH in two sectors out of ten. In addition, these two sectors rank 10th and 6th with their cumulative CO₂ emission factors in the ten carbon intensive sectors (see **Table 1**), *i.e.*, they are not the most carbon-intensive sectors.

6. Discussion

6.1. Pollution Haven or Factor Endowments?

China and the EU differ much in both their pollution policy and in their factor endowments. Compared with China, the EU is both capital abundant and has stricter CO₂ emissions targets. EU’s stringent CO₂ mitigation policy may tend to make it a dirty-good importer, but its capital abundance tends to make it a dirty-good exporter. The pattern of the bilateral trade depends on which of these effects is stronger.

The results in section 5.8 provide very weak supports for the PHH. It is indicated that for most of the carbon intensive sectors, differences in the stringency of environmental regulations between EU and China do not provide the latter with a significant comparative advantage in carbon intensive production and not drive China the pollution haven for the EU. On the contrary, factor endowments such as labor and capital have played a much more dominant role. It should be the lower cost of the Chinese labor and the more abundance of the EU capital that form the main comparative advantages in factor endowments and thus determine the structure of the trading patterns between China and EU.

6.2. Policy Implications

We have shown in the previous sections that the bilateral

trade between China and EU has actually increased the global emissions. How to change this situation with reasonable and feasible policies?

International trade has made consumption and production spatially separated possible. However, a question arises that which party should be responsible for the possible pollutions of the production. In the case of climate change, the present accounting system of the national emissions inventories has clearly represents the principle of producers. The United Nations Framework Convention on Climate Change (UNFCCC) defines the national emissions inventories to “include all greenhouse gas emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction” [19].

This way of responsibility allocation has worsened the problem of climate change. Kyoto Protocol, the most influential international climate change agreement, set emission targets to Annex I countries, which are developed countries. In order to achieve their targets, they have incentives to shift their emissions, in the ways of international trade and direct investment, to the developing countries that are not subject to binding targets. This is referred to as “carbon leakage”.

As Adam Smith says “Consumption is the sole end and purpose of all production” [20], we should reconsider the emissions accounting methods. If the responsibility of emissions is assigned to consumers, great change of the national emissions inventories will occur. The emissions of the developed countries like the EU will be increased and their responsibility of emissions reduction will be enlarged.

However, since the marginal CO₂ abatement costs are in general much higher in the developed countries than in developing countries, it will be cost inefficient if the developed countries try to abate the emissions within their territory borders. Therefore, the cost efficient solution for this problem should be letting the developing countries to reduce the embodied emissions in carbon intensive exports under the technical/financial support in clean production from the developed countries. In a policy perspective, we advocate that more programs in the form of Clean Development Mechanism (CDM) be applied.

7. Conclusions

In this paper we have focused upon the impact of bilateral trade between China and the EU on both national and global CO₂ emissions and try to verify whether the trading pattern is dominated by pollution haven effect or factor endowments. Because of the bilateral trade, China’s emissions from 2002 to 2008 increased by 2458 MMT (6.64%), and the EU’s emissions decreased by 539 MMT (1.81%). The trade increased the world’s total emissions by 1919 MMT, which worsens the problem of

global warming. However, the trading pattern is not mainly determined by the difference of the stringency of climate change policies, but by the comparative advantages in factor endowments.

In order to reduce the increased emissions caused by international trade, we propose a fundamental change of the accounting system of the national emissions inventories and allocate the responsibility of emissions to the consumers in replace of the producers. Furthermore, in order to simulate a cost efficient way of CO₂ emissions reduction under the new accounting system, we propose that more CDM programs be established to help the developing countries increase their energy efficiency in production techniques and thus reduce the emissions in their exports to the developed countries.

We notice that Yang *et al.* (2011) have studied the similar topic and get similar results that the emissions embodied in China-EU trade are very imbalanced. However, our research differs from theirs in several ways. First, we cover more countries (EU-27 compared to EU-15) and use a higher resolution in sector classifications (29 sectors compared to 15 ones); second, in addition to analyzing the impact of China-EU trade on CO₂ emissions, we further detect the main driving force that lies behind the trading pattern; third, we make different policy implications. We share the same idea with Yang *et al.* (2011) that a new consumer-based accounting system should be implemented. However, we suggest that by using CDMs instead of a cap-and-trade system, the difficulty of including the developing countries and allocating the initial emissions certificates to them could be circumvented.

Besides, we do not agree with one alternative that is proposed by Yang *et al.* (2011) that the EU could introduce tariffs on CO₂-intensive Chinese imports to maintain the status quo. The rationality of imposing carbon tariffs on Chinese imports is to eliminate the difference in the stringency of the climate change regulations between China and the EU. However, we have shown in our study that the trading pattern is actually not dominated by the pollution haven effect, but by the comparative advantage in factor endowments. Therefore, it will be fundamentally distortive to use the carbon tariffs in order to correct the trading pattern that is caused by labor and capital endowments, *l et al.* one that this kind of intervention might be against the principles of free trading.

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Appendix 1. Aggregated Sectors for Input-Output Analysis in China

Code	Sector	Code	Sector
01	Farming, Forestry, Animal Husbandry, Fishery & Water Conservancy	16	Manufacture of General Purpose and Special Purpose Machinery
02	Mining and Washing of Coal	17	Manufacture of Transport Equipment
03	Extraction of Petroleum and Natural Gas	18	Manufacture of Electrical Machinery and Equipment
04	Mining and Processing of Metal Ores	19	Manufacture of Communication Equipment, Computers and Other Electronic Equipment
05	Mining and Processing of Nonmetal Ores and Other Ores	20	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work
06	Manufacture of Foods and Tobacco	21	Manufacture of Artwork and Other Manufacturing
07	Manufacture of Textile	22	Recycling and Disposal of Waste
08	Manufacture of Textile Wearing Apparel, Footwear, Caps, Leather, Feather and Related Products	23	Production and Distribution of Electric Power and Heat Power
09	Processing of Timber, Manufacture of Furniture	24	Production and Distribution of Gas
10	Manufacture of Paper, Printing, Manufacture of Articles For Culture, Education and Sport Activity	25	Production and Distribution of Water
11	Processing of Petroleum, Coking, Processing of Nuclear Fuel	26	Construction
12	Chemical Industry	27	Transport, Storage, Postal & Telecommunications Services
13	Manufacture of Non-metallic Mineral Products	28	Wholesale, Retail Trade and Catering Service
14	Smelting and Pressing of Metals	29	Other service activities
15	Manufacture of Metal Products		