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Export-Import of Virtual Carbon Emissions and Water Flows Embodied in International Trade

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In the globalised world the greenhouse gas emission and water consumption are becoming increasingly important indicators for policy and decision making. Development of footprint assessment techniques over the last decade has provided a set of tools for monitoring CO_2 emissions and water flows in the world. An overview of the virtual CO_2 and virtual water flow trends in the international trade based on consumption perspective is performed. Review of the recent literature indicates that: (1) There are significant CO_2 gaps between producer's and consumer's emissions, and US and EU have high absolute net imports CO_2 budget. (2) China is an exporting country and increasingly carries a load of CO_2 emission and virtual water export that are triggered due to consumption in other importing countries. (3) By imported products that are produced with lower carbon emission intensity and less water consumption then in the domestic industry, international trade can reduce global environmental pressure. A future direction should be focused into two main areas: (1) To provide the self-sufficient regions based on more efficient processes by combining production of surrounding countries. (2) To develop the shared mechanism and market share of virtual carbon and virtual water between trading partners regionally and internationally.

1. Introduction

International trade has been significantly growing and in past decades even accelerating. Figure 1 shows the international merchandise trade balance from the year 1990 to 2013 (UNTSAD, 2014). The United State, followed by Japan and India, are the largest import county. China, Russian Federation and recently the EU28 are the major exporting countries in the world. The growth of international trade is increasing the separation between the location of consumption and the location of production and emissions.

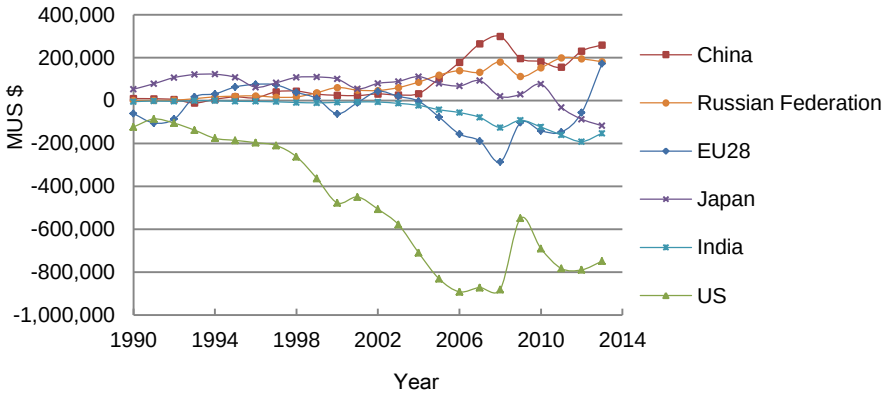

Figure 1: Merchandise trade balance in international trade, 1990 - 2013 (UNTSAD, 2014)

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GHG emissions growth is usually reported on a territorial basis not accounting for the international trade. As a consequence, emissions can markedly differ from those global emissions required to produce only the products consumed in a region. The products consumed in many countries increasingly rely on coal, oil and gas extracted and burned in those countries where CO_2 emissions are not so tightly regulated. Analysing CO_2 emissions embodied in international trade and using the results obtained to estimate the so-called "consumption-based" emissions has been an actively researched topic in the last decade. Various studies shown that the emissions embodied in a country's international trade measured have been increasing over time.

Figure 2 shows the difference between the CO_2 emissions in a region, which are based on the production and consumption principles in the year 2009 (OECD, 2015). Considering the production-based CO_2 emission, China is the biggest CO_2 emissions producer, emitting about 1,600 Mt of CO_2 more than the US. However, based the consumption-based CO_2 emissions, US and China emit similar amount of CO_2 and are the greatest CO_2 emitters. China, India and Russian Federation all have lower consumption-based carbon emissions compared with the production-based carbon emission. The US, EU28 and Japan are benefiting from the international trade by importing significant amounts of embodied CO_2.

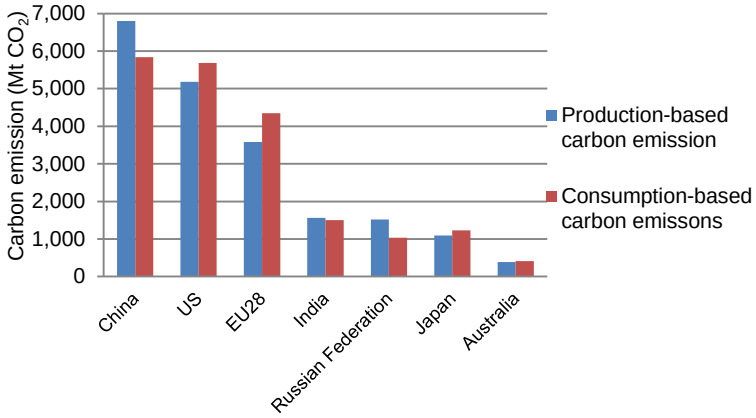

Figure 2: The carbon emissions in 2009 based on the production-based and consumption-based principle (OECD, 2015)

A similar situation has also been developing in water and fresh water supply (Klemeš and Varbanov, 2013), where several countries heavily rely on water resources elsewhere. This has significant impacts on water consumption and pollution in the other parts of the world. This paper overviews recent trends in flows of carbon and water footprints due to international trade. Based on this the conclusions could be drawn that possible efforts should be made to for minimise the carbon emission and water consumption in the globalised trade.

2. Carbon emissions and virtual carbon flows

The surge of economic globalisation has resulted in a dynamic shifting in the geographic patterns of production and consumption of consumer goods, and consequently in shifting of the CO_2 emissions and water consumptions.

2.1 Carbon emissions intensity of economy

Carbon emissions intensity of economy is an indicator that is based on the ratio of the annual national greenhouse gas emission per gross domestic product (GDP). Figure 3 shows the CO_2 intensity trends in the main world regions. The developed counties including the US, Japan and EU28 have low CO_2 intensity below 0.5 kg/$. The developing countries including China and India have CO_2 emission intensity of more than 1.4 kg/$. From the year of 1990 the total CO_2 emissions intensity continues to decrease with the technological developments.

Carbon emissions intensity of economy is also a key carbon embodied indicator in global trade. As the same export financial count, China exports more virtual CO_2 embodied in goods compared with developed countries (e.g. European countries, Japan) also means that it is a significant difference from the virtual carbon trade balance in the merchandise trade balance in Figure 1.

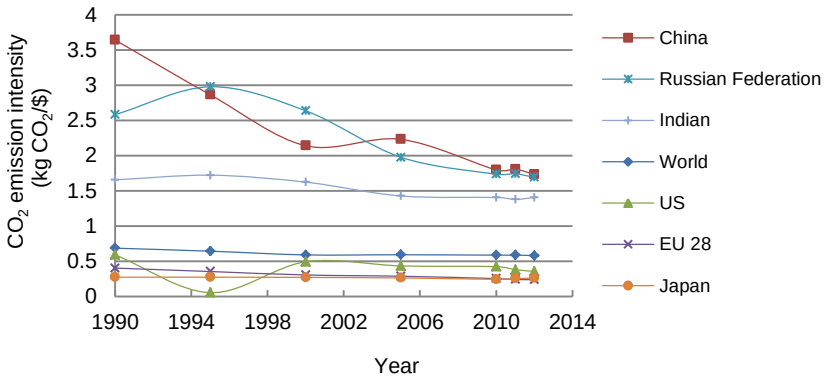

Figure 3: CO_2 emissions intensity, 1990 - 2012 (after IEA, 2014)

2.2 Virtual carbon flows in the international trade

Ten largest inter-regional flows of embodied CO_2 emissions in the international trade are shown in Figure 4. The largest single inter-regional flow is from China to US, of which the embodied carbon emission transfer is 375 Mt. Four of the top 10 embodied emissions flow routes originate from China. The US, EU and Japan are destinations for the majority of the embodied carbon emissions trade flows. The embodied CO_2 emission to Europe and North America from China account 17 % of total embodied CO_2 transfer (Carbon trust, 2011). It is the net embodied emissions imbalance between China (exporter) and the US, EU (importer) that is the most significant inter-regional flow of embodied emissions. Other inter-regional flows, such as those between Oceania, South America, Africa or India and all other regions, collectively account for less than 30 % of inter-regional embodied emissions flows (Peters et al, 2012).

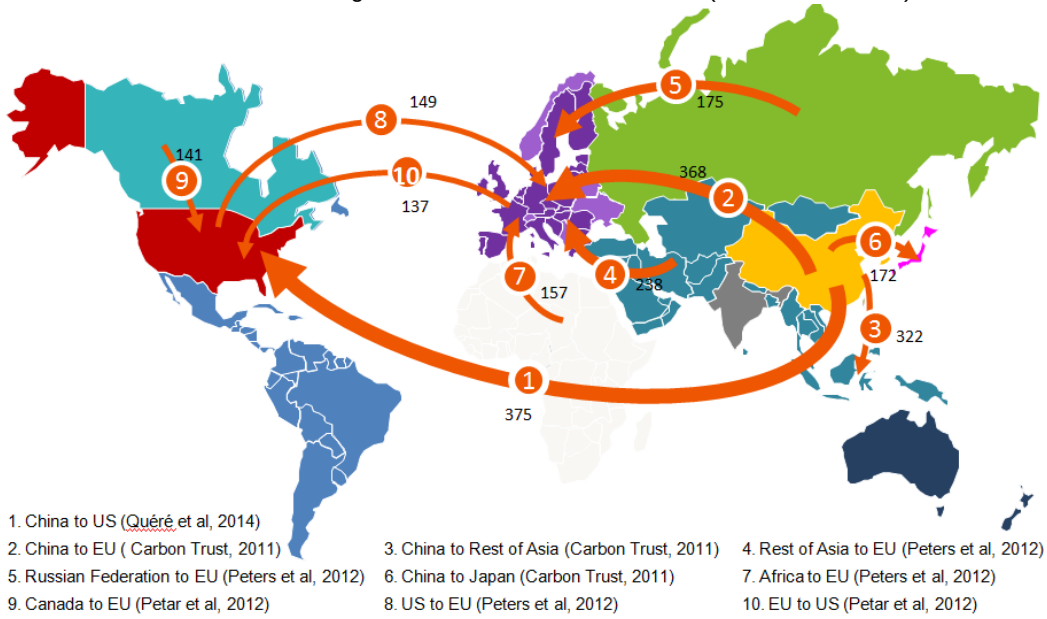

Figure 4: Ten largest inter-regional flows of embodied CO_2 emissions in 2004 (Mt CO_2)

2.2.1. Computer case

Notebook/Laptop is a typical product, which is made in China and exported to the globally. Even when by mass it is not significant the numbers are. The export from China in 2010 exceeded 190,000,000 units (Zhang et al, 2014). Table 1 shows export trends from 2005 to 2010. Notebooks/laptops export from China increases significantly in recent years. The number produced in China mainly from foreign investment was 189,000,000 (Zhang et al, 2014). Since there are also many accessories that are produced in other counties and transferred to China to complete the computer production, the carbon emissions in the production consists of two parts, which are emissions in China and emissions out of China - see Table 2. One computer vents 425 kg CO_2, and 273 kg is vented in China. Based on this result, the embodied CO_2 emission in export from China is 51.87 Mt in year 2010.

Table 1: China laptop product export data between 2005 and 2010 (After Zhang et al., 2014)

Item	2005	2006	2007	2008	2009	2010
Laptop/10^9 $	29.9	38.5	53.1	65.6	66.6	95.3
Electromechanical product/10^9 $	426.8	549.4	701.1	821.7	713.0	933.3

Table 2: The carbon emissions in computer production (Zhang et al., 2014)

Item	main part	CO_2 emission (kg)	Percent (%)
China	Lithium battery	22.6	5.32
	Power adapter	3.3	0.77
	Exterior and others	49.1	11.55
	Monitor and accessories	198.0	46.60
	Total	273.0	64.20
Other countries	Hardware	3.9	0.92
	Mother board	40.2	9.46
	Monitor	103.0	24.16
	CD drive	4.7	1.11
	Total	152.0	35.80
Total emissions		425.0	100.00

3. Virtual water footprint in international trade

The international trade is associated to the displacement of the water used to produce goods and embedded in trade. The concept of virtual water is illustrated to provide the relationships between water inputs and industry products output (Antonelli et al, 2012). The international virtual water trade constitutes a weighted and directed network, in which link direction is given by the direction of trade (i.e. from exporting to importing country), and link weights are the volumes of virtual water traded between countries. About one-fifth of the global water footprint was related to the production in the international export (Hoekstra and Mekonnen, 2012).

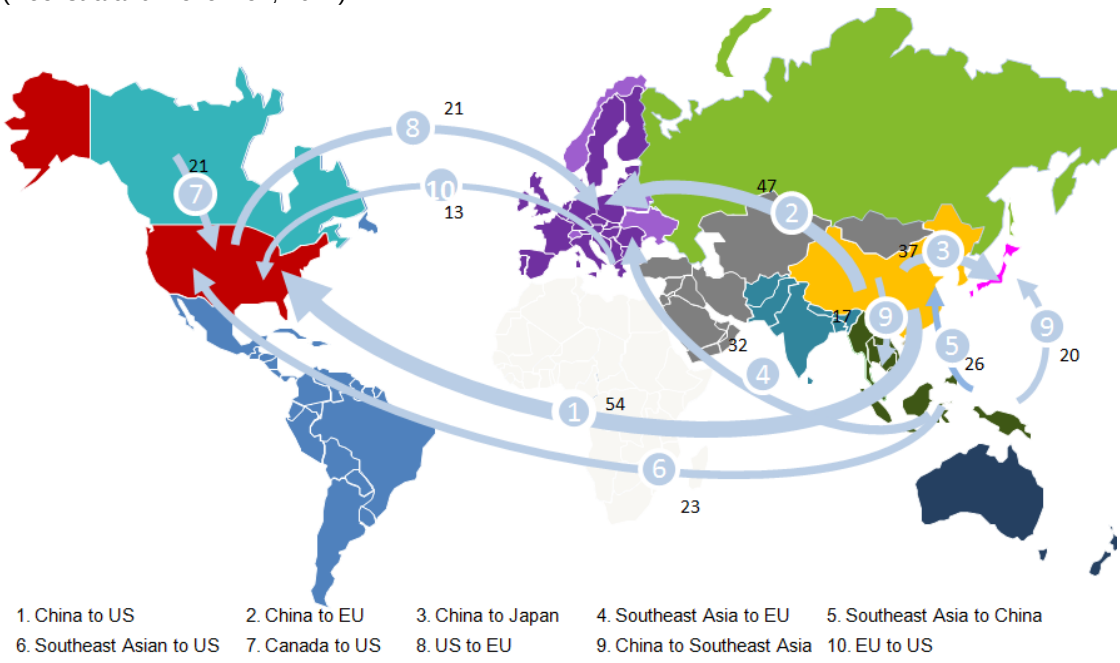

Figure 5: Ten largest inter-regional virtual water trade fluxes (Gm^3) - after Chen and Chen (2013)

3.1 Virtual water flows in international trade

Virtual water trade indicates the virtual water flows embodied in international commodity trade, which are also evaluated as the indicator of water consumption to produce the traded goods. According to the Chen and Chen (2013) 57 % of international virtual water trade is embodied in all industry product trade, and 43 % is embodied in agricultural and processed food trade alone. The major international virtual water trade

fluxes are shown in Figure 5. The virtual water associated with all products is illustrated. China is the leading virtual water exporter, and the main part virtual water is embodied in industrial products, which account for 79.4 % of total virtual water export (Chen and Chen, 2013). Southeast Asia Nations become one of major virtual water exporter as very high amount of virtual water is embodied in agricultural and process food. Four flows of top ten are from Southeast Asian Nations to other regions. Similarly with virtual carbon emissions EU, US and Japan are also the highest virtual water importing region. Japan is the leading net virtual water importer; the virtual water import is 6 times of the value of export (Chen and Chen, 2013). China, US, the association of Southeast Asian Nations and the EU are shown as the world's trading centres of the international virtual water flow connected with at least one of those regions.

3.2 Virtual water consumption in different industries

The total volume of international virtual water flows related to trade in agricultural and industrial products was 2,320 Gm^3/y (Hoekstra and Mekonnen, 2012). The most freshwater consuming sector was agriculture (Dalin et al, 2012). Table 3 shows the virtual water consumption in the selected sectors in China global merchandise trade (Zhang and Xu, 2014).

Table 3: Virtual water consumption in the 15 sectors of China in global trade (Zhang and Xu, 2014)

Industry (15 sectors)	Virtual Blue and Green water(L/$)	Virtual Grey water (L/$)	Total virtual water (L/$)
Agriculture	411.18	45.80	456.98
Mining industry	3.04	7.00	10.03
Food manufacturing industry	6.93	2.97	9.90
Textiles leather and footwear manufacturing industry	5.68	2.97	8.65
Other manufacturing industry	5.61	4.36	9.97
Electric thermal and water manufacturing industry	14.72	1.25	15.97
Coking, gas and petroleum processing industry	0.73	2.11	2.84
Chemical industry	11.75	12.41	24.16
Building materials and non-metallic products industry	11.75	12.41	24.16
Metal products industry	1.65	4.55	6.20
Machinery and electrical equipment manufacturing	1.39	2.71	4.09
Construction industry	3.30	5.48	8.78
Transport, posts and telecommunications industry	1.72	0.20	1.91
Wholesale and retail trade, and catering industry	1.45	1.91	3.37
Other service industry	1.78	1.52	3.30

From Table 3, it could be seen that agriculture sector in the international trade consists of crops and derived crop products, and has much higher virtual water consumption compared to other sectors. Chemical industry and non-metallic mineral products industry both have also high virtual water consumption with more than 24 L/$. The remaining industries have lower virtual water footprints.

4. Discussions

The purpose of consumption-based carbon (Greenhouse Gas) emission and virtual water consumption assessment in the international trade is to improve the understanding of real emissions, and to acquire more justified decision. The total virtual carbon embodied in international trade is equivalent to around 30 % of global emissions (Sato, 2014) while the total virtual water embodied in international trade is around one third of the global water withdrawal (Chen and Chen, 2013). These huge virtual carbon and water flows are confirming the fact that commodity trade plays a significant role in redistributing carbon emission pressure and water resources between nations. China has been the highest virtual carbon as well as net virtual water exporter during last years. The US, EU and Japan appears as the world's leading gross and net virtual carbon and water importers. Since the technology has been improving, the carbon intensity decreases as well as the water consumption. The international trade can reduce overall environmental pressure if imported products with lower carbon intensity are consumed that are produced in the regional/domestic industry. The results of this study can be used for the initial assessment; however more research is needed towards the self-sufficient regions based on more efficient processes by combining surrounding countries/regions and to develop the participation mechanism, and market share of virtual carbon and virtual water between international trading partners. To consider global trade is also crucial for locally affecting emissions as e.g. NOx.

5. Conclusions

The virtual carbon emissions and water consumption in the national and international trade are an important factor influencing the global environment sustainability. This study has been directed to an overview on virtual carbon and virtual water footprints in trade. Virtual carbon emissions in trade constitute a large and growing share of global emissions. There is a considerable gap of virtual carbon emission and virtual water consumption in producing and consuming countries. China, India, Russian Federation has been net virtual carbon exporters, while the developed countries including the US, Japan, and Europe countries are net virtual carbon importers. Agriculture goods are requiring very high virtual water consumption and low embodied carbon emissions, while industrial products are responsible for higher embodied carbon emissions in the trade. International trade affects the carbon and water footprints transfer globally based on the goods international delivered. Global trade can reduce global environmental pressure when the imported products are produced with lower carbon emission intensity and less water consumption than in the domestic industry. To develop self-sufficient regions based on more efficient processes by combining neighbouring countries can be a promising development. The global status of virtual carbon and water distribution pattern should be also considered to support policy making process with a target to develop the participation mechanism and market share of virtual carbon and virtual water amongst international trading partners.

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