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CO2 Emissions Embodied in International Trade — A Comparison on BRIC Countries

Yang Laike

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CO_2 Emissions Embodied in International Trade — A Comparison on BRIC Countries[1]

Yang Laike[2]

East China Normal University, School of Finance and Statistics, 200241, Shanghai, China

Abstract

International trade has strong impacts on climate change. Trade can act as a strong factor for some countries to transfer their own Green House Gas (GHG) emissions to their trade partners. In the last decade, BRIC countries (Brazil, Russia, India and China) have witnessed the highest economic growth rates as well as the fastest expansion in trade. Within the same time span they also emerged as the world's largest GHG emitting countries. Now, the question arises, is this increase in pollution in BRIC countries due to international trade? Are these countries becoming so called global "pollution havens"? In this article, I use the single region input-output analysis model to assess the CO_2 emissions embodied in trade in BRIC countries, and also identify if there are carbon leakages in these countries. The result shows that due to its massive export of manufacturing products, China has emitted a huge amount of CO_2. Russia also has a big imbalance on trade embodied CO_2 emission mainly due to its massive export of energy products. However, the paper finds that the increase in Brazil's CO_2 emissions is not related to trade but to land-use and agriculture and India actually benefits from the trade flow, environmentally.

Key words: CO_2 Emission, Trade, BRIC

JEL classification: F18, Q56

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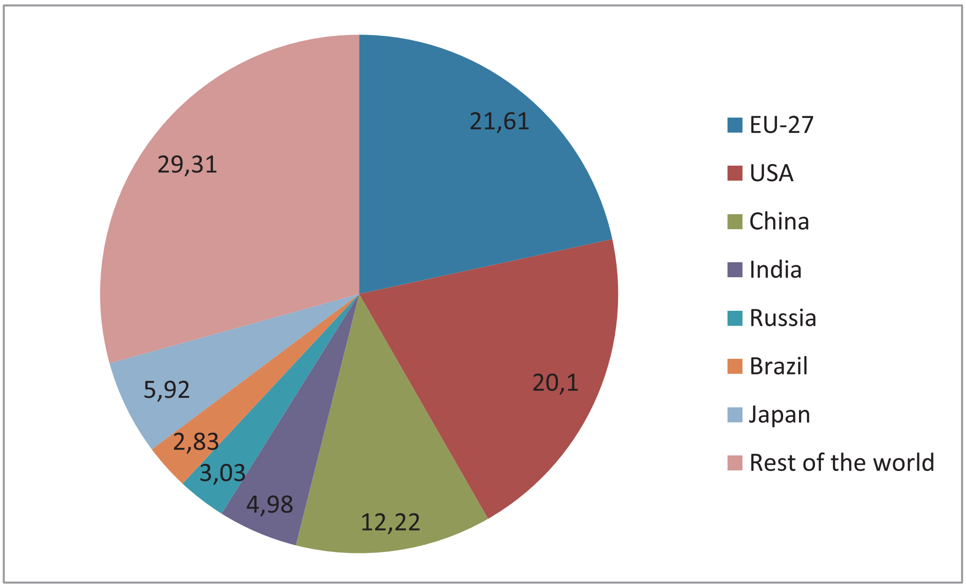
[2] Corresponding e-mail: lkyang@bs.ecnu.edu.cn. Tel.: +86-13585828580. Fax: +86-21-52068520.

I. Introduction

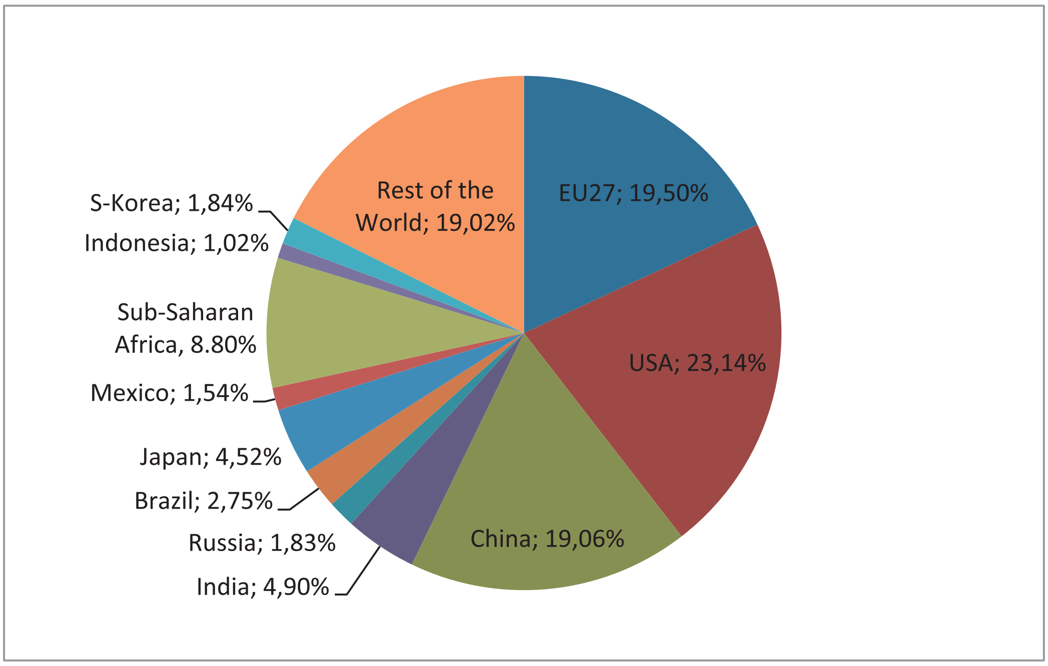
One of the most important recent developments in the world economy is the increasing economic integration of large developing countries, in particular, the so-called BRIC countries, which include Brazil, Russia, India and China. Their rapidly growing GDP and the expanding foreign trade have increased the importance of these countries in the global economy. According to the IMF, the BRIC countries represented only 18% of world GDP (by Purchasing Power Parity) in 1990, which has jumped to over 25% by 2009, with China alone accounting for 12.22% of total global GDP (see Figure 1). It is projected that, by the year of 2050, China, India and Brazil will all be in the top 5 largest economies in the world, if the current high rate of economic growths are maintained in these countries (IMF, 2009).

Figure 1a: Shares of the Global GDP in 2009 (by PPP)



Source: World Economic Outlook Database, International Monetary Fund, 2009.

Figure 1b: Shares of the Global GDP in 2040 (by PPP)



Source: World Economic Outlook Database, International Monetary Fund, 2009.

However, on the other hand, the BRIC countries are also becoming the world's main Green House Gas (GHG) emitters. As we can see from Table 1 and Table 2, all BRIC countries are already within the top 10 largest GHG and CO_2 emitters in absolute terms[3]. According to IEA statistics, in 2008, these four countries, plus South Africa, represented 31% of global energy use and 35% of CO_2 emissions from fuel combustion. These shares are likely to rise further in coming years if no significant measures are taken to tackle the problem.

[3] In BRIC countries, the main sources of CO_2 emissions are different, Brazil's main emission is from land use, but in the other three emissions come mainly from the energy sector.

Table 1: Total GHG Emissions in 2005 (excludes land use)[4]

Unit: MMT (Million Metric tons)

Country	GHG emissions	Rank	% of World Total	GHG emissions Per Person	Rank
China	7,234.30	1	19.13%	5.5	82
US	6,931.40	2	18.33%	23.5	9
EU (27)	5,049.20	3	13.35%	10.3	43
Russian	1,947.40	4	5.15%	13.6	22
India	1,866.10	5	4.94%	1.7	149
Japan	1,356.20	6	3.59%	10.6	39
Brazil	1,011.90	7	2.68%	5.4	85
Germany	975.2	8	2.58%	11.8	28
Canada	739.3	9	1.96%	22.9	10
UK	645.3	10	1.71%	10.7	38

Source: International Energy Agency (IEA) data base.

Table 2: Total CO_2 Emissions in 2005 (excludes land use change)

Unit: (MMT)

Country	MMT	Rank	% of World Total	MMT Per Person	Rank
US	5,859.10	1	21.25%	19.8	6
China	5,592.40	2	20.28%	4.3	69
EU (27)	4,102.60	3	14.88%	8.4	37
Russian	1,555.40	4	5.64%	10.9	21
Japan	1,262.40	5	4.58%	9.9	26
India	1,234.80	6	4.48%	1.1	123
Germany	826.6	7	3.00%	10	25
Canada	566.8	8	2.06%	17.5	9
UK	544	9	1.97%	9	31
Korea	494.5	10	1.79%	10.3	23
Brazil	349.8	18	1.27%	1.9	105

Source: International Energy Agency (IEA) data base.

International trade has strong impacts on climate change. Trade results in a geographic separation between consumption and the related pollution from the production of these consumable goods. This creates a mechanism for consumers to shift pollution associated with their consumption to other countries from where the goods are imported. This could offset the current efforts to address the problems of

[4] The major Green House Gases are carbon dioxide (CO_2), ozone, methane, nitrous oxide, halocarbons and other industrial gases. According to the Intergovernmental Panel on Climate Change (IPCC), CO_2 accounts for 77% of the total GHG.

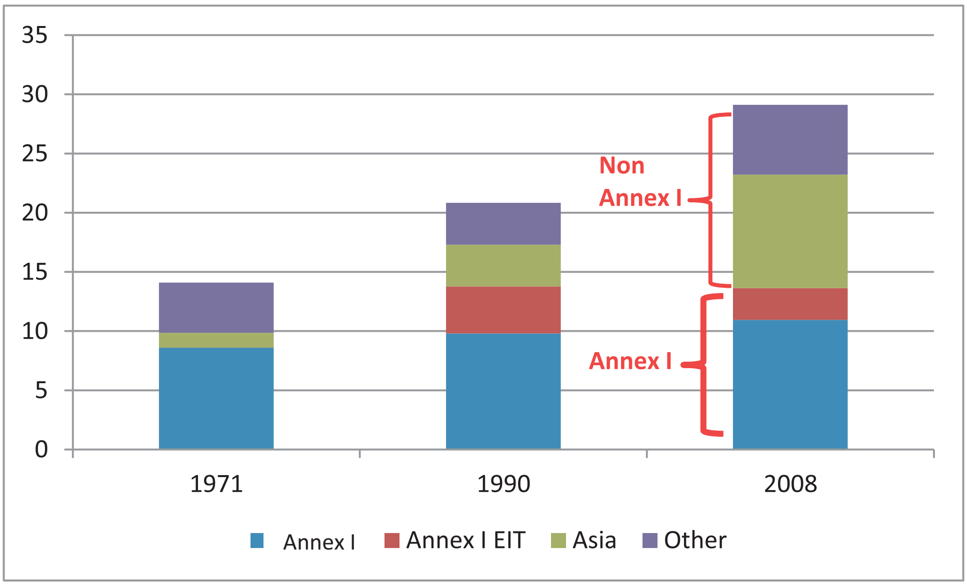
climate change by merely outsourcing emissions of GHGs from one country to others. The Kyoto Protocol set legally binding commitments for the Annex I countries[5] to reduce their combined emissions of six GHGs[6] by 5.2% below the 1990 level during the years 2008-2012. However, if the Annex I countries reach their emission targets by importing CO_2-intensive products from developing countries, achieving the goals will be less meaningful in global terms. We can see from Figure 2 that, in 2008, CO_2 emissions from Annex I countries were almost reduced to 1990 levels, while emissions from non-Annex I countries continued to grow. Also for the first time in 2008, the CO_2 emissions from non-Annex I countries surpassed those of Annex I countries. During 1990-2005, CO_2 emissions in Annex I countries only increased 1.7%, whereas the increase is 74.2% in non-Annex I countries.

This paper tries to address few commonly raised questions. What is the relationship between GHG emission decrease in Annex I countries and international trade? Are there some carbon-leakages from Annex I to non-Annex I countries? What is the situation in each single BRIC country?

[5] Annex I countries include OECD member countries and EIT countries (Economies in Transition).

[6] The six GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6).

Figure 2: CO_2 Emissions in Annex I and non-Annex I Countries



Source: International Energy Agency database.

Note: **"EIT"** refers to Economy in transition. **"Asia"** includes Korea and excludes Japan (which is included in Annex I). **"Other"** includes Africa, Latin America, Middle East, non-Annex I EIT, Turkey, international bunkers, and, for 1971,Annex I EIT.

In this paper, I try to answer the above questions by estimating the CO_2 emissions embodied in trade of BRIC countries and analyzing the sectoral characteristics of foreign trade and energy use in BRIC countries. At the end, I analyze what BRIC countries can learn from each other regarding the reduction of GHG emission.

II. Literature Review

Compared to many other trade topics, studies on environment related trade issues are relatively new. In the early 1990s, several studies established theoretical models to analyze the environmental effects of trade. Grossman and Krueger (1991) developed a conceptual framework and an econometric model to examine how trade may affect the environment. This framework decomposes the environmental impact of the North American Free Trade Agreement (NAFTA) into three "effects": the scale effect; the composition effect and the technology effect. Copeland and Taylor (1994, 1995) and Chichilnisky (1994) developed the North-South trade model to examine linkages between pollution and international trade. They argued that free trade deteriorates the environment and encourages the North countries to shift their pollutions to the South. In recent years, more and more studies use this analytic framework to investigate the link between trade and climate change (Antweiller et al., 2001; Peters et al., 2008; Guan et al., 2008). Antweiller et al. (2001) estimated the scale, composition and technology effects of SO_2 emissions using a general equilibrium model of trade and environment. Focusing on the EU, Kornerup et al. (2008) found that global CO_2 emissions caused by total consumption in EU were 12% higher than the total CO_2 emissions that occurred within the EU in 2001.

Due to the rapid expansion of foreign trade and the deteriorating environment of China, many studies in recent years focused on this particular country and most of these studies found a positive correlation between China's foreign trade and its CO_2 emission. Shui and Harriss (2006) estimated that about 7% in 1997 and 14% in 2003 of China's CO_2 emissions are the results of producing goods for export to the USA. Li and Hewitt (2008) found that China–UK trade resulted in an additional 117 MMt of CO_2 to global CO_2 emissions in 2004. Wang and Watson (2008) concluded that net exports from China accounted for 23% of its total CO_2 emissions in 2004. Similarly, Weber et al. (2008) found that in 2005, around one-third of Chinese CO_2 emissions were due to production of exports, and this proportion had risen from only 12% in 1987 to 21% in 2002. Yan and Yang (2010) also argued that 10.03% in 1997 and 26.54% in 2007 of China's annual CO_2 emissions were produced during the manufacture of its exports. Peters and Hertwich (2008) analyzed the emissions embodied in China's foreign trade for 87 countries and found that China exported 24% of its CO_2 emissions and imported 7% of China's domestic emissions.

However, there are less comprehensive studies on this issue for other BRIC countries. Using the Single Region Input-Output model (SRIO), Schaeffer and de Sa (1996) analyzed the CO_2 embodied in Brazilian foreign trade of non-energy products. Their result showed that in the 1970s Brazil was a net importer of embodied CO_2, 19.6% of its total CO_2 was from net import. However, since the 1980s, Brazil has become a net exporter of embodied CO_2, trade-embodied-CO_2 accounts for 11.4% of its total emission. Their study supports the "Pollution Haven Hypothesis". Nevertheless, another study made by Machado et al. (2001), rejected this hypothesis.

They estimated energy efficiency and CO_2 emission intensity of Brazilian non-energy export products, and found that the CO_2 emission intensity is 40%-56% higher in imported non-energy goods than in export goods. As for India, Dietzenbacher and Mukhopadhyay (2007) examined the India-EU trade, and found out quite interestingly that, India actually benefits from the trade. The trade embodied CO_2 emission in export is only half the emission embodied in import. Obviously, their study rejected the “Pollution Haven Hypothesis” for India. So far, there is very little literature on Russia related to this topic.

The purpose of this paper is to estimate the trade embodied CO_2 using updated data, and to analyze why China and Russia are becoming “pollution havens”, but Brazil and India so far have been able to prevent it.

III. Data and Methodology

3.1. The Model

As originally formalized by Leontief in the 1970s, the total output of an economy x, can be expressed as the sum of intermediate consumption Ax, and final consumption y:

$$x = Ax + y \qquad (1)$$

Where *A* is the economy’s direct requirements matrix and y is the demand for which the supply-chain output x is to be derived. The matrix *A* describes the relationship between all sectors of the economy. When solved for total output, this equation yields

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

Where x is the vector of output, I is the identity matrix, which is a diagonal matrix with the diagonal elements one and others zero. A is a matrix of direct requirements, and $(I - A)^{-1}$ is the Leontief inverse, which represents the total requirements matrix (direct plus indirect). y is the vector of final demand.

Appropriate extensions of the input-output system allow us to evaluate the direct and indirect impacts of economic policies on other economic variables such as labor, capital, energy and emissions. CO_2 emissions embodied in international trade can be assessed by multiplying the CO_2 emissions factor by foreign trade figures (export and import vectors).

When coupled with an environmental matrix, F, which shows the environmental emissions caused by each sector in the model, the total amount of emissions, f, can be calculated as

$$f = F(I - A)^{-1} y \qquad (3)$$

Considering the foreign trade, the emissions embodied in exports (EEE) can be calculated as:

$$f^e = F(I - A^d)^{-1} e \qquad (4)$$

Here A^d is the domestic matrix of direct requirements, *e* represents exports, and *m* represents imports (as in euquations 5 and 6).

Similarly, the emissions embodied in imports (EEI) can be calculated as:

$$f^m = F\ (I - A^d)^{-1} m \qquad (5)$$

Thus, the emissions balance of a country can be calculated as:

$$f^b = f^e - f^m = F(I - A^d)^{-1} e - F(I - A^d)^{-1} m \qquad (6)$$

3.2. The Data

Most of the data used to test this model are from the international harmonized database of OECD, the sector classification of OECD input-output table, bilateral trade database (BTD) and the IEA. CO_2 emissions from fuel combustion are basically formatted and harmonized, following the sector classification of “International Standard Industrial Classification of All Economic Activities” (ISIC Revision 3). Due to the limitations of detailed emission factors by different sectors, the 15 aggregated sectors (Table 3) are used in this study. And the empirical analysis of EU is limited to EU-15 due to their importance in the EU and lack of data for the other countries.

Table 3: Sector Classification

Sector	ISIC Rev.3
1 Agriculture, hunting, forestry and fishing	1+2+5
2 Mining , quarrying and petroleum refining	10-14, 23
3 Food products, beverages and tobacco	15+16
4 Textiles, textile products, leather and footwear	17+18+19
5 Wood and products of wood and cork	20
6 Pulp, paper, paper products, printing and publishing	21+22
7 Chemicals and chemical products	24
8 Basic metals and other non-metallic mineral products	26+27
9 Fabricated metal products, machinery & equipment	28-32
10 Transport equipment	34+35
11 Rubber and plastics products and other manufacturing	25+33+36+37
12 Utilities	40+41
13 Construction	45
14 Transport and storage	60-63
15 All other services	50-55, 64-99

Source: Nakano et al., 2009.

Before going into the detailed result, some explanations of the data are provided below.

Direct CO_2 emission factor: It refers to the CO_2 emission per unit of output in a sector. As the data are not directly available, it is constructed from IEA's CO_2 emissions from fuel combustion data, which is also based on ISIC Rev. 3. Direct CO_2 emission factor by sector for each country is simply calculated through dividing emissions to sector by output (Nakano et al. 2009). The data of CO_2 emissions by sectors is obtained from IEA CO_2 emissions from fuel combustion.

Input-output tables: I used the latest version of the OECD input-output database (2009 edition) which includes the input-output tables of BRIC countries for the years 1995, 2000, and 2005. To have a harmony with the trade data which is updated until 2008, I filled the table with data from the nearest and most available years. In doing so, it is assumed that production technologies and relative prices (hence IO coefficients) remain constant for short periods of time (Ahamad & Wyckoff, 2003).

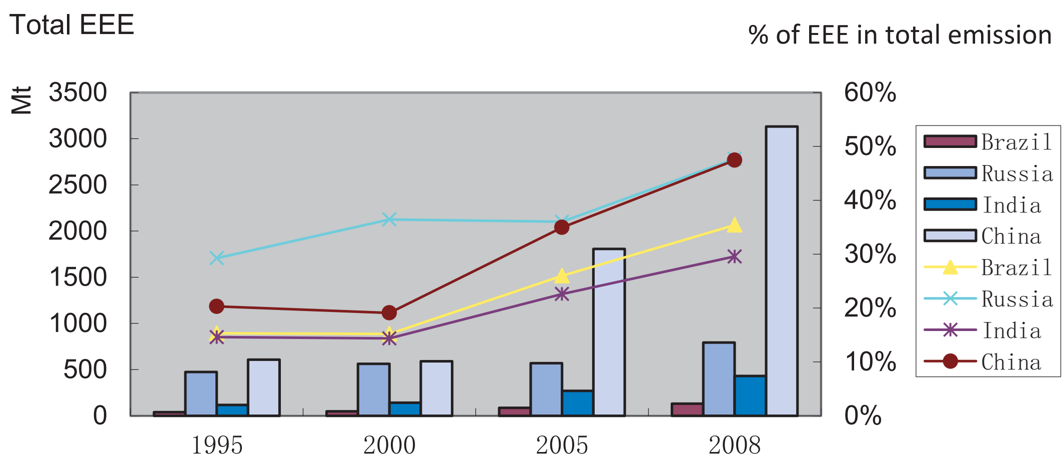
Trade data: To match with input-output tables, the latest OECD structural analysis bilateral trade database (STAN BTD) is used here, which is based on ISIC Rev.3 and similar to the OECD input-output database. The data is updated up to 2008.

IV. Results and Discussion

4.1. Emissions Embodied in Exports (EEE) of BRIC Countries

The analysis shows that, from 1995 to 2008, *EEE* in all BRIC countries have increased. However, the increase in EEE for China is the highest as well as the fastest compared to the other three countries. Figure 3 shows that, China's *EEE* jumped from 607 MMT in 1995 to 3,131 MMT in 2008. At the same time, its ratio in China's total CO_2 emissions also increased from 20.30% in 1995 to 47.43% in 2008. In Russia, the *EEE* increased from 474 MMT (29.25%) in 1995 to 793 MMT (47.66%). Similarly, the figures in India increased from 117 MMT (14.59%) to 431 MMT (29.56%), and in Brazil from 39 MMT (15.3%) to 130 MMT (35.40%).

Figure 3: BRIC's CO_2 Emissions Embodied in Exports (MMT, bars and left axis) and their Ratio in Total CO_2 Emissions (%, lines and right axis)

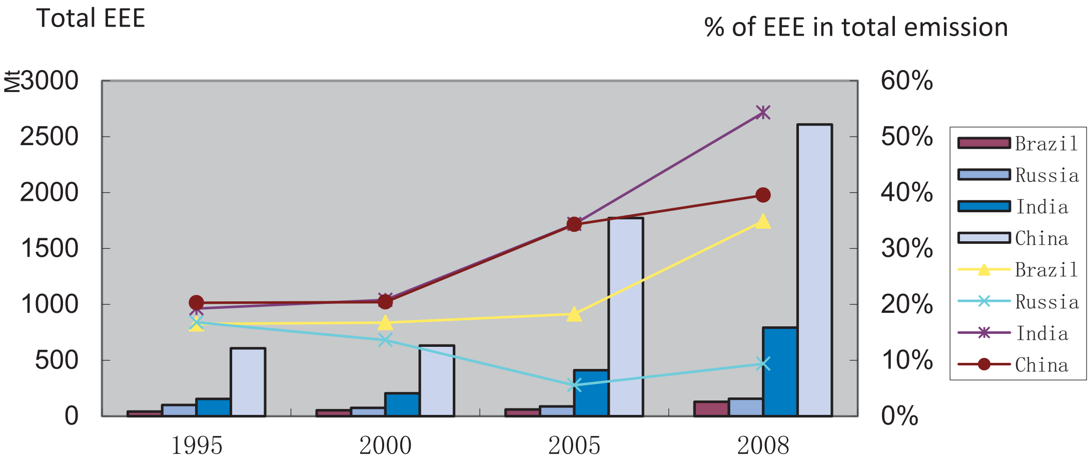


Source: International Energy Agency database.

4.2. Emissions Embodied in Imports (EEI) of BRIC Countries

Unlike the *EEE*, the trends of *EEI* in BRIC countries are diversified. In 2008, India had the highest ratio of EEI in its total CO_2 emissions (54.32%) and China the highest volume of EEI (2,610 MMT). In Russia and Brazil, *EEI* are relatively small and stable (see Figure 4).

Figure 4: CO_2 Emissions Embodied in Imports (MMT, bars and left axis) and its Ratio in Total CO_2 Emissions of BRIC Countries (%, lines and right axis)

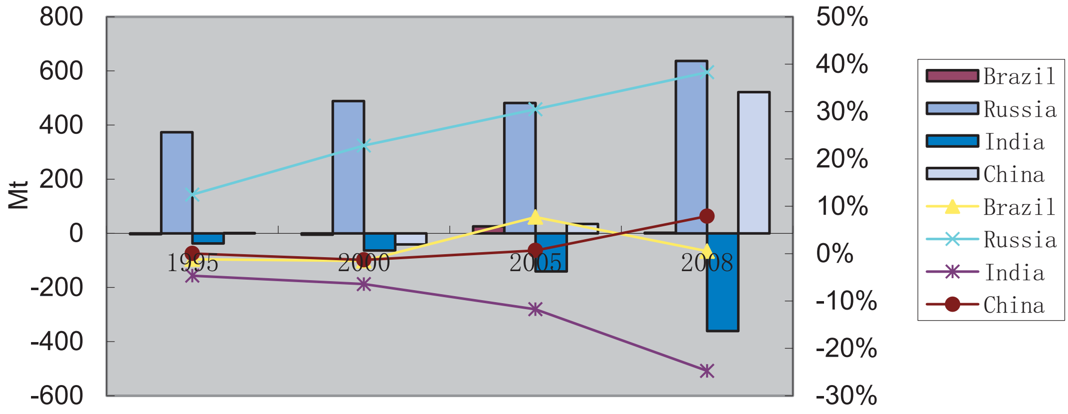


Source: International Energy Agency database.

4.3. Balance of Emission Embodied in Trade (BEET) of BRIC Countries

As seen in Figure 5, from 1995 to 2008, Russia witnessed an all-time surplus of *BEET* while India had an all-time deficit. The trade embodied CO_2 emission (*TECE)* surplus accounts for 24.75% of Russia's total CO_2 emission in 2008, which increased from 12.4% in 1995. Brazil used to be a net importer of TECE, but the situation reversed in 2005. However, in general, Brazil kept a relatively balanced *TECE*. China is the only country among the other BRIC countries, whose *EEE* has increased dramatically, which makes China's surplus of *TECE* reach 522 MMT in 2008 (7.9% of China's *TECE)*, much higher than it was in 1995 and 2005.

Figure 5: Balance of Emission Embodied in Trade (MMT, bars and left axis) and its Ratio in Total CO_2 Emission of BRIC Countries (%, lines and right axis)



Source: International Energy Agency database.

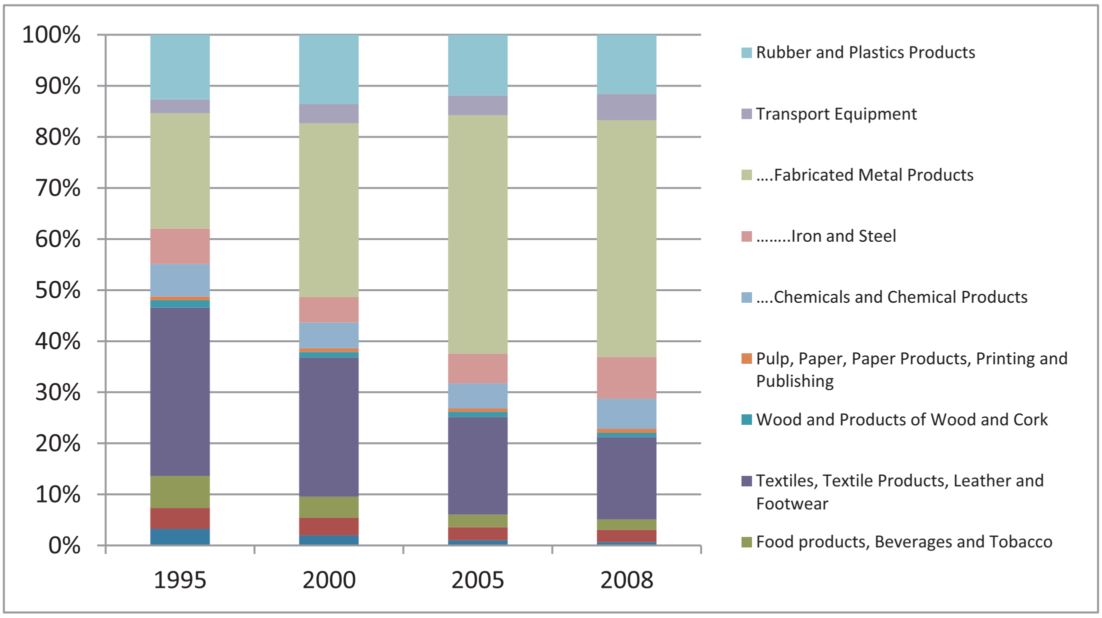
4.4. Discussion

The empirical analysis shows that, there has been a carbon leakage through trade in China and Russia, but not in India and Brazil. However, even India has caused a carbon leakage to some of its trade partners. What accounts for these differences? How to explain these results? To understand this, we have to analyze the traded products mix and the energy intensity of these four countries.

4.4.1. Export Products Mix

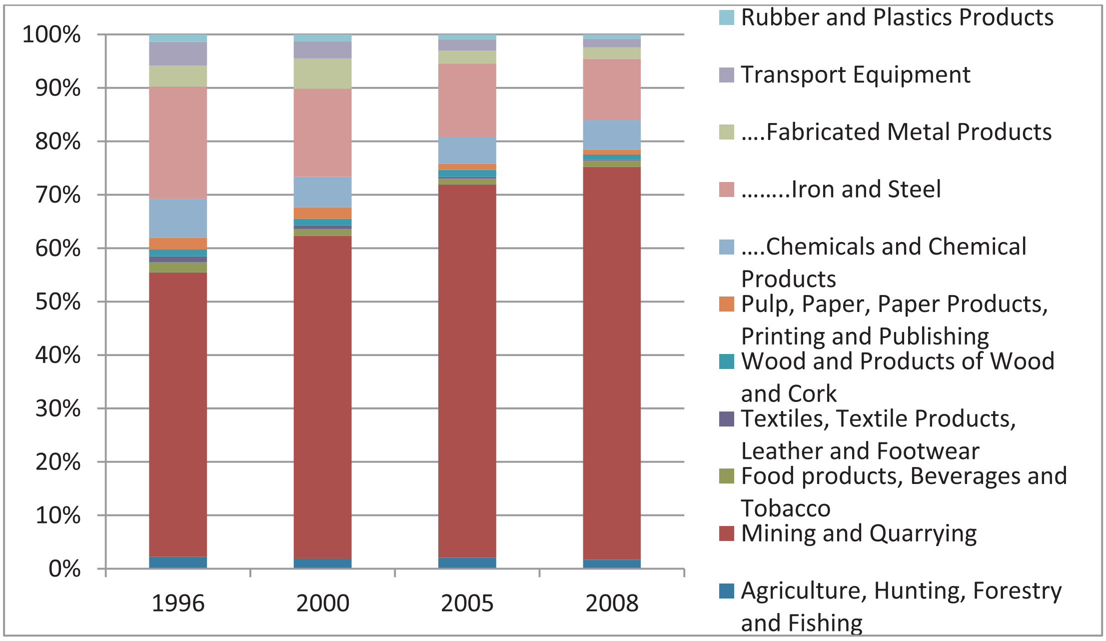
As we can see in Figure 6 to Figure 9, among all BRIC countries, China's export products mix is the "dirtiest". It is dominated by heavy industry products (metal and equipment, iron and steel), as well as labor intensive products (textile and clothing, electronics, rubber and plastics). In 2008, metal and machinery accounted for 46.4% of China's total exports, while textile and apparel accounted for 16.1% of it. Russia's export products are extremely concentrated in mining and steel (accounting for 70-80% of its total export value), which are all highly energy intensive. On the contrary, Brazil and India both have a relatively clean export products structure. Thanks to its strong export in services (software, services outsourcing), India is the only BRIC country with a deficit on BEET. Brazil's foreign trade is relatively emission neutral, since its main export products are not particularly dirtier than the products it imports, which means that there is no carbon leakage between Brazil and its trade partners.

Figure 6: China's Export Products Mix (1995-2008)



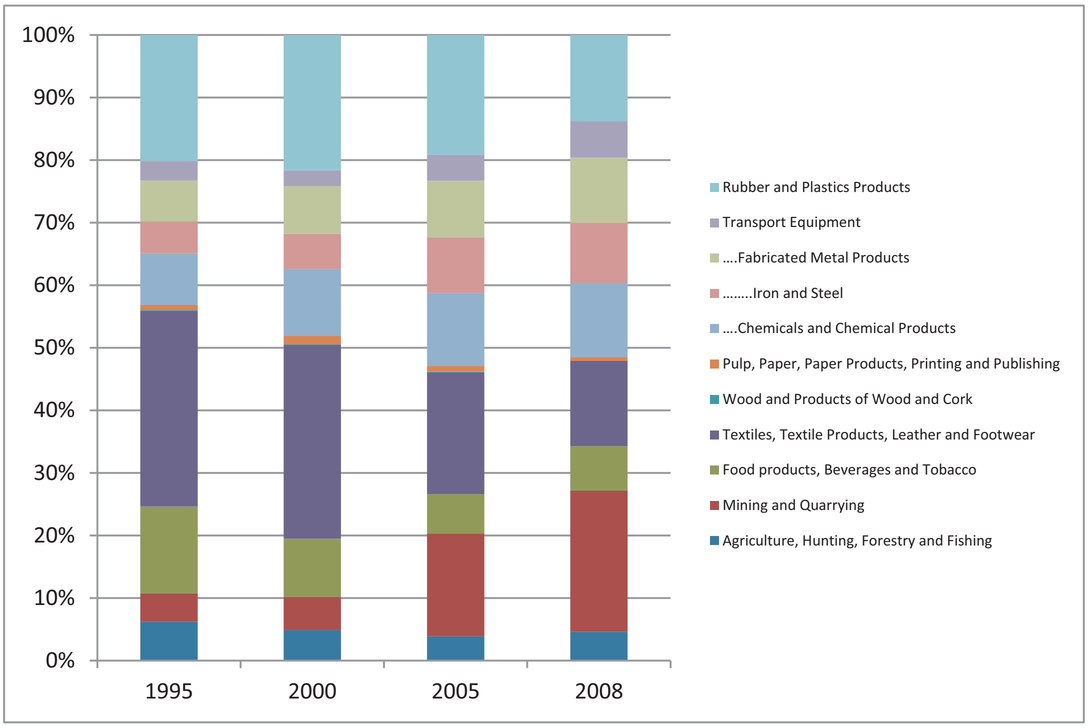
Source: International Energy Agency database.

Figure 7: Russia's Export Products Mix (1995-2008)



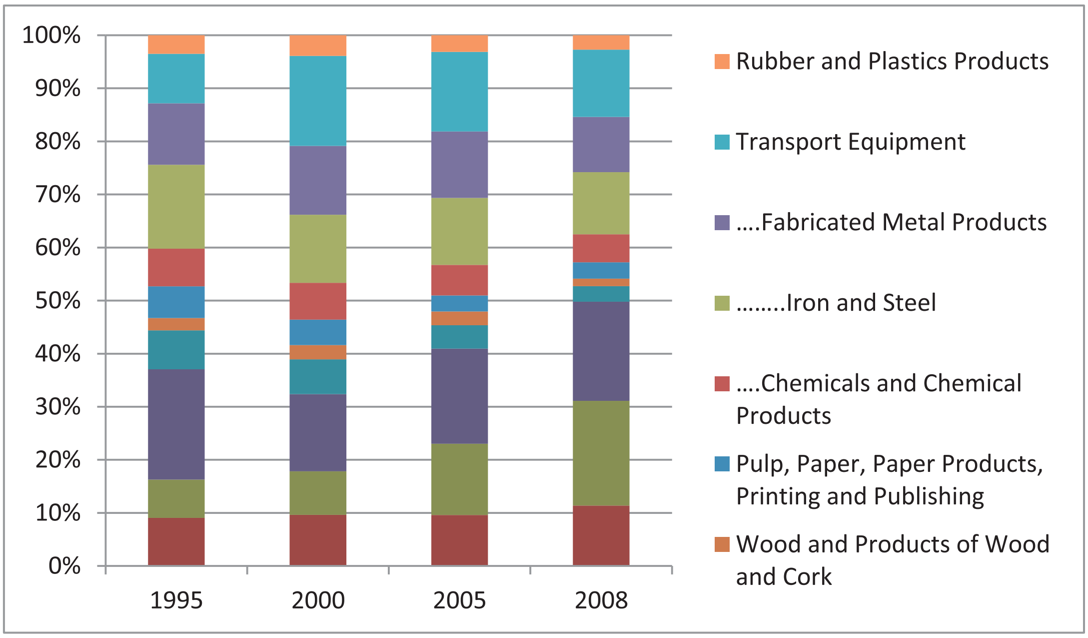
Source: International Energy Agency database.

Figure 8: India's Export Products Mix (1995-2008)



Source: International Energy Agency database.

Figure 9: Brazil's Export Products Mix (1995-2008)



Source: International Energy Agency database.

4.4.2. Emission Intensity

As we can see in Table 4, the CO_2 emission intensity in Russia is very high, followed by China and India. Brazil constantly keeps a very low figure, which is 10 times lower than that of Russia's. It is because Brazil's energy sector is one of the cleanest in the world. In Brazil's energy matrix renewable sources account for 44% of the Total Primary Energy Supply (TPES). Compared to Russia, China and India, CO_2 emissions from fuel combustion in Brazil are small, representing only 1.2% of global CO_2 emissions from fuel combustion. Brazil is also one of the world's largest producers of hydropower.

Table 4: CO_2 Emission Intensity of in BRIC Countries (kg CO_2/US$)

	1995	1996	2000	2001	2002	2003	2004	2005	2006	2007	2008
Brazil	0.41	0.43	0.47	0.47	0.46	0.45	0.45	0.44	0.43	0.42	0.43
Russia	6.56	6.69	5.80	5.53	5.23	4.99	4.61	4.34	4.20	3.88	3.71
India	2.27	2.22	2.13	2.05	2.03	1.92	1.89	1.80	1.77	1.74	1.73
China	3.21	3.11	2.25	2.13	2.11	2.23	2.40	2.43	2.42	2.32	2.30

Source: OECD.

However, Brazil has its own problem, its GHG emissions arise from land-use change (deforestation and forest degradation), agriculture and waste, which are much bigger than in the other three countries. Therefore, Brazil is among the top ten biggest GHG emitters, even if its CO_2 emissions are small.

V. Conclusion

In general, there is a huge carbon leakage from the Annex I parties of the Kyoto Protocol to the non-Annex I parties, but it is not evenly distributed. This study shows that, in BRIC countries, this leakage mainly takes place in China and Russia (an Annex I country), not in Brazil and India. Brazil has a fairly balanced *TECE*, India even has a deficit on *BEET*. The increase of total GHG emission in India is mainly due to the expansion of economic activities, or so called "scale effect". In Brazil, it is mainly from land-use change, agriculture and waste. In both countries, trade is not the key factor of environmental degradation.

China is becoming the "pollution haven" for developed countries due to its massive export of manufacture products; particularly the capital intensive manufacture, which is typically considered as a "dirty industry". Through the outsourcing of the production of manufacturing goods to China, developed countries also outsource GHG emissions in the country. Since China is already the world's biggest emitter of CO_2 and SO_2, it has had a central role in international climate and trade negotiations. China is required to take more responsibilities and make more commitments on emission mitigations, which is a major concern of the Chinese government, because it hinders its international competitiveness. What China can learn from India and Brazil's experiences is to give more preferential policy on service and energy sectors. In terms of international trade, China should import more environmental goods and technologies and implement more trade contraction measures on heavy pollution products.

As the only Annex I country in the BRIC group, Russia has the highest emission intensity and the biggest *TECE* surplus, because of its fossil fuel dominated export product mix. Although Russia has performed well in reducing GHG emissions in the past years, to reach the required mitigation target of the Kyoto Protocol, its extremely high energy intensity shows that Russia can do much more.

India has a better industry structure, although its economic growth is behind China. Strong export in services gives India the opportunity to avoid carbon leakage from developed countries. But its fast growing manufacturing sector and energy consumption put India in danger of following China's scenario. Similar to China, India is not likely to substitute fossil fuel by biofuel as in Brazil, due to the huge population and food safety concerns. But it has to improve energy efficiency through clean technology and environmental goods and services.

Exports are not main contributors of Brazil's CO_2 emissions. Thanks to its large renewable energy supply, Brazil's CO_2 emission intensity is much lower than in other

BRIC countries. Most of Brazil's CO_2 emissions are from transport and industry, which in 2008 accounted for 41% and 30% of its total CO_2 emissions respectively. However, Brazil needs to put tight regulations on land-use change, agriculture and waste, particularly on deforestation. Finally, due to the recent discovery of oil reserves, it is possible that the fossil fuel use in Brazil's energy matrix will increase.

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