CEEP-BIT WORKING PAPER SERIES

CEEP-BIT

Spatial-Temporal Variations of Embodied Carbon Emission in Global Trade Flows: 41 Economies and 35 Sectors

Jing Tian
Hua Liao
Ce Wang

Working Paper 78
http://ceep.bit.edu.cn/english/publications/wp/index.htm

Center for Energy and Environmental Policy Research
Beijing Institute of Technology
No.5 Zhongguancun South Street, Haidian District
Beijing 100081
September 2014

This paper can be cited as: *Tian J, Liao H, Wang C. 2014. Spatial-Temporal Variations of Embodied Carbon Emission in Global Trade Flows: 41 Economies and 35 Sectors. CEEP-BIT Working Paper.*

The authors acknowledge financial support from the "Strategic Priority Research Program" of the Chinese Academy of Sciences (No. XDA05150600), National Natural Science Foundation of China (No. 71322306 and 71273027), Program for New Century Excellent Talents in University of Ministry of Education of China (No. NCET-13-0040), and Program for Excellent Young Talents in Universities of Beijing (No. YETP1181). The views expressed herein are those of the authors and do not necessarily reflect the views of the Center for Energy and Environmental Policy Research.

The Center for Energy and Environmental Policy Research, Beijing Institute of Technology (CEEP-BIT), was established in 2009. CEEP-BIT conducts researches on energy economics, climate policy and environmental management to provide scientific basis for public and private decisions in strategy planning and management. CEEP-BIT serves as the platform for the international exchange in the area of energy and environmental policy.

Currently, CEEP-BIT Ranks 47, top 3% institutions in the field of Energy Economics at IDEAS（http://ideas.repec.org/top/top.ene.htm), and Ranks 52, top 3% institutions in the field of Environmental Economics at IDEAS (http://ideas.repec.org/ top/top.env.html).

Yi-Ming Wei
Director of Center for Energy and Environmental Policy Research, Beijing Institute of Technology

For more information, please contact the office:

Address:
Director of Center for Energy and Environmental Policy Research
Beijing Institute of Technology
No.5 Zhongguancun South Street
Haidian District, Beijing 100081, P.R. China

Access:
Tel: +86-10-6891-8551
Fax: +86-10-6891-8651
Email: ceeper@vip.163.com
Website: http://ceep.bit.edu.cn/english/index.htm

Spatial-Temporal Variations of Embodied Carbon Emission in Global Trade Flows: 41 Economies and 35 Sectors

Jing Tian [1,2], Hua Liao [1,2,*], Ce Wang [1,2]

[1] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China;
[2] Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China.

Abstract: The spatial-temporal variations of embodied carbon emissions in international trade at global scope are still unclear. This paper studies the variations of outflows and inflows of embodied carbon emissions at 35-disaggregated sectors level of 41 countries and regions, and an integrated world input-output model is employed. It also examines what would happen if there were not international trade flows in China, USA and Finland, the representatives of three different levels of the global balance of embodied carbon. We find that: (1) Embodied carbon in global trade increases at about 3% per year since 1995 World Trade Organization founded, and East Asia tends to burden more from the net increase of the balance of embodied carbon. (2) China's export has the largest and increasing outflow of carbon burden, USA's import the largest and increasing inflow of carbon burden, and Finland's export and import have the decreasing carbon burden. (3) The global trade structure tends to be not so much carbon-intensive. BRIIAT (Brazil, Russia, India, Indonesia, Australia and Turkey) has the largest embodied carbon intensity in export (about 7.35 kg/$) while NAFTA (the United States, Canada and Mexico) the largest embodied carbon intensity in import (about 10.32 kg/$). (4) There existed some inclination of embodied carbon flows including neighbors-centered outflows and country-centered inflows.

Keywords: Embodied carbon flow; International trade; Spatial-temporal variations; Input-output analysis

1 Introduction

In the last decades, studies about emissions embodied in trade (EET) have become a popular topic related to the relationship between trade and environment (e.g. carbon reduction, carbon migration, carbon responsibility and climate policy in international trade). Producing goods and service usually results in fossil fuel using and CO_2 emissions, which is generally involved in the producers' CO_2 emission accounts even though these goods and service are imported and consumed by other countries or regions. According to the consumption-based principle, CO_2 emission embodied in the trade should be accounted to the importer (consumer) not the exporter (producer).Emissions embodied in trade (EET), followed by the consumption-based approach to accounting emissions, is the index to describe the direct and indirect emissions occurring along the chains of production and consumption. Production-based and consumption-based approaches are applied widely to account global greenhouse gas (GHG) emissions and the former is the base of the current global climate system. However, more and more studies find that problems caused by production-based approach such as carbon leakage (Peters, 2008a), the lack of consideration for international transport (Peters, 2008b), negative drives of reducing GHG emissions for net exporters of emissions (Peters and Hertwich, 2008b) and influences of unhealthy consumption patterns (Aldy, 2005) may make GHG untrue under production-based approach (Lenzen, 1998; Schaeffer and de Sá, 1996; Wyckoff and Roop, 1994). Meanwhile, these problems may be avoided by consumption-based approach to some extent (Wiedmann, 2009). Studies of EET make contributions to analyzing the embodied emissions flow in trade at macro-scale and micro-scale (Druckman and Jackson, 2009; Huimin and Ye, 2010; Kenny and Gray, 2009; Rodrigues et al., 2010; Glen and Solli, 2010; Weber and Matthews, 2008; Yan and Yang, 2010).

Owing to the recognition of significance of intersectoral linkages, the Input-Output Analysis (IOA) is widely used in calculating EET and mainly consists of Single Region Input-Output (SRIO) (Yan and Yang, 2010), Bilateral Trade Input-output (BTIO) (Huimin and Ye, 2010) and Multi-Region Input-Output (MRIO) (Rodrigues et al., 2010; Glen and Solli, 2010). Because MRIO can take interdependencies between foreign sectors with different production technology, resource use and pollution intensities into consideration for embodied emissions flows, MRIO has become the more and more popular method recently (Ahmad and Wyckoff, 2003; Lenzen et al., 2004; Peters and Hertwich, 2006; Wiedmann, 2009).

Embodied carbon, as an integral part of EET, can reveal the influence of trade on environment (Arto and Dietzenbacher, 2014; Baiocchi and Minx, 2010; Hertwich and Peters, 2009; Jakob and Marschinski, 2013; Peters and Hertwich, 2008a). When it comes to the influence of trade on carbon emissions, some studies find that trade not only influences the volumes of GHG and pollutants (Hao and Liu, 2015; Jayadevappa and Chhatre, 2000; Managi et al., 2008; McCarney and Adamowicz, 2005; Nordström and Vaughan, 1999), but also imposes profound impacts on spatial distributions of GHG (Daly and Goodland, 1994). What's more, some studies find that global pollution can decrease due to trade liberation policies (Beladi and Oladi, 2011; Bommer and Schulze, 1999), but others argue that whether or not trade has a beneficial impact on carbon emissions varies depending on the country (Managi et al., 2009). However, it is worth noting that, according to Michael Jakob and Robert Marschinski, to explore the answer to the 'but-for' question (What would global carbon emissions be but for the presence of foreign trade) is by no means trivial (Jakob and Marschinski, 2013). Therefore, it is necessary to consider the spatial-temporal variations of embodied carbon flows and the relation between trade and environment with the absence of trade.

However, four points in the literature need to be noted as follows. (1) Prior studies concentrated more on embodied emissions in trade of one country or a region (Ackerman et al., 2007; Maenpaa and Siikavirta, 2007; Mongelli et al., 2006; Nguyen and Ishihara, 2006; Reinders et al., 2003) rather than systematic analyses of interdependencies of embodied carbon flows at global and regional level. Besides, the time span of most researches is either one year or shorter than the period 1995~2009 and the embodied carbon intensity in trade is not stressed enough in terms of the low-carbonation of international trade, which may not describe the embodied carbon flows well. (2) Most studies focus more on the gaps between production-based embodied carbon and consumption-based embodied carbon than the characters of patterns of inflows and outflows of EET. (3) Most studies about the influence of trade on environment are based on the fact that economies have imports or exports with other economies and they neglect the condition without trade flows. (4) Compared with the use of GATP and other databases, the application of WIOD which provides data about 35 sectors in 41 economies[1] in studying the relationship among trade, embodied carbon and carbon responsibility is relatively not enough.

We make three contributions to the literature: (1) we use the WIOD to improve the applicability of MRIO model exploring spatial-temporal variations of embodied carbon flows and embodied carbon intensity of 41 economies and 35 sectors during the period 1995~2009, (2) we focus on both outflows of emissions embodied in exports (EEE) and inflows of emissions embodied in imports (EEI) for selected economies, (3) according to the rank of the balance of emissions embodied in trade (BEET), we choose the top economy, the median one and the last one to explore the influence of trade on environment at the three different levels in the world by calculating gaps between emissions embodied in trade and carbon emissions without the effects of trade flows.

2. Data and Description

The data source is WIOD (Dietzenbacher et al., 2013; WIOD, 2012), the first public database funded by the European commission. WIOD provides time-series of world input-output tables for 41 economies from 1995 when international trade developed sharply with the establishment of WTO to 2011. These tables have been constructed in a clear conceptual framework on the basis of officially published input-output tables in conjunction with national accounts and international trade statistics. The other main data tables are national input-output tables, socio-economic accounts, and environmental accounts based on the data on energy use, CO_2 emissions and emissions to air at the sector level for 41 economies.

[1] According to the economic statics practice of the Chinese government and international organization such as the United Nations and World Trade Organization, Taiwan (province of China) needs to be listed separately and the data of China does not include that of Taiwan. Besides, 41 economies in WIOD include ROW, the Rest of the World.

In comparison with current data sources, WIOD has some advantages: (1) due to the data collection effort, harmonization procedures were applied to ensure international comparability of the data (Nakano et al., 2009), (2) WIOD includes sectoral price deflators, allowing one to retain important information and the heterogeneity of the sectors with respect to price developments (Nakano et al., 2009).

The data used for the present analysis is as follows. (1) We gain intermediate use and domestic final use for 35 sectors in 41 economies from the world input-output tables for the year 1995~2009 to calculate direct input coefficients and carbon emissions intensities for 41 economies. (2) We get carbon emissions for 41 economies from environmental accounts for the year 1995~2009 to calculate carbon emissions coefficients and carbon emissions intensities for 41 economies. 41 economies and 35 sectors names with codes in WIOD are shown in Table A1 and A2 from Appendix.

3. Model 1 and Results

3.1 Model 1: Embodied carbon emission in trade and its intensity.

By establishing MRIO model based on WIOD, we calculate Emissions embodied in exports (EEE), Emissions embodied in imports (EEI) and the balance of emissions embodied in trade (BEET) for 35 sectors of 41 economies.

$$\boldsymbol{C_s^r} = \boldsymbol{e}(\boldsymbol{I} - \boldsymbol{A})^{-1} \tag{3}$$

Where $\boldsymbol{C_s^r}$ represents the transfer of EET from economy r to economy s and $\boldsymbol{C} = \boldsymbol{C_{rs}}, r = 1 \dots 41, s = 1 \dots 41$. $\boldsymbol{e}^*$ is the matrix of carbon emissions coefficients (i.e. the carbon emissions per unit output) for 35 sectors of 41 economies (1435 sectors) and $\boldsymbol{e} = diag(\boldsymbol{e}^*)$. $\boldsymbol{A}$ is the matrix of production coefficients $\boldsymbol{a_{ij}}$ from sector $\boldsymbol{i}$ to sector $\boldsymbol{j}$ and $\boldsymbol{A} = \boldsymbol{a_{ij}}, i = 1 \dots 1435, j = 1 \dots 1435$. $\boldsymbol{Y}$ is the matrix of final demands $\boldsymbol{Y_{jn}}$ from $\boldsymbol{j}$ to $\boldsymbol{n}$ and $\boldsymbol{Y} = \boldsymbol{Y_{jn}}, j = 1 \dots 1435, n = 1 \dots 41$. $\boldsymbol{I}$ is the unit matrix.

Take economy r with its sector g for example, the emissions embodied in exports (EEE) between economy r and s, the emissions embodied in imports between economy r and s, and the balance of emissions embodied in trade (BEET) between economy r and s are formulated as follows:

$$E_s^r = \sum_{g=1}^{35} C_{gs}^r \tag{4}$$

$$I_s^r = \sum_{g=1}^{35} C_g^s \tag{5}$$

Where E_s^r is the EEE generated by r to satisfy the needs of s, and C_{gs}^r is the carbon emission produced by r's sector g to satisfy its needs. I_s^r is the EEI generated by r to satisfy the needs of s, C_g^s is the carbon emission produced by s to satisfy r's sector g.

Then the total emissions embodied in exports of r (i.e.E^r), the total emissions embodied in imports of r (i.e.I^r) and the total balance of emissions embodied emissions in trade (i.e. B^r) of p are shown as follows, respectively:

$$E^r = \sum_{s=1}^{40} E_s^r - \sum_{g=1}^{35} C_{gr}^r \tag{6}$$

$$I^r = \sum_{s=1}^{40} I_s^r - \sum_{g=1}^{35} C_{gr}^r \tag{7}$$

$$B^r = E^r - I^r \tag{8}$$

Where C_{gr}^r is the carbon emission produced by r to satisfy its needs.

We introduce two concepts—embodied carbon intensity in export trade and embodied carbon intensity in import trade—to illustrate the relationship between volume of trade and embodied emissions in trade.

Embodied carbon intensity in export trade is the amounts of embodied carbon in export trade caused by the unit volume of export trade. Embodied carbon intensity in import trade is the amounts of embodied carbon in import trade caused by the unit volume of import trade. When it comes to the changing trends of embodied carbon intensity in trade, final demands from 1995 to 2009 in world input-output tables in basic prices are important to calculate the volume of trade but the final demands for these 15 years are expressed in current prices. In this paper, we use gross output price index which is expressed in basic 1995 prices and convert them to million US$ (2005) based on Purchasing Power Parity (PPP) to gain the results of the final demands (1995~2009) in basic prices. The formulas for the volume of exports and imports are shown as follows:

$$Fcon_{ex}^{r} = \sum_{s \neq r} \sum_{i=1}^{35} Fcon_{i}^{rs} = \sum_{s \neq r} \frac{Y_{i}^{rs}}{EXR^{r} \times GOP_{j}^{r} / EXR_{05}^{r}} \tag{1}$$

$$Fcon_{im}^{r} = \sum_{s \neq r} \sum_{j=1}^{35} Fcon_{j}^{sr} = \sum_{s \neq r} \frac{Y_{j}^{sr}}{EXR^{s} \times GOP_{i}^{s} / EXR_{05}^{s}} \tag{2}$$

where $Fcon_{ex}^{r}$ is the total volume of exports and $Fcon_{im}^{r}$ the total volume of imports of economy *r* in basic 2005 price. $Fcon_{i}^{rs}$ is the volume of exports from economy *r* to sector *i* of economy *s* and $Fcon_{j}^{sr}$ is the volume of imports from *r* to sector *j* of *s*. $Y_{\mathrm{i}}^{\mathrm{rs}}$ is the final demands of *r* to satisfy the sector i of *s* and Y_{j}^{sr} those of *s* to the sector j of *r*. EXR^{r} is the exchange rate of *r* against US$ and EXR_{05}^{r} is EXR^{r} in 2005. EXR^{s} is the exchange rate of *s* against US$ and EXR_{05}^{s} is EXR^{s} in 2005. GOP_{j}^{r} is the gross output price index of sector *j* of *r* and GOP_{i}^{s} that of sector *i* of *s*.

3.2 Results from Model 1

3.2.1 Analysis for embodied carbon emission

Embodied carbon in global trade, on the whole, has increased at about 3% per year, leading to the underlying transfer of carbon emissions, and the change of embodied carbon has the time-independent influence on that of carbon emissions. As shown in Figure 3.1, Global EET increased from 40.42 GtCO_2 in 1995 to 72.4 GtCO_2 in 2008 with a fluctuation in growth in spite of the decrease in 2009 (about 61.49 Gt CO_2) due to the influence of global financial crisis. Additionally, the ratio of global embodied carbon to carbon emissions has maintained at about 25%, that is to say, the changing trends of global embodied carbon is in consistence with those of carbon emissions.

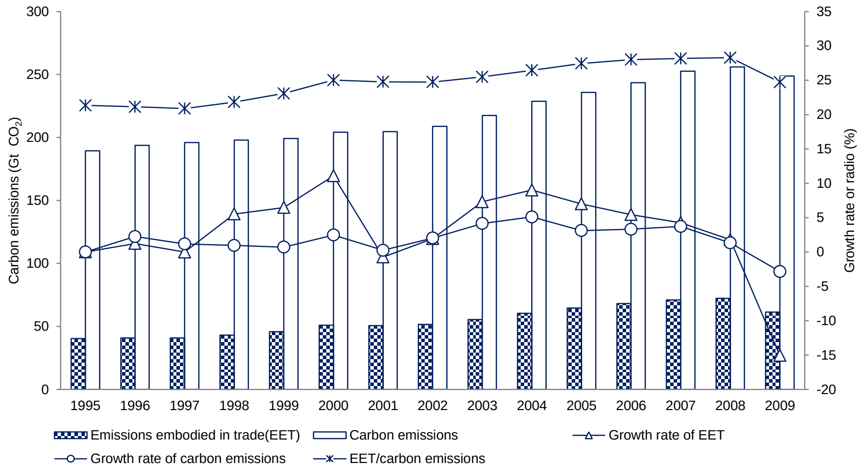
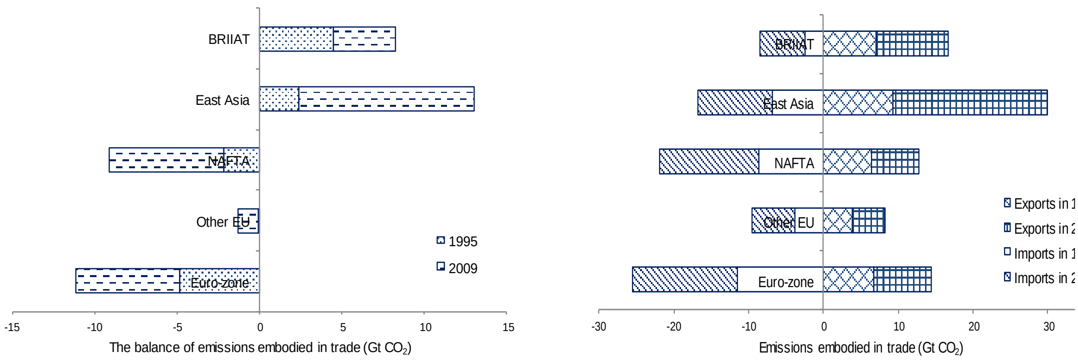


FIGURE 1. Emissions embodied in trade and carbon emissions from 1995 to 2009

We divide the 40 economies into 5 trade areas including Euro-zone, Other EU, NAFTA, East Asia and BRIIAT in line with the clarification of trade areas in WIOD. The larger differences of the balance of embodied emissions in trade (BEET) exist within these trade areas. EURO, other EU and NAFTA were the net importers of embodied emissions while East Asia and BRIIAT were the net exporters of embodied emissions. Additionally, East Asia has undertaken more and more embodied emissions in trade. In detail, EURO's negative BEET increased from (-4.8) GT CO_2 in 1995 to (-6.3) GT CO_2 in 2009, Other EU from (-0.1) GT CO_2 in 1995 to (-1.3) GT CO_2 in 2009 and NAFTA from (-2.2) GT CO_2 in 1995 to (-6.9) GT CO_2. On the contrary, East Asia owned an increase of positive BEET between 2.4 GT CO_2 in 1995 and 10.6 GT CO_2 in 2009 and BRIIAT a decrease of positive BEET between 4.5 GT CO_2 in 1995 and 3.8 GT CO_2 (Figure 2 (a).). Additionally, East Asia has become the only trade area to undertake the net increase of BEET compared with the other four trade areas. More details about BEET such as the regional embodied carbon in export and import can be obtained from Figure 2(b).



(a) The balance of emissions embodied in trade **(b) Embodied emissions in trade**

FIGURE 2. Embodied carbon in trade for selected trade areas, 1995 and 2009

Note: In order to distinguish the embodied carbon in export from that in import obviously, we make the positive values of the embodied carbon in import negative.

Sectoral embodied carbon in export trade preferred energy-intensive sectors; economies with better or more rapid development were prone to influence the sectoral embodied carbon in export trade. Specially, the top five sectors in the amounts of embodied emissions in exports in 2009 were Electricity, gas and water Supply (E), Basic materials and Fabricated metal (27t28), Chemicals and chemical products (24), Mining and quarrying (C), and Coke, refined petroleum and nuclear fuel (23). It is obvious to see that G8 (Canada, Germany, The United Kingdom, France, Japan, Russia and America) and China owned the larger percent of sectoral embodied carbon to the total sectoral embodied carbon, particularly for these economies' sector—E and 27t28—whose radio (i.e. the radio of embodied emissions to global emissions) is over 60% (Figure 3). Among the top 5 sectors, the proportion of sectoral embodied carbon in the export trade of China (above 20%) and that of Russia (about 10%) account for the top 2 largest percentage according to their amounts of sectoral embodied carbon on average (Figure 3.).

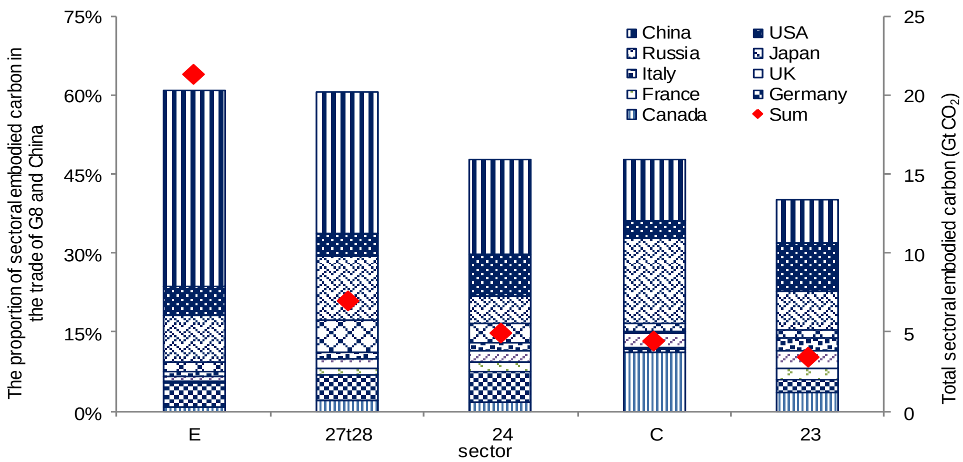


FIGURE 3. The proportion of sectoral embodied carbon in exports of G8 and China in 2009

Note: The total sectoral embodied emissions refer to those of selected sectors in Figure3.

In terms of sectoral embodied carbon in exports of trade areas, no matter how developed these trade areas are, the embodied carbon in exports focused mainly on both the energy-intensive sectors such as E, 27t28, C, 23, 24 and 26, and transport sectors like 60 and 61. In addition, the amounts of embodied carbon in exports of E were larger than those of other sectors, which was more significant in East Asia. Considering the changing trends of sectoral embodied emissions in exports of these trade areas, as we can see from the Table 1, the increases of secoral embodied emissions in exports of EURO, other EU and NAFTA were small and some sectors even experienced the decreasing trend. On the contrary, the sectoral embodied emissions in exports of East Asia and BRIIAT were good at the amounts and the increasing rates in comparison with these of the other trade areas. Particularly, the sectoral embodied carbon in the exports of East Asia has increased to 9.5Gt CO_2 in 2009, surpassing those of the other trade areas, which may be much relevant to its export structure preferring the carbon-intensive products or service.

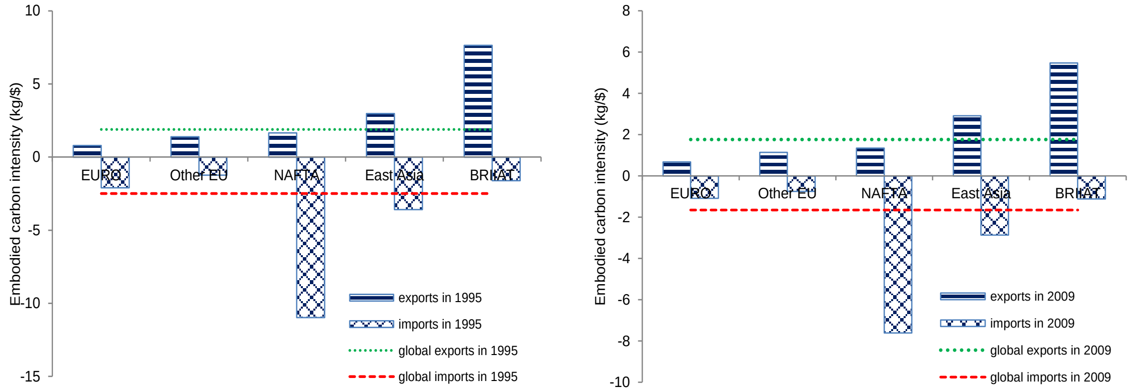
Table 1. The top 5 sectors in sectoral embodied carbon in export, 1995 and 2009

Sector	Sectoral embodied carbon in exports ($Gt\ CO_2$)		Sector	Sectoral embodied carbon in exports ($Gt\ CO_2$)	
	1995	2009		1995	2009
EURO			***Other EU***		
E	1.4	2.0	E	1.1	1.1
27t28	1.1	0.9	27t28	0.6	0.4
24	0.8	0.8	24	0.3	0.3
26	0.6	0.6	61	0.3	0.6
23	0.4	0.6	26	0.2	0.2
NAFTA			***East Asia***		
E	1.4	1.5	E	2.7	9.5
27t28	0.7	0.5	27t28	1.5	2.9
C	0.6	0.8	24	0.9	1.3
24	0.5	0.5	26	0.7	1.2
23	0.4	0.5	61	0.7	1.6
BRIIAT					
E	2.8	3.6			
27t28	1.2	1.6			
C	0.9	1.6			
60	0.5	0.7			
26	0.3	0.4			

3.2.2 Analysis for embodied carbon intensity

After the establishment of WTO, global embodied carbon intensity (i.e. the embodied carbon per volume of trade in Year 2005 price) was time-dependent, which shows that despite the increase of the volume of trade and embodied emissions in trade, the global trade structure has not taken on the carbon-intensive tendency. On the whole, embodied carbon intensity in the exports of the world (i.e. 41 economies in this paper) maintained at about 1.88 kg/$, and that in 41 economies' import trade at about 2.19 kg/$ (Figure 4).

Among the five trade areas (i.e. EURO, other EU, NAFTA, East Asia and BRIIAT), embodied carbon intensities in the exports of BRIIAT and East Asia were high with an evident increase. On the other hand, embodied carbon intensities in the imports of NAFTA and East Asia were high without a significant increase. In details, the embodied carbon intensities in the exports for EURO, other EU and NAFTA were lower than that for the world in 1995 and almost unchangeable in 2009 while the embodied carbon intensities for East Asia and BRIIAT were higher than that for the world in 1995 and continued to increase in 2009, which means that the export trade structure was more carbon-intensive. What's more, only the embodied carbon in the imports for NAFTA and East Asia was higher than that for the world, reflecting that the import trade structure of NAFTA and East Asia remained carbon-intensive. Last but not least, it was valuable to know that BRIIAT continued to be the largest embodied carbon intensity in its exports (about 7.35 kg/$) and NAFTA the largest embodied carbon intensity in its imports (about 10.32 kg/$), which shows that the United States and Canada have imported lots of carbon-intensive products and service, transferring the carbon emissions to other countries and regions.



(a) Embodied carbon intensity in 1995 **(b) Embodied carbon intensity in 2009**

FIGURE 4. Embodied carbon intensity in exports and imports, 1995 and 2009

Note: In order to distinguish embodied carbon intensity in exports from that in imports evidently, we make the positive values of embodied carbon intensity in imports negative.

When considering the embodied carbon intensity in exports, this paper selects the top five sectors according to the rank of amounts of embodied emissions in trade. Among these five sectors, electricity, gas and water supply sector (E) in every trade area had the largest embodied carbon intensity amid the other sectors, which was more obvious in East Asia and BRIIAT. What's more, only East Asia's E experienced the increase of embodied carbon intensity in exports, showing E's embodied carbon in exports was mostly linked with its high carbon-intensive character. In addition, compared with the Table 1, Table 2 depicts that the rank according to the amounts of sectoral embodied carbon in exports was not in accord with that according to the sectoral embodied carbon intensity in exports, which means that the amounts of embodied carbon in the exports of energy-intensive sectors and transport sectors were not only based on these sectors' carbon-intensive degree but also determined by their volume of trade.

Table 2. The sectoral embodied carbon intensity in regional export trade, 1995 and 2009

Sector	Sectoral embodied carbon intensity (kg/$)		Sector	Sectoral embodied carbon intensity (kg/$)	
	1995	2009		1995	2009
EURO			***Other EU***		
E	67.9	39.0	E	149.0	84.4
27t28	5.4	4.8	27t28	12.9	8.1
24	1.7	0.6	24	1.4	0.7
26	16.3	23.1	61	7.1	53.8
23	1.7	1.4	26	11.9	18.6
NAFTA			***East Asia***		
E	335.3	203.9	E	1140.6	3600.0

27t28	10.3	6.6	27t28	12.7	21.5
C	32.7	30.3	24	11.5	7.0
24	3.7	1.6	26	28.6	48.7
23	4.4	3.9	61	9.0	30.4
BRIIAT					
E	1605.2	1115.1			
27t28	150.6	43.3			
C	24.0	141.3			
60	18.0	33.3			
26	84.0	61.0			

3.2.3 Analysis for the outflows and inflows of emissions embodied in trade

After ranking the balance of emissions embodied in trade (BEET) among 40 economies (excluding ROW), China, Korea, Taiwan, India, Indonesia, Russia, Canada and Poland have been the top 5 of BEET and most economies were in East Asia and BARIIAT. On the contrary, most countries in NAFTA and Euro-zone such as The United States, The United Kingdom, France, Germany and Italy have been the last 5 of BEET for the period from 1995 to 2009. Besides, some exceptions such as Japan which has been the last 5 of BEET occurred in the same duration.

With the development of international trade for 15 years, the economies above have formed the time-independent outflow patterns of EEE and inflow patterns of EEI (Table 3 and 4.).

The outflow patterns of EEE were neighbor-centered. EEE in these economies mostly flowed with the inclination of choosing their neighbors as the importers of their EEE. In detail, EEE in China flowed towards Asia and USA, those in Taiwan towards East Asia, UK, Germany and USA, those in Russia and India towards Europe, Japan and USA, those in Indonesia towards East Asia, Germany and USA , those in Canada towards USA, and those in Poland towards Europe (Table 3).

The inflow patterns of EEI were country-centered. It is easy to realize the fact that China and Russia have been the main source of these economies' EEI, which means their real carbon emissions have been distorted by production-based approach to accounting emissions. What's more, EEI in these economies preferred coming from their neighbors. In detail, the inflows of USA's EEI focused on China and Canada, those of Japan's EEI on its neighbors and USA, China and India, those of Germany's EEI on its neighbors, China, Russia and USA, those of France's EEI on its neighbors, China, Russia and USA, and those of UK's EEI on its neighbors, China, Russia and USA (Table 4).

Table 3. The percentage for outflows of EEE for selected economies (%)

Destination / Source		East Asia			Euro-zone			NAFTA	BRIIAT	Other EU
		JPN	KOR	CHN	DEU	ITA	FRA	USA	RUS	UK
CHN	1995	17	3	-	7	-	-	27	-	4

	2009	9	3		6			24	-	3
IDN	1995	14	-	-	9	4	-	21	-	6
	2009	3	-	-	5	2	-	21	-	5
KOR	1995	21	-	8	4	-	-	20	-	2
	2009	7	-	19	4	-	-	13	-	2
RUS	1995	6	-	-	18	8	7	8	-	-
	2009	4	-	-	7	7	5	9	-	-
TWN	1995	21	-	9	4	-	-	27	-	3
	2009	15	-	19	5	-	-	16	-	2
IND	1995	32	5	4	4	-	-	16	-	-
	2009	13	4	10	4	-	-	13	-	-
CAN	1995	10	-	2	4	-	-	54	-	3
	2009	3	-	6	4	-	-	53	-	4
POL	1995	-	-	-	31	5	5	6	6	-
	2009	-	-	-	18	6	6	4	5	-

Table 4. The percentage for inflows of EEI for selected economies (%)

Source / Destination		East Asia				Euro-zone			NAFTA			BRIIAT	Other EU	
		CHN	JPN	KOR	TWN	NET	DEU	FRA	USA	CAN	MEX	RUS	POL	UK
USA	1995	22	4	-	-	-	-	-	-	12	5	5	-	-
	2009	33	3	-	-	-	-	-	-	8	4	4	-	-
DEU	1995	-	-	-	-	4	-	-	6	10	-	20	7	-
	2009	-	-	-	-	4	-	-	5	22	-	9	4	
FRA	1995	8	-	-	-	-	8	-	8	-	-	16	-	6
	2009	18	-	-	-	-	7	-	6	-	-	10	-	3
UK	1995	13	-	-	-	4	7	-	11	-	-	6	-	-
	2009	20	-	-	-	4	6	-	8	-	-	6	-	-
JPN	1995	25	-	5	4	-	-	-	13	-	-	6	-	-
	2009	35	-	4	7	-	-	-	7	-	-	5	-	-
ITA	1995	8	-	-	-	-	7	5	6	-	-	21	-	-
	2009	15	-	-	-	-	7	3	4	-	-	16	-	-

China and USA have had significant influences on embodied carbon of their trade partners based on the discussion above. The sectors producing EEE in China were in accordance with those consuming EEI in USA to a large extent. Among the sectors producing EEE in China, energy-intensive sectors such as E, 27t28, 26 and 24 were the main sectors which owned the larger amount of EEE. Besides, E, 27t28, 61 and 62 were the sectors that grew faster owing to the gaps between EEE in 1995 and that in 2009. As for the sectors consuming EEI in USA, energy-intensive sectors like E, 27t28, C, 24, 26 and 23 were the primary sectors that had the greater amount of EEI. In addition, E and C experienced the increasing growth in EEI due to the gaps between EEI in 1995 and that by 2009 (Figure 5.).

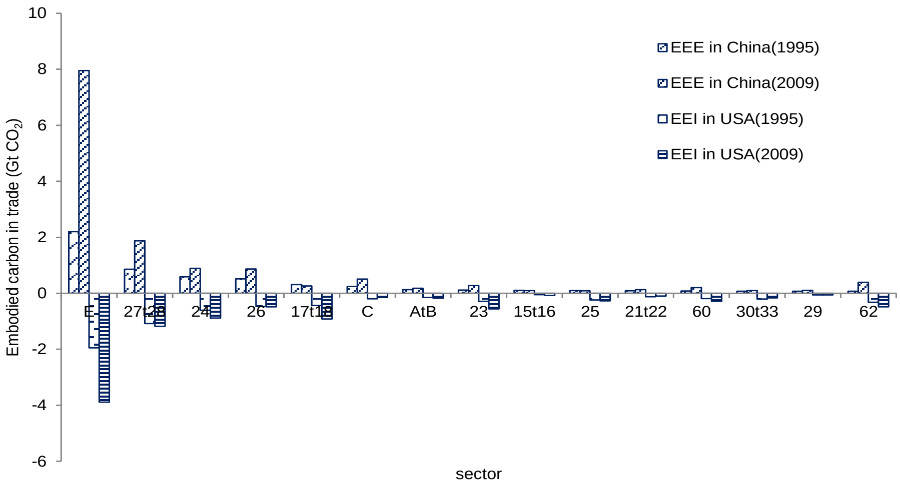


Figure 5. The sectoral embodied carbon in China's export trade and in USA's import trade

Note: In order to distinguish embodied carbon in exports from that in imports apparently, we make the positive values of embodied carbon in imports negative.

4. Model 2 and Results

4.1 Model 2: Gaps between embodied carbon and carbon emissions without trade flows

According to Yan Yunfeng and Yang Laike, they considered the influence of China's foreign trade on carbon emissions of the rest of world but neglected the difference of carbon coefficients of economies in the rest of world (Yan and Yang, 2010). Therefore, we improve their method to study the influence of trade including exports and imports on environment. At first, we introduce a new concept, namely carbon burden. Carbon burden is under the Production-based approach to accounting emissions, the gap between embodied carbon in one economy's trade and carbon emissions which are generated if the economy satisfies its needs for its import or the economy's trade partners satisfy their needs for the economy's exports. One economy's positive carbon burden represents the inflow of carbon burden, which can be divided into two aspects: one is that embodied carbon in one economy's export is more than the economy's trade partners' carbon emission which is generated if the economy's trade partners satisfy their needs for the economy's export; the other is that embodied carbon in one economy's import is less than one economy's carbon emission which is generated if the economy satisfies its needs for its import. So does one economy's negative carbon burden. Then, take the bilateral trade as an example to show our improvements as follows (Table 5.).

Table 5. Carbon burden for bilateral trade

	Export	Import
Total output		

	Export	Import
(1) carbon emissions with r's trade	X^{rs}	X^{sr}
(2) carbon emissions without r's trade	X^{rs}	X^{sr}
Carbon emission coefficient		
(1) carbon emissions with r's trade	e^{r}	e^{s}
(2) carbon emissions without r's trade	e^{s}	e^{r}
Carbon burden		
carbon burden ≥ 0	Inflow of carbon burden	Outflow of carbon burden
carbon burden < 0	Outflow of carbon burden	Inflow of carbon burden

Note: ***r*** and ***s*** represent two economies among the 41 economies we study in this paper. The situation (1), namely carbon emissions with r's trade, is the situation where the real trade occurs among economies. The situation (2), namely carbon emissions without r's trade, is the situation where carbon emissions which are generated when the economies satisfies its needs for its imports or the economy's trade partners satisfy their needs for their exports.

Then, we apply our improvements in Table 4 to the situation where one economy conducts the multiply trade as follows.

When it comes to effects of one economy *r*'s exports on carbon emissions, we introduce $\boldsymbol{EC}$ to represent 40 economies' carbon emissions which are generated when they satisfy their needs for their exports from *r* and build a model by substituting carbon emissions intensities of 40 economies for those of *r* as follows.

$$\boldsymbol{EC}^{*} = \boldsymbol{e_o X} \quad (9)$$

Where $\boldsymbol{e_o} = \boldsymbol{e_{nj}}, \mathrm{n} = 1 \dots 40, \mathrm{j} = 1 \dots 35.$ and $\boldsymbol{e_o}$ is the matrix of carbon emissions coefficients of 35 sectors in 40 economies. $\boldsymbol{X} = \boldsymbol{X_n^j}, j = 1 \dots 35, n = 1 \dots 40.$ and $\boldsymbol{X}$ stands for total output of *r*'s sector $\boldsymbol{j}$ to 40 economies. In order to remove the influence of time on the technical development and difference of different economies' technologies, we apply the carbon emission coefficients in 1995 prices as the same carbon emission coefficients from 1995 to 2009. Then we make the carbon emission coefficients in 1995 prices expressed in the basic 2009 prices to remove the effects of price.

Besides, $\boldsymbol{EC}^{*}$ is not the ultimate matrix for carbon emissions of 40 economies without *r*'s exports, and the final result (i.e.$\boldsymbol{EC}$) is the diagonal elements of $\boldsymbol{EC}^{*}$**.**

Then we can get *r*'s carbon burden in exports:

$$GE_s^r = E_s^r - EC_s^r \quad (10)$$

As for impacts of *r*'s imports on carbon emissions, we introduce $\boldsymbol{IC}$ to stand for *r*'s carbon emission which is generated if *r* satisfies its needs for its import. Therefore, we establish a model replacing carbon emissions intensities of 40 economies with those of *r*. Similarly, to remove the influence of time on the technical development and difference of different economies' technologies, we apply the carbon emission coefficients in 1995 prices as the same carbon emission coefficients from 1995 to 2009. Then we make the carbon emission coefficients in 1995 prices expressed in the basic 2009 prices to remove the effects of price.

$$\boldsymbol{IC} = \boldsymbol{e_r M} \quad (11)$$

Where $\boldsymbol{e_r}$ is the row matrix of carbon emissions coefficients of 35 sectors in $\boldsymbol{r}$ and $\boldsymbol{e_r} = e_j, j = 1 \dots .35.$ $\boldsymbol{M}$ is the matrix of total output of *r*'s sector *j* from economy *n* and $\boldsymbol{M} = \boldsymbol{X_j^n}, n = 1 \dots 40, j = 1 \dots 35.$

Then we can get *r*'s carbon burden in imports:

$$GI_s^r = I_s^r - IC_s^r \quad (12)$$

4.2 Results from Model 2

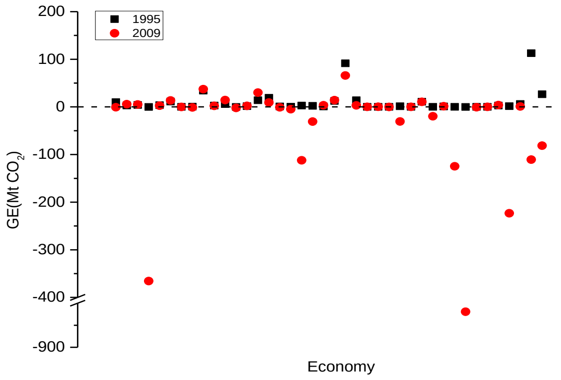
According to the rank of BEET, China is the top economy, USA the last one and Finland the one whose BEET is near the average for most times during the period 1995~2009. Therefore, we choose China, USA and Finland to stand for the two extreme conditions and the mean condition, respectively.

In terms of the total amounts of carbon burden, the outflows of carbon burden caused by China's exports (i.e. the outflows of China's GE) were the largest and the inflows of carbon burden caused by USA's import (i.e. the inflows of USA's GI) were the largest, which means that China's carbon reduction has benefited most from its export trade and USA's carbon reduction has benefited least from its import trade. Comparing the carbon burden in exports in 1995 with that in 2009, we can find that China's carbon burden and USA's carbon burden turned positive into negative, reflecting that China and USA have lowered their carbon burden in their exports. On the contrary, the carbon burdens in USA's import and Finland's import were positive in 1995 and negative in 2009, which means that USA and Finland have increased their carbon burden in their imports (Table 6).

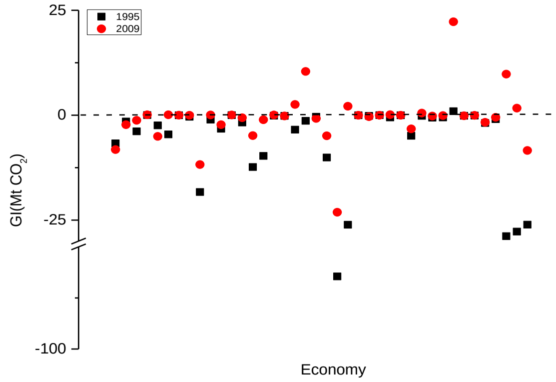
Table 6. Total carbon burden for exports and imports in China, USA and Finland

Economies	GE (Mt CO_2)		GI (Mt CO_2)	
	1995	2009	1995	2009
CHN	397.5	-1704.4	-281.5	-31.5
USA	198.69	-536.1	83.7	-830.1
Finland	-36.9	-103.7	12.3	4.16

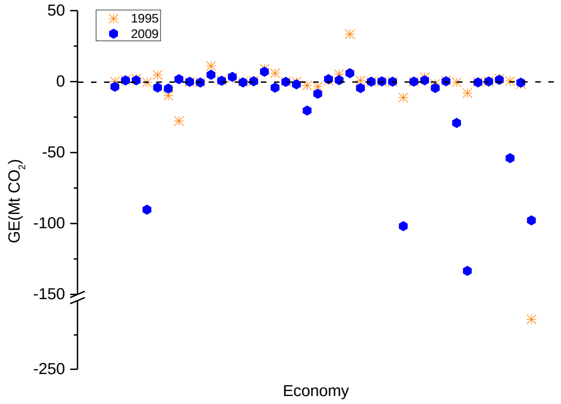
In consideration of every economy trading including importing and exporting with China, USA or Finland, most economies made the outflows of carbon burdens in the three economies' exports increase and the numbers of this kind of economy were increasing, which can be illustrated from the increasing numbers of points below the zero value in Figure 6(a), (c) and (f). As for the imports in China, USA and Finland, their carbon burdens varied a lot. In detail, most economies made the inflows of carbon burdens in the USA' exports increase and the numbers of this kind of economy were increasing, seen from the increasing numbers of points below the zero value in Figure 6 (d). Then the economies making carbon burden caused by China's import go up in 2009 were less than those in 1995, shown from the increasing numbers of points above the zero value in the Figure 6 (b). Finally, more economies making the inflows of carbon burden caused by Finland's import stable in 2009 compared with those in 1995, according to the increasing numbers of points maintaining around the zero value in Figure 6 (f).



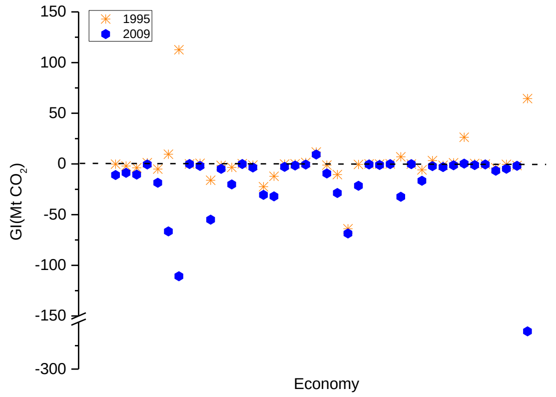
(a) China's GE



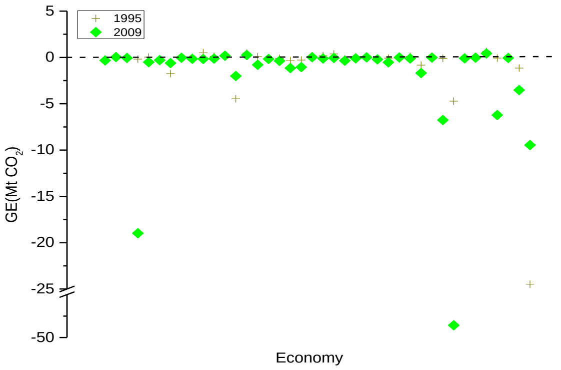
(b) China's GI



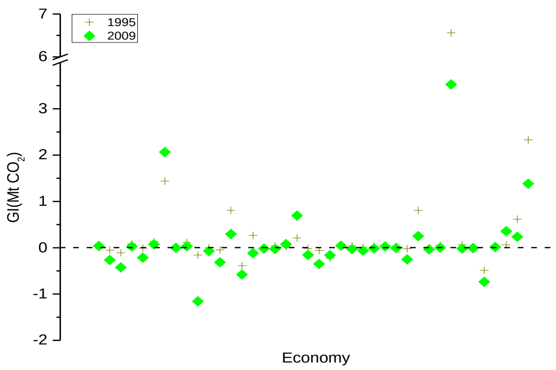
(c) USA's GE



(d) USA's GI



(e) Finland's GE



(f) Finland's GI

FIGURE 6. Carbon burdens for exports (GE) and imports (GI) in China, USA and Finland

5. Conclusions

According to MRIO model, this paper analyzes embodied carbon flows in 41 economies and 35 sectors during 1995 ~ 2009 at global and regional level, sheds light on the inflows of EEI and outflows of EEE, and studies the impacts of trade on environment of China, USA and Finland in terms of gaps between embodied carbon and carbon emissions without trade flows.

Our contributions and findings are as follows:

Firstly, we provide an overview of embodied carbon with a geographical and temporal focus based on WIOD. At global level, international trade has a persistent impact on the volumes of carbon emissions, which leads to the underlying transfer of carbon emissions. The differences of balances of emissions embodied in trade were more obvious: EURO, other EU and NAFTA were the net importers of embodied carbon while East Asia and BRIIAT were the net exporters of embodied carbon. The fact that East Asia was the only one economy experiencing the net increase of balances of emissions embodied in trade shows that specification of international trade has urged East Asia to undertake more and more carbon emissions. At the sectoral level, the embodied carbon has focused more on the energy-intensive sectors whose amounts of embodied carbon were apt to be profoundly influenced by the economies with good or rapid development. In addition, in terms of the regional embodied carbon, no matter how developed the trade areas are, the embodied carbon in exports concentrated more on the energy sectors and transports sectors. Furthermore, the sector for electricity, gas and water supply (E) has the largest amounts of embodied carbon among other sectors, which was more evident in East Asia.

Secondly, we analyzed the spatial-temporal trends of embodied carbon intensity based on WIOD. On one hand, at the global and regional level, after the establishment of WTO, global embodied carbon intensity has maintained its level, which shows that despite the increase of volumes of trade as well as embodied carbon, global trade structure has not taken on the carbon-intensive tendency obviously. The embodied carbon intensities in exports of BRIIAT and East Asia were much higher in 2009 compared with those in 1995 and the embodied carbon intensity in the imports of NAFTA and East Asia experienced the same trends. Moreover, the embodied carbon intensity in the exports of BRIIAT was the largest and the embodied carbon intensity in the imports of NAFTA the largest, which means that USA and Canada have imported many carbon-intensive products and service with the transfer of carbon emissions to other countries and regions. On the other hand, at the sectoral level, as for the top 5 sectors according the rank of the amounts of embodied carbon in exports, the sector for electricity, gas and water supply (E) in every trade area has the largest embodied carbon intensity in exports among the other sectors, which was more obvious in East Asia. Additionally, all trade areas except East Asia have experienced the declining trend of embodied carbon intensity in the exports of E.

Thirdly, we classify the inflows of EEI and outflows of EEE for selected economies. According to the ranks of BEET among 40 economies, we got the economies which have been the top five and the last five of BEET from 1995 to 2009. We figure out that the economies above have formed the neighbor-centered outflow patterns of EEE and the country-centered inflow patterns of EEI. Besides, the major sectors producing EEE in China were in accordance with those consuming EEI in USA to a large extent in 2009.

Finally, we review impacts of global trade on its environment. This paper selects China, USA and Finland as the representatives of the three different levels of balances of embodied carbon. On the whole, we figure that China has the largest outflow of carbon burden in its exports, followed by USA and Finland. Then USA has the largest inflow of carbon burden in its imports, followed by China and Finland. The two findings shows that among China, USA and Finland, China's export has added most carbon burden to China and USA's import has imposed most carbon burden on USA. In detail, the numbers of economies causing the increase of carbon burden in the exports of China, USA and Finland, on general, are growing up, which shows that the numbers of these economies existed more evenly. As for the imports of China, USA and Finland, we find that the numbers of economies making the carbon burden of the imports of USA increase were growing up, those making the carbon burden of the imports of China increase were coming down, and those making the carbon burden of the imports of Finland balance around the zero value were increasing.

Acknowledgment

We thank the financial supports from the "Strategic Priority Research Program" of the Chinese Academy of Sciences (No. XDA05150600), National Natural Science Foundation of China (No. 71322306 and 71273027), Program for New Century Excellent Talents in University of Ministry of Education of China (No. NCET-13-0040), and Program for Excellent Young Talents in Universities of Beijing (No. YETP1181). We are grateful to Prof. Zhu Sun and Dr. Jingli Fan for their comments and constructive suggestions. The views expressed in this paper are solely authors' own and do not necessarily reflect the views of the supporting agencies and Beijing Institute of Technology.

References

Ackerman, F., Ishikawa, M., Suga, M., (2007). The carbon content of Japan-US trade. Energy Policy 35(9): 4455-4462.

Ahmad, N., Wyckoff, A., (2003). Carbon dioxide emissions embodied in international trade of goods. OECD Publishing, Paris. DOI : 10.1787/18151965.

Aldy, J. E. (2005). An environmental Kuznets curve analysis of US state-level carbon dioxide emissions. Journal of Environment & Development, 14(1): 48-72.

Arto, I., Dietzenbacher, E., (2014). Drivers of the growth in global greenhouse gas emissions. Environmental Science & Technology 48 (10): 5388–5394.

Baiocchi, G., Minx, J.C., (2010). Understanding changes in the UK's CO_2 emissions: a global perspective. Environmental Science & Technology 44(4): 1177-1184.

Beladi, H., Oladi, R., (2011). Does trade liberalization increase global pollution? Resource and Energy Economics 33(1): 172-178.

Bommer, R., Schulze, G.G., (1999). Environmental improvement with trade liberalization. European Journal of Political Economy 15(4): 639-661.

Daly, H., Goodland, R., (1994). An Ecological-Economic Assessment Of Deregulation Of International Commerce under Gatt. Ecological Economics 9(1): 73-92.

Dietzenbacher, E., Los, B., Stehrer, R., Timmer, M.P., de Vries, G.J., (2013). The Construction of World Input-Output Tables in the WIOD Project. Economic Systems Research 25(1): 71-98.

Druckman, A., Jackson, T., (2009). The carbon footprint of UK households 1990-2004: A socio-economically disaggregated, quasi-multi-regional input-output model. Ecological Economics 68(7): 2066-2077.

Hao, Y., Liu, Y.M., (2015). Has the development of FDI and foreign trade contributed to China's CO_2 emissions? An empirical study with provincial panel data. Natural Hazards 76(2): 1079-1092.

Hertwich, E.G., Peters, G.P., (2009). Carbon footprint of nations: a global, trade-linked analysis. Environmental Science & Technology 43(16): 6414-6420.

Huimin, L., Ye, Q., (2010). Carbon embodied in international trade of China and its emission responsibility. Chinese Journal of Population Resources and Environment 8(2): 24-31.

Jakob, M., Marschinski, R., (2013). Interpreting trade-related CO_2 emission transfers. Nature Climate

Change 3(1): 19-23.
Jayadevappa, R., Chhatre, S., (2000). International trade and environmental quality: a survey. Ecological Economics 32(2): 175-194.
Kenny, T., Gray, N.F., (2009). A preliminary survey of household and personal carbon dioxide emissions in Ireland. Environment International 35(2): 259-272.
Lenzen, M., (1998). Primary energy and greenhouse gases embodied in Australian final consumption: an input-output analysis. Energy Policy 26(6): 495-506.
Lenzen, M., Pade, L. L., Munksgaard, J., (2004). CO_2 multipliers in multi-region input-output models. Economic Systems Research 16(4): 391-412.
Maenpaa, M., Siikavirta, H., (2007). Greenhouse gases embodied in the international trade and final consumption of Finland: An input-output analysis. Energy Policy 35(1): 128-143.
Managi, S., Hibiki, A., Tsurumi, T., (2008). Does trade liberalization reduce pollution emissions. Discussion papers 8013, Research Institute of Economy, Trade and Industry, Japan. http://www.rieti.go.jp/jp/publications/dp/08e013.pdf
Managi, S., Hibiki, A., Tsurumi, T., (2009). Does trade openness improve environmental quality? Journal of Environmental Economics and Management 58(3): 346-363.
McCarney, G.R., Adamowicz, W.L., (2005). The effects of trade liberalization on the environment: an empirical study, Annual Meeting, July 6-8, 2005, San Francisco, CA. Canadian Agricultural Economics Society. http://purl.umn.edu/34157
Mongelli, I., Tassielli, G., Notarnicola, B., (2006). Global warming agreements, international trade and energy/carbon embodiments: an input-output approach to the Italian case. Energy Policy 34(1): 88-100
Nakano, S., Okamura, A., Sakurai, N., Suzuki, M., Tojo, Y., Yamano, N., (2009). The measurement of CO_2 embodiments in international trade: Evidence from the harmonised input-output and bilateral trade database. OECD Publishing, Paris. DOI : 10.1787/18151965.
Nguyen, T.A.T., Ishihara, K.N., (2006). Analysis of changing hidden energy flow in Vietnam. Energy Policy 34(14): 1883-1888.
Nordström, H., Vaughan, S., (1999). Trade and environment. Special Studies 4. World Trade Organization, Geneva.
Peters, G., (2008a). Reassessing carbon leakage, 11th Annual Conference on Global Economic Analysis, Helsinki, Finland.
Peters, G.P., (2008b). From production-based to consumption-based national emission inventories. Ecological Economics 65(1): 13-23.
Peters, G.P., Hertwich, E.G., (2006). Pollution embodied in trade: The Norwegian case. Global Environmental Change 16(4): 379-387.
Peters, G.P., Hertwich, E.G., (2008a). CO_2 embodied in international trade with implications for global climate policy. Environmental Science & Technology 42(5): 1401-1407.
Peters, G.P., Hertwich, E.G., (2008b). Trading Kyoto. Nature Reports Climate Change 2(0804): 40-41. doi:10.1038/climate.2008.25
Reinders, A.H.M.E., Vringer, K., Blok, K., (2003). The direct and indirect energy requirement of households in the European Union. Energy Policy 31(2): 139-153.
Rodrigues, J.F., Domingos, T.M., Marques, A.P., (2010). Carbon responsibility and embodied emissions: theory and measurement. Routledge, Taylor & Francis.
Schaeffer, R., de Sá, A., (1996). The embodiment of carbon associated with Brazilian imports and exports. Energy Conversion and Management 37(6): 955-960.
Glen, P., Solli, C., (2010). Global carbon footprints: Methods and import/export corrected results from the Nordic countries in global carbon footprint studies. TemaNord 2010:592. Nordic Council of Ministers.

Copenhagen, Denmark.

Weber, C.L., Matthews, H.S., (2008). Quantifying the global and distributional aspects of American household carbon footprint. Ecological Economics 66(2-3): 379-391.

Wiedmann, T., (2009). A review of recent multi-region input–output models used for consumption-based emission and resource accounting. Ecological Economics 69(2): 211-222.

WIOD, (2012). World Input-Output Database: Construction and Applications, FP7-founded project. Http://www.wiod.org/.

Wyckoff, A.W., Roop, J.M., (1994). The embodiment of carbon in imports of manufactured products: Implications for international agreements on greenhouse gas emissions. Energy Policy 22(3): 187-194.

Yan, Y.F., Yang, L.K., (2010). China's foreign trade and climate change: A case study of CO_2 emissions. Energy Policy 38(1): 350-356.

Appendix

Table A1. 41 economies in WIOD

Euro-zone	Other EU	NAFTA	East Asia	BRIIAT	ROW
Austira, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, Spain	Bulgaria, Czech Rep., Denmark, Hungary, Latvia, Lithuania, Poland, Romania, Sweden, UK	Canada, Mexico, USA	China, Japan, Korea, Taiwan	Austrialia, Brazil, India, Indonesia, Russia, Turkey	The rest of the world

Table A2. 35 sectors in WIOD and their definition by NACE

NACE	Sector	NACE	Sector
AtB	Agriculture, Hunting, Forestry and Fishing	F	Construction
C	Mining and Quarrying	50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
15t16	Food, Beverages and Tobacco	51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
17t18	Textiles and Textile Products	52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
19	Leather, Leather and Footwear	H	Hotels and Restaurants
20	Wood and Products of Wood and Cork	60	Inland Transport
21t22	Pulp, Paper, Paper , Printing and Publishing	61	Water Transport
23	Coke, Refined Petroleum and Nuclear Fuel	62	Air Transport
24	Chemicals and Chemical Products	63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
25	Rubber and Plastics	64	Post and Telecommunications
26	Other Non-Metallic Mineral	J	Financial Intermediation
27t28	Basic Metals and Fabricated Metal	70	Real Estate Activities
29	Machinery, Nec	71t74	Renting of M&Eq and Other Business Activities
30t33	Electrical and Optical Equipment	L	Public Admin and Defence; Compulsory Social Security
34t35	Transport Equipment	M	Education
36t37	Manufacturing, Nec; Recycling	N	Health and Social Work
E	Electricity, Gas and Water Supply	O	Other Community, Social and Personal Services
		P	Private Households with Employed Persons