The Game of Trading Jobs for Emissions

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Abstract

Following the debate on the implications of international trade for global climate policy, this paper introduces the topic of the economic benefits to exporting countries of products for exports in relation to the emissions generated in this production. In 2008, 24% of global GHG emissions and 20% of the employment around the world were linked to international trade. China exported 30% of emissions and hosted 37.5% of the jobs generated by trade worldwide. The European Union and the United States of America were the destination of 25% and 18.4% of the GHG emissions embedded in trade. The imports of these two regions contributed to the creation of 45% of the employment generated by international trade. This paper proposes the idea of including trade issues in international negotiations, taking into account not only the environmental burden generated by developed countries when displacing emissions to developing countries through their imports, but also the economic benefits of developing countries when releasing the emissions to produce goods delivered to developed countries. By analysing these opposing aspects, we aim to show how global emissions could be reduced effectively and with lower costs.

Keywords: Employment; Greenhouse gas emissions; Multiregional Input-Output Model.

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1. Introduction

In the last few decades world economies have experienced a rapid and profound process of globalisation that has favoured the flow of goods, services and production factors around the world. This phenomenon becomes clear when we look at the statistics of international trade. According to the World Trade Organisation, between 1995 and 2011 world trade volume tripled in nominal terms to exceed $18 trillion (30% of world GDP).

The consequences of this growth in international trade can be observed in many dimensions of modern societies. For instance, by exporting goods and services countries can obtain economic benefits, such as the creation of new jobs (Sousa et al., 2012). On the other hand, exporting countries have to tackle the environmental consequences of producing these products (Muradian et al., 2002). This relationship between increasing trade flows, employment generation and environmental degradation is well known in the climate change literature (Weber et al., 2008).

This triangle formed by trade, employment and emissions connects with the outstanding political debate about how to evaluate the relative contribution of different countries to climate change. The Kyoto Protocol establishes that each country is responsible for the emissions generated within its national territory (i.e. the so-called producer responsibility principle) (UNCCC, 1997; IPCC, 2006). According to this approach, countries could accomplish their national emission targets by importing goods from other countries and, therefore, avoiding the emission of greenhouse gases (GHG) generated when producing those goods. This question is closely linked to the problem of "carbon leakage" (Wyckoff and Roop, 1994). This term is used to describe a situation in which companies, in order to reduce costs, move their production to other countries which have a more lax climate policy.

During the last few years, emerging/developing countries have driven global emissions up by increasing significantly the release of GHGs to the atmosphere. At the same time, the emissions generated by developed countries have been stabilised. It has been argued that these trends are related, among other factors, to the increasing exports of developing countries and to their growing market share in the final demand of developed economies (Raupach, 2007). In this context, the so-called consumer responsibility incorporates emissions embedded in trade into an accounting framework, and postulates that each country should be responsible for all the emissions embodied in its final demand, regardless of where they have been generated (Peters, 2008). Following the consumer responsibility argument, developed countries should bear more responsibility for the emissions generated in emerging and/or developing economies.

During the last few years, a growing number of studies have focused on quantifying these transfers of emissions (carbon leakage) between countries via international trade (Wiedmann, 2009, Davis and Caldeira, 2009, Peters et al., 2011). However, there has been little attention paid to the quantification of the related economic consequences for the exporting countries, which can be considered as part of a game in which one partner is willing to bear the costs of environmental degradation in exchange for the inherent economic benefits of international trade, in terms of, for example, jobs creation. This issue is especially relevant for some emerging economies, for which exports are among the main drivers of national employment and economic growth.

The objective of this paper is twofold: firstly, it aims to describe the GHG emissions and the employment embodied in the exports of the world's main economies during 1995-2008; and secondly, it discusses the relevance of the employment benefits obtained by countries when producing exported goods.

The paper is structured as follow: section 2 describes the database and the methodology used. Section 3 summarises the main findings. Section 4 discusses the relevance of the results for policy making and section 5 concludes.

2. Methodology and database

Multi-regional Input-Output (MRIO) models have been widely used to analyse the environmental consequences of trade (see Wiedman, 2009 and Wiedmann, et at., 2011 for a comprehensive revision of the literature and the existing databases). In this paper, a MRIO will be used to calculate the emissions of GHGs and the employment embodied in international trade.
For the sake of simplicity, the methodology is described for the case of 3 regions with *n* sectors, but it can be applied to any number of regions and sectors.
The starting point of the model is a MRIO table. This table describes the flows of goods and services from every industry in a certain country to the intermediate and final users of other countries. We can distinguish 3 main components in a MRIO table, where superscripts indicate regions:

$$\mathbf{Z} = \begin{bmatrix} \mathbf{Z}^{11} & \mathbf{Z}^{12} & \mathbf{Z}^{12} \\ \mathbf{Z}^{21} & \mathbf{Z}^{22} & \mathbf{Z}^{23} \\ \mathbf{Z}^{31} & \mathbf{Z}^{32} & \mathbf{Z}^{33} \end{bmatrix};$$

$$\mathbf{f} = \begin{bmatrix} \mathbf{f}^{1} \\ \mathbf{f}^{2} \\ \mathbf{f}^{3} \end{bmatrix} = \begin{bmatrix} \mathbf{f}^{11} + \mathbf{f}^{12} + \mathbf{f}^{13} \\ \mathbf{f}^{21} + \mathbf{f}^{22} + \mathbf{f}^{23} \\ \mathbf{f}^{31} + \mathbf{f}^{32} + \mathbf{f}^{33} \end{bmatrix};$$

$$\mathbf{x} = \begin{bmatrix} \mathbf{x}^{1} \\ \mathbf{x}^{2} \\ \mathbf{x}^{3} \end{bmatrix}$$

where $\mathbf{Z}^{rs}$ denotes a sub-matrix of intermediate deliveries from country *r* to country *s*, with industries in columns and products in rows, $\mathbf{f}^{rs}$ denotes the final demand of country *s* for goods and services produced by country *r*, and $\mathbf{x}^{r}$ stands for the total product or industry outputs[1] of country *r*. The relation between $\mathbf{x}$, $\mathbf{Z}$ and $\mathbf{f}$ is defined by the accounting equation [1]

$$\mathbf{x} = \mathbf{Zi} + \mathbf{f} \qquad [1]$$

[1] It is product output when the MRIO table is of a product by product type and industry output when it is of an industry by industry type.

where $\mathbf{i}$ is the column summation vector.

Furthermore, let us assume that the MRIO table is extended to include a vector of sectorial emissions of GHG denoted by $\mathbf{g}$, a vector of direct emissions from households $\mathbf{h}$, and a vector of employment by sector $\mathbf{m}$:

$$\mathbf{g} = \begin{bmatrix} \mathbf{g^1} \\ \mathbf{g^2} \\ \mathbf{g^3} \end{bmatrix};$$

$$\mathbf{h} = \begin{bmatrix} h^1 \\ h^2 \\ h^3 \end{bmatrix};$$

$$\mathbf{m} = \begin{bmatrix} \mathbf{m^1} \\ \mathbf{m^2} \\ \mathbf{m^3} \end{bmatrix}$$

For each region, total emissions would be given by the sum of sectorial emissions plus household emissions, as reported in equation [2]:

$$G^r = \mathbf{g^r i} + h^r \qquad [2]$$

Similarly, the total employment of each region would be the sum of the employment in each sector, as summarised in equation [3]

$$M^r = \mathbf{m^r i} \qquad [3]$$

The input coefficients are obtained as in equation [4]

$$\mathbf{A}^{rs} = \mathbf{Z}^{rs}\left(\hat{\mathbf{x}}^s\right)^{-1} \qquad [4]$$

where $\left(\hat{\mathbf{x}}^s\right)^{-1}$ denotes the inverse of a diagonal matrix of total outputs in country *s*. Likewise, the emissions coefficients ($\mathbf{e}^r$) and employment coefficients ($\mathbf{d}^r$) are defined in equations [5] and [6] for region *r*:

$$\mathbf{e}^r = \left(\hat{\mathbf{x}}^r\right)^{-1}\mathbf{g}^r \qquad [5]$$

$$\mathbf{d}^r = \left(\hat{\mathbf{x}}^r\right)^{-1}\mathbf{m}^r \qquad [6]$$

Equation [1] can now be written as a standard input-output model as:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f} \qquad [7]$$

The solution to the this model is given by $\mathbf{x} = \mathbf{Lf}$, where $\mathbf{L} \equiv \left(\mathbf{I} - \mathbf{A}\right)^{\mathbf{-1}}$ denotes the so-called Leontief inverse. The total emissions and total employment are given by [8] and [9]

$$\mathbf{g} = \hat{\mathbf{e}}\mathbf{x} = \hat{\mathbf{e}}\mathbf{L}\mathbf{f} \qquad [8]$$

$$\mathbf{m} = \hat{\mathbf{d}}\mathbf{x} = \hat{\mathbf{d}}\mathbf{L}\mathbf{f} \qquad [9]$$

We can write [8] in its partitioned form as reported in [10]

$$\begin{bmatrix} \mathbf{g}^1 \\ \mathbf{g}^2 \\ \mathbf{g}^3 \end{bmatrix} = \begin{bmatrix} \mathbf{e}^1 & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{e}^2 & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{e}^3 \end{bmatrix} \begin{bmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} & \mathbf{L}^{13} \\ \mathbf{L}^{21} & \mathbf{L}^{22} & \mathbf{L}^{23} \\ \mathbf{L}^{31} & \mathbf{L}^{32} & \mathbf{L}^{33} \end{bmatrix} \begin{bmatrix} \mathbf{f}^{11} + \mathbf{f}^{12} + \mathbf{f}^{13} \\ \mathbf{f}^{21} + \mathbf{f}^{22} + \mathbf{f}^{23} \\ \mathbf{f}^{31} + \mathbf{f}^{32} + \mathbf{f}^{33} \end{bmatrix} \qquad [10]$$

From [10] we can calculate the emissions embodied in exports[2] $\mathbf{gexp}^{\mathbf{1}}$ and imports $\mathbf{gimp}^{\mathbf{1}}$ of region 1, as reported in equations [11] and [12]:

$$\mathbf{gexp}^{\mathbf{1}} = \mathbf{e}^1\mathbf{L}^{11}\left(\mathbf{f}^{12} + \mathbf{f}^{13}\right) + \left[\mathbf{e}^1\mathbf{L}^{12}\left(\mathbf{f}^{22} + \mathbf{f}^{23}\right) + \mathbf{e}^1\mathbf{L}^{13}\left(\mathbf{f}^{32} + \mathbf{f}^{33}\right)\right] \qquad [11]$$

$$\mathbf{gimp}^{\mathbf{1}} = \left(\mathbf{e}^2\mathbf{L}^{21} + \mathbf{e}^3\mathbf{L}^{31}\right)\mathbf{f}^{11} + \left[\left(\mathbf{e}^2\mathbf{L}^{22} + \mathbf{e}^3\mathbf{L}^{32}\right)\mathbf{f}^{21} + \left(\mathbf{e}^2\mathbf{L}^{23} + \mathbf{e}^3\mathbf{L}^{33}\right)\mathbf{f}^{31}\right] \qquad [12]$$

Equation [11] represents the emissions generated in region 1 that are linked to the domestic final demand of region 2 and 3. This vector of emissions embodied in exports of region 1 can be expressed as the sum of 2 components:

- $\mathbf{e}^1\mathbf{L}^{11}\left(\mathbf{f}^{12} + \mathbf{f}^{13}\right)$, yields the emissions generated in region 1 when producing goods and services for final use which are exported to regions 2 and 3 (e.g. German cars exported to Japan);
- $\left[\mathbf{e}^1\mathbf{L}^{12}\left(\mathbf{f}^{22} + \mathbf{f}^{23}\right) + \mathbf{e}^1\mathbf{L}^{13}\left(\mathbf{f}^{32} + \mathbf{f}^{33}\right)\right]$, yields the emissions generated in region 1 when producing the intermediate exports that are used abroad to produce final goods and services consumed by regions 2 and 3 (e.g. German engine components sold to the Czech Republic for the production of Czech cars to be exported to Japan)

Analogously, expression [12] is the vector of emissions generated in regions 2 and 3 that are linked to the domestic final demand of region 1, which can be expressed as the sum of 2 components:

- $\left(\mathbf{e}^2\mathbf{L}^{21} + \mathbf{e}^3\mathbf{L}^{31}\right)\mathbf{f}^{11}$, yields the emissions generated in regions 2 and 3 when producing the intermediate imports used by region 1 to produce final goods and services

[2] Excluding intermediate exports to be used for the production of goods and services to be imported by countries in order to satisfy their final demand.

consumed in region 1 (e.g. imports of dishwasher components from China for the production of German dishwashers to be sold in the domestic market);

- $\left[\left(\mathbf{e}^2\mathbf{L}^{22}+\mathbf{e}^3\mathbf{L}^{32}\right)\mathbf{f}^{21}+\left(\mathbf{e}^2\mathbf{L}^{23}+\mathbf{e}^3\mathbf{L}^{33}\right)\mathbf{f}^{31}\right]$, yields the emissions generated in regions 2 and 3 when producing the intermediate imports used by regions 2 and 3 to produce the final goods and services imported by region 1 (e.g. imports of dishwasher components from China to be used in Taiwan for the fabrication of dishwashers to be exported to Germany).

We can define the emission trade balance $\mathbf{etb^1}$ of region 1 as the difference between the emissions exported and imported, as reported in equation [13]

$$\mathbf{etb^1} = \mathbf{gexp^1} - \mathbf{gimp^1} \qquad [13]$$

The emission trade balance allows us to analyze to what extent a country is a net exporter or importer of emissions. If the emissions embodied in the exports of a country are larger than those embodied in its imports, then the country will be a net emission exporter and, therefore, it will have an emission surplus. This might be the cases for developing countries, which, in some cases, host the displaced production of high emission intensive products that ultimately are conveyed to the market of developed economies. Otherwise, a country will be a net importer and will show an emission deficit.

In a similar way, we can calculate the emissions embodied in imports and exports, and the trade balance of the other 2 regions. Moreover, applying expressions [11], [12] and [13] to [9], we can obtain the embodied employment in trade, and the employment trade balances. The interpretation of the embodied employment in exports and imports is similar to those of the emissions. The employment trade balance compares the employment linked to the exports of one country against the employment generated abroad by its imports. This indicator shows to what extent a country is an employment net exporter (i.e. embodied employment in exports is greater than that of imports) or an employment net importer (i.e. embodied employment in imports is greater than that of exports).

In this paper, we have used expressions [11], [12] and [13] to calculate the embodied GHG emissions and embodied employment both in exports and imports, plus the subsequent trade balances. We have conducted our analysis using the World Input-Output Database (WIOD) (Timmer et al, 2012). This database comprises a set of harmonized Supply, Use and Symmetric Input-Output (I-O) tables, valued at current and previous year prices. It also includes data on international trade and satellite accounts related to environmental and socio-economic indicators. It covers the period 1995 to 2009[3], with information from 35 industries, 60 products and 41 regions: 27 Member States of the European Union (EU-27), 13 non-EU27 countries (Australia, Brazil, Canada, China, India, Indonesia, Japan, South Korea, Mexico,

[3] The figures for the year 2009 are preliminary estimates, therefore the time scope has been constrained in this paper to the period 1995-2008.

Russia, Turkey, the United States of America (USA) and the Rest of the World (RoW) as an aggregated region[4]). For our analysis we treated the EU-27 as a single region, therefore we analysed 15 regions in total.

We have also used the environmental extensions of the World Input-Output Database (WIOD), which include time series of sectoral emissions of GHGs based on the accounting principles of national accounts (residence principle). These environmental accounts can be linked directly to other relevant socio-economic information of the WIOD database, and can also be used to track the flows of emissions across the world, too. The GHG accounts cover for each country the emissions of CO_2, CH_4, and N_2O released from national economic activities, i.e. those generated by economic activities of its resident units. This accounting principle differs from the one followed by the emissions inventories of the United Nations, which consider the environmental pressures generated within the area under national jurisdiction (territorial principle). Finally, we have also used data on sectoral employment from the socio-economic accounts of WIOD. A more detailed description on the database can be found at www.wiod.org and in Timmer et al, (2012).

3. Results

This section provides a summary of the results obtained from applying equations [11], [12] and [13] to the WIOD database. Section 3.1 is focused on embodied GHG emissions and the section 3.2 on embodied employment in international trade.

3.1 GHG emissions generated by trade

3.1.1. Who is who in exporting GHG emissions?

According to the data reported on the left hand side of Figure 1, in 2008 24% of global GHG emissions (9.4 Giga tonnes of CO_2 equivalents, Gt) were transferred between countries through international trade. China was the world's largest exporter of emissions, by exporting 2.8 Gt, which represents 30% of the total GHGs embodied in international trade. The RoW is the second region in terms of emissions exported to satisfy the final demand of other countries (2.4 Gt, 25.7% of global exports). The EU-27 exported 8.3% of the worldwide emissions embodied in international trade (0.78 Gt), while Russia contributed 8.2% (0.77 Gt), the USA 7.5% (0.71 Gt) and India 4% (0.37 Gt).

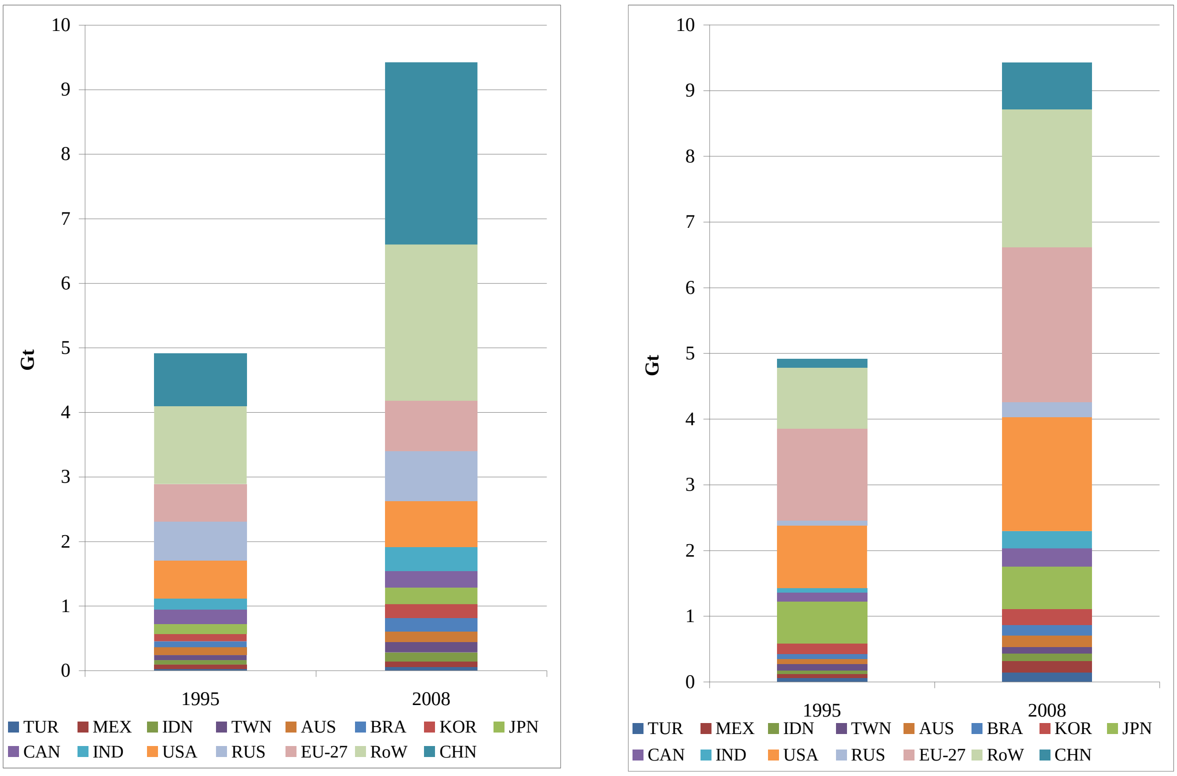
Comparing the shares of the emissions exported by country with respect to their total emissions, Taiwan had the largest share (49.7%), followed by Canada (37.4%), Korea (35%), China (33.6%) and Russia (33.3%). On the contrary, the USA (11.1 %), Turkey (15 %), the EU-27 (15.4%), Mexico (15.9 %) and India (16.3 %) showed the lowest rates of embodied emissions in exports over their national emissions.

[4] The RoW is composed of the non Annex B countries (exc. Brazil, China, India, Indonesia, Mexico, South Korea, Taiwan and Turkey) of the Kyoto protocol and some minor Annex B countries (Croatia, Finland, Iceland, Liechtenstein, Monaco, New Zealand, Norway, Switzerland and Ukraine). Annex B of the Kyoto Protocol includes the countries that have a commitment to limit GHG emissions.

Between 1995 and 2008, the GHG emissions linked to trade almost doubled, from 4.9 Gt (16.2% of total emissions) to 9.4 Gt (24%). That growth was equivalent to 50% of the change in global emissions during the same period. China was the country that most contributed to this growth. Between 1995 and 2008, Chinese exports of GHGs increased by a factor of 3.4, i.e.: from 0.8 Gt to 2.8 Gt (44.5% of the growth in the global trade on emissions and 51.6% of the growth in national Chinese emissions). The emissions exported by the RoW doubled from 1.2 Gt in 1995 to 2.4 Gt in 2008 (26.9% of the global change and 45.9% of the growth in the emissions of the RoW). Other countries like Australia, India and Russia also contributed to the growth in the global volume of emissions traded, although their contribution was below 5% in all cases.

Figure 1: Global emissions embodied in trade by country, 1995-2008. (Gt)

Emissions embodied in exports **Emissions embodied in imports**

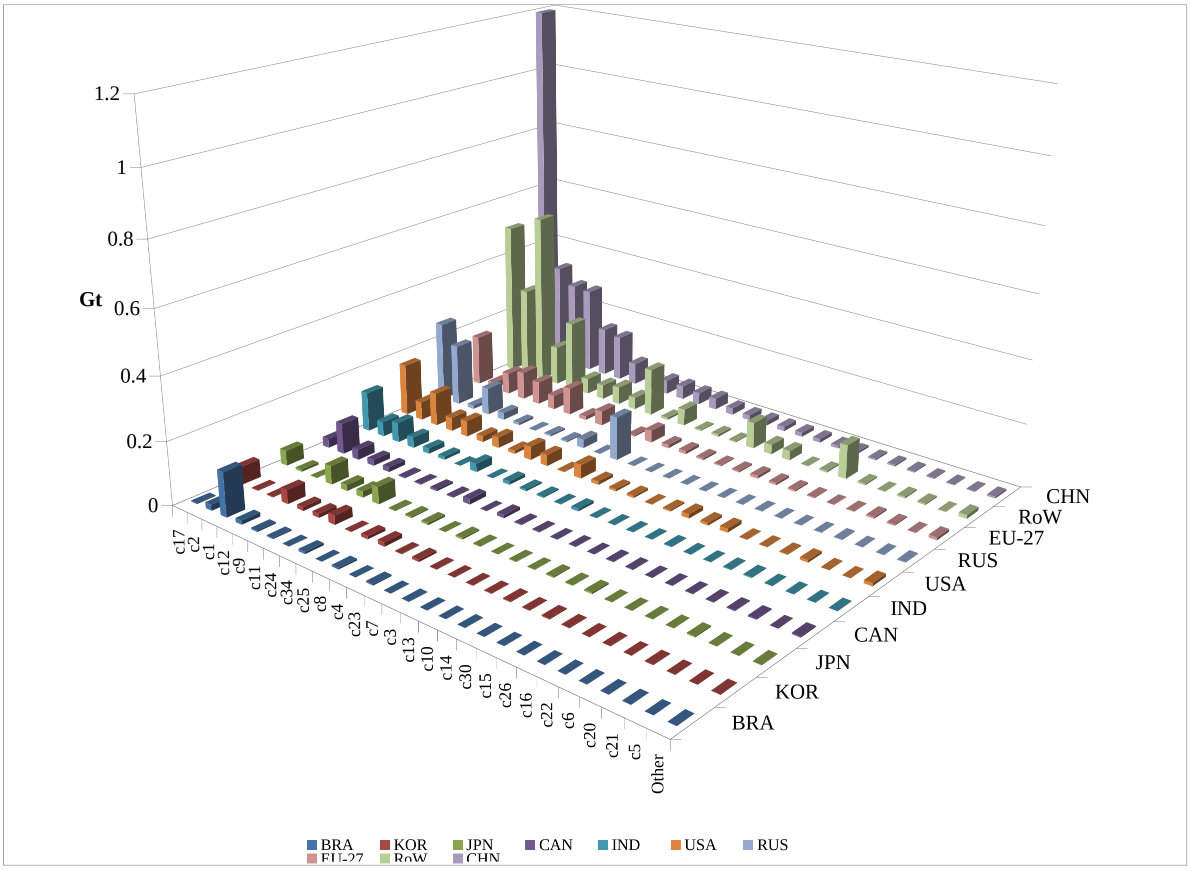


Note: AUS: Australia; BRA: Brazil; CAN: Canada; CHN: China; EU-27: European Union; IDN: Indonesia; IND: India; JPN: Japan; KOR: Korea; MEX: Mexico; RoW: Rest of the World; RUS: Russia; TWN: Taiwan; USA: United States of America.

These results can also be disaggregated to distinguish which sectors contributed to the atmospheric release of the emissions embodied in trade (Figure 2). In the year 2008, 28.5% of the GHG emissions embodied in exports were generated by the electricity sector, 14.4% by agriculture, 12.7% by mining, 9.2% by basic metals, and 6.7% by the chemical industry. The electricity sector generated most of the trade related emissions in the top-four exporting regions: 42.3% in the case of China, 20.8% in the EU-27, 33.2% in Russia, and 23.7% in the USA. In the RoW, although electricity amounted to 20.7% of the exported emissions, the agricultural sector was the main emission exporter (23.1%). In particular, 67.5% of the emissions exported by Brazil were released by agriculture.

In China, primary sectors and heavy industries emit more than 40% of the exported emissions (agriculture 11.7%, mining 10%, basic metals 9.9%, chemical 5.6%, and non-metallic industries 5.2%). In the EU-27, the main emission exporting sectors, excluding electricity, were basic metals (11.5%), maritime transport (11.3%), chemicals (9.6%), agriculture (8.9%), and air transport (6%). In the USA, primary sectors generated 23.6% of the emissions embodied in exports (agriculture 15.1% and mining 8.4), while 17.2% of the emissions exported were generated by transport activities (including inland, air and maritime transportation).

Figure 2: Global emissions embodied in trade by sector in selected countries, 2008 (Gt)



c1: Agriculture, Forestry and Fishing; c2: Mining and Quarrying; c3: Food, Beverages and Tobacco; c4: Textiles; c5: Leather Footwear.; c6: Wood Products; c7: Pulp, Paper, Printing and Publishing; c8: Coke, Refined Petroleum and Nuclear Fuel; c9: Chemical Products; c10: Rubber and Plastics; c11: Other Non-Metallic Mineral; c12: Basic and Fabricated Metal; c13: Machinery, Nec; c14: Electrical and Optical Equipment; c15: Transport Equipment; c16: Other Manufactures; c17: Electricity, Gas and Water Supply; c20: Wholesale Trade; c21: Retail Trade; c22: Hotels and Restaurants; c23: Inland Transport; c24: Water Transport; c25: Air Transport; c26: Other Transport Services; c30: Renting of M&Eq and Other Business Activities; c34: Other Services.

3.1.2. Who is who in importing GHG emissions?

The emissions embodied in international trade can also be analysed from the perspective of the importer country (right hand side of figure 1). In 2008, the EU-27 was the main destination for the global emissions generated by international trade (2.4 Gt, 25% of the total emissions traded). The RoW was the second region in terms of embodied emissions in imports (2.1 Gt, 22.3% of total imports). Embodied emissions in the USA imports amounted to 18.4% of the emissions embodied in global trade (1.7 Gt); in China, 7.6% (0.71 Gt); in Japan, 6.8% (0.65 Gt); and in Canada 3% (0.28 Gt). During the same period, the RoW showed the highest increase in terms of emissions embodied in imports (+1.17 Gt), followed by the EU-27 (+0.95 Gt), the USA (+0.78 Gt) and China (+0.58 Gt). The RoW, the EU-27, the USA and China turned out to be the main drivers of the growth in global trade related emissions between 1995 and 2008 (26%, 21.1%, 17.4%, and 12.8%, respectively).

As regards the share of the embodied emissions in imports over the total emissions by country, Japan (53%), the EU-27 (46.3%), South Korea (40.7%), Canada (40.1%), and Turkey (37.9%) were the top-five countries with the largest shares. In contrast, Indonesia (18.5%), Brazil (17 %), India (11.5%), Russia (9.9 %), and China (8.5 %) showed the lowest rates of emissions imported over their total national emissions.

Table A.1 of the appendix depicts the inter-country emissions embodied in bilateral trade flows in 2008 for the main world economies. The RoW, the EU-27, and the USA were the top-three destination regions of Chinese exports of GHG emissions (28.6%, 23.1%, and 20.1%, respectively). The top-four emission importer regions from the RoW were the EU-27 (34.9%), the USA (21.5%), China (12.2%), and Japan (8.6%). Half of the emissions exported by the EU-27 were conveyed to the RoW, 18.4% to the USA, and 8.4% to China. The main trade partners of the USA in terms of exports of GHG were the RoW (30.6%), the EU-27 (21.5%), Canada (11.3%), China (9.1%), and Mexico (8.9%). The USA imported 62.4% of the emissions exported by Mexico and 50% of Canadian exports of GHG.

3.1.3. Who is net exporter and net importer of GHG emissions?

Comparing the emissions embodied in exports and imports, we can analyse the emission trade balance of each country. We can differentiate two groups of countries according to their emission trade balance: those for which the emissions embodied in exports are lower than those imported (i.e. net emission importers or with an emission deficit, mostly developed countries), and those for which the emissions embodied in exports are greater than those exported (i.e. net emission exporters or with an emission surplus, mostly developing countries).

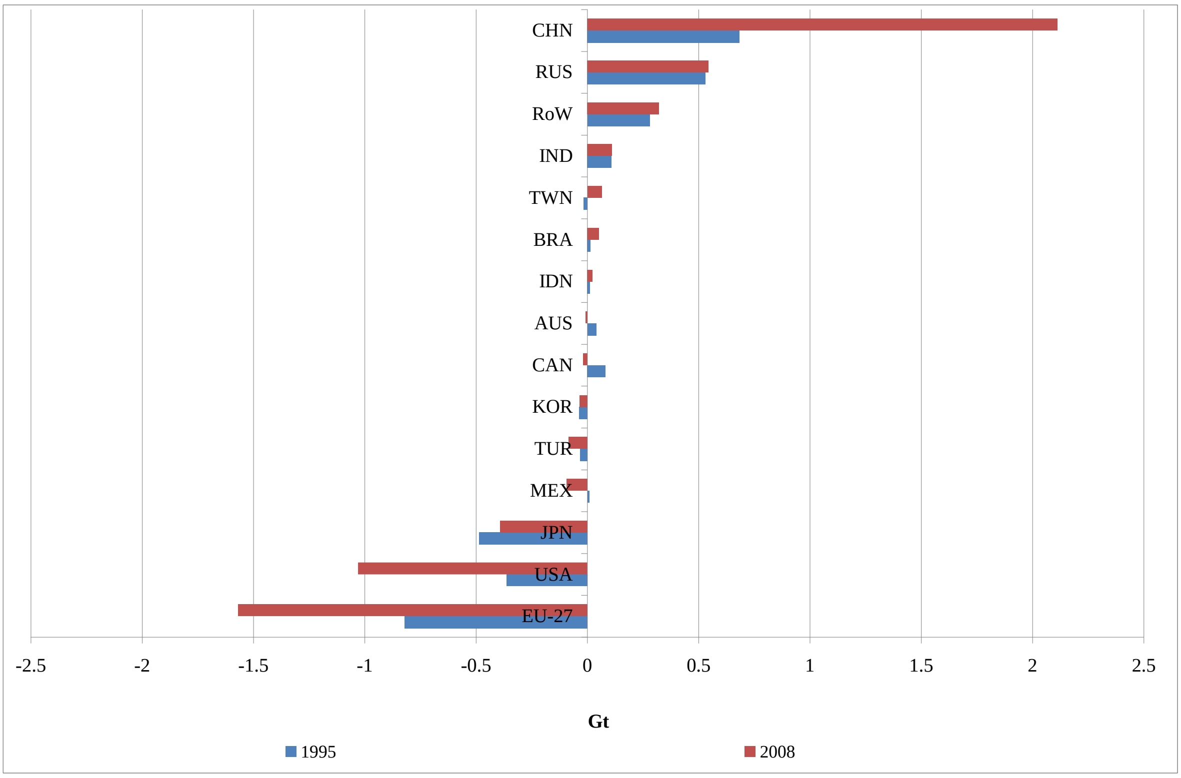
According to the data reported in

Figure 3 for 2008, the EU-27 was the region with the largest emission deficit (1.6 Gt), followed by the USA (1.03 Gt). Japan (with a deficit of 0.39 Gt), Mexico (0.09 Gt), Turkey (0.08 Gt), South Korea (0.03 Gt), Canada (0.02 Gt), and Australia (0.01 Gt) were also net emission importers, though their deficits were somewhat lower in absolute terms than those of the EU-27 and the USA.

The emission deficit of such group of countries was supported by the surplus of other countries. In 2008, China was the world's largest net exporter of emissions, with a surplus of 2.1 Gt (25.2% of its total emissions). Russia (0.55 Gt, and 23.4% of its emissions), the RoW (0.32 Gt, 3.6%), India (0.11 Gt, 4.8%), and Taiwan (0.06 Gt, 19.9%), followed China in the ranking of net emission exporters.

Figure 3 also shows an increasing gap between the main net exporters and importers. Thus, while the emission deficit of the EU-27 and the USA has increased since 1995 by a factor of 1.9 and 2.8 respectively, the surplus of China has increased by a factor of 3. Moreover, the increase in the emission deficit of the EU-27 and the USA (0.75 and 0.67 Gt respectively), is equivalent to the increase in the surplus of China (1.4 Gt). Besides, while Mexico, Canada and Australia showed an emission surplus in 1995, it turned into a deficit in 2008.

Figure 3. GHG emission trade balance, 1995 and 2008. (Gt)



3.2. Employment generated by trade

3.2.1. Who is who in exporting employment?

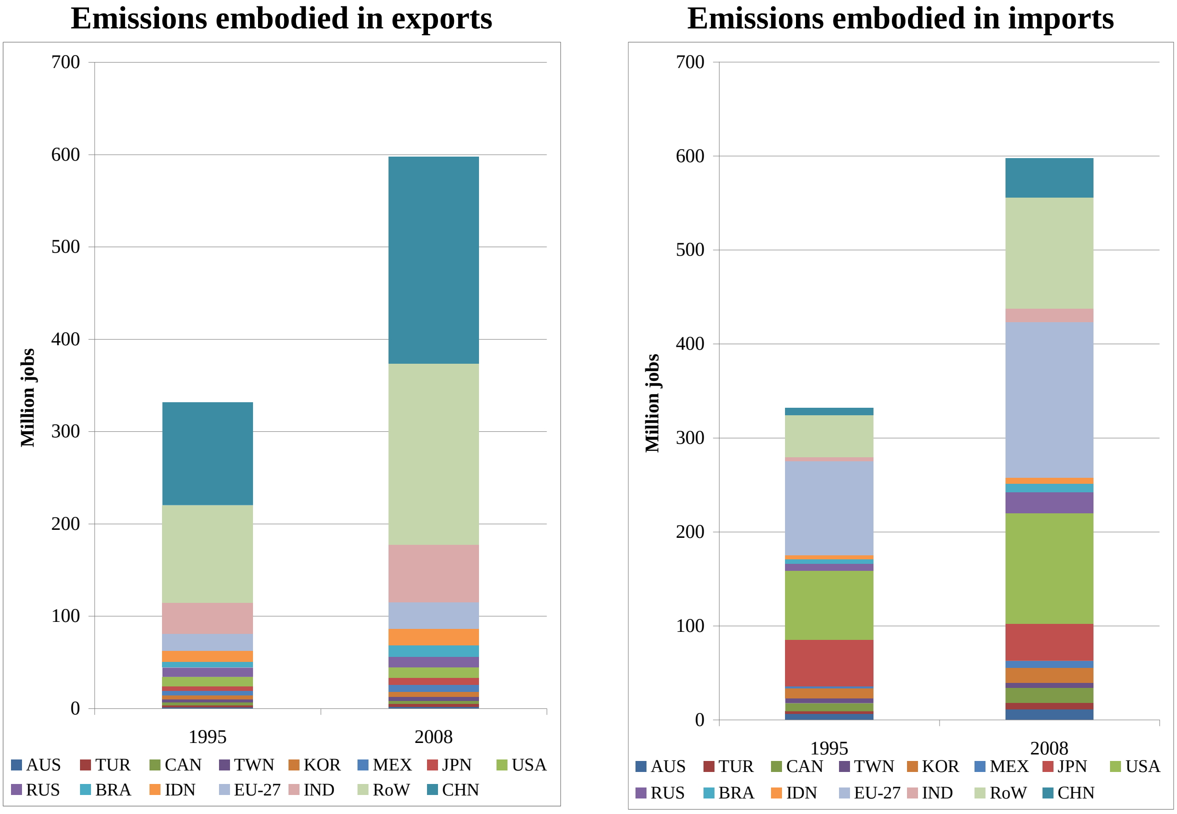
The increase in the volume of international trade has also affected employment all around the world. In the period 1995-2008, the total employment generated worldwide by international trade increased by 266 M-job, from 332 M-job in 1995 (13.8% of total employment) to 598 M-job in 2008 (20.1% of total employment).

In 2008, China was the country in which international trade generated the largest amount of jobs (224 M-job, 37.5% of the total employment generated by trade worldwide) (left hand side of

Figure 4). In the same year, the production of exported goods and services generated 196 M-job in the RoW (32.8% of global employment in trade), 63 M-job in India (10.5%), 29 M-job in the EU-27 (4.8%), 17 M-job in Indonesia (2.1%), 13 M-job in Brazil (2.1%), 12 M-job in the USA (1.9%), and 11 M-job in Russia (1.9%). Taiwan (38.5%), China (28.9%), South Korea (24.4%), the RoW (22.3%), and Canada (20.6%) were the countries with the highest share of their total employment linked to exports. In all remaining countries analyzed the share was below the world average (20.1%): 12.6% in the EU-27, 12.2% in Japan, and 7.4% in the USA.

Between 1995 and 2008, the international trade related employment grew by 266 M-job (+46.2%) worldwide. China was the country that benefitted most from the increase in international trade during this period. Between 1995 and 2008, the number of Chinese workers linked to the production be exports grew by 113 M-job (32.8% of the growth in global trade related employment), while the total employment in China grew by 94 M-job. In the RoW, the number of jobs embodied in exports grew by 91 M-job, equivalent to 37.5% of the growth in the global employment generated by trade, and to 31.8% of the employment growth in such region. The following regions also benefitted notably from the growth in the employment generated by international trade: India, with 29 M-job of new jobs linked to exports (34.9% of the change in the total employment in the country); the EU-27, with 10 M-job (36%); Brazil, with 6.2 M-job (27.1%), and Indonesia 5.9 M-job (31.8%).

Figure 4: Global employment embodied in trade by country, 1995-2008. (M-job)



Note: AUS: Australia; BRA: Brazil; CAN: Canada; CHN: China; EU-27: European Union; IDN: Indonesia; IND: India; JPN: Japan; KOR: Korea; MEX: Mexico; RoW: Rest of the World; RUS: Russia; TWN: Taiwan; USA: United States of America.

At the sectorial level (Figure 5), 37.2% of the global employment linked to the production of exports was generated in agriculture; 6.3% in other services; around 5% in the textile industry, mining, retail trade, renting machinery and other business activities; and 3% in electrical equipment and inland transportation. Agriculture was the sector that employed most of the jobs linked to international trade, e.g. China (33.5%), RoW (52.8%), India (42.9%) and Brazil (36.4%). In the EU-27, the USA and Canada half of the employment generated by exports was linked to service activities.

In China, 35.3% of the employment embodied in exports was linked to primary sectors. There, one third of the jobs were employed in manufacturing industries, standing out the manufacture of textiles (7%), electrical and optical equipment (5%) and rubber and plastics (3.1%). In the EU-27 and the USA, basic and fabricated metals, electrical and optical equipment, machinery and transport equipment were the manufacturing industries that most benefitted from trade in terms of employment.

Figure 5: Global employment embodied in trade by sector in selected countries, 2008. (Million jobs)

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c17: Electricity, Gas and Water Supply; c2: Mining and Quarrying; c1: Agriculture, Forestry and Fishing; c12: Basic and Fabricated Metal; c9: Chemical Products; c11: Other Non-Metallic Mineral; c24: Water Transport; c34: Other Services; c25: Air Transport; c8: Coke, Refined Petroleum and Nuclear Fuel; c4: Textiles; c23: Inland Transport; c7: Pulp, Paper, Printing and Publishing; c3: Food, Beverages and Tobacco; c13: Machinery, Nec; c10: Rubber and Plastics; c14: Electrical and Optical Equipment; c30: Renting of M&Eq and Other Business Activities; c15: Transport Equipment; c26: Other Transport Services; c16: Other Manufactures; c22: Hotels and Restaurants; c6: Wood Products; c20: Wholesale Trade; c21: Retail Trade; c5: Leather Footwear.

3.2.2. Who is who in importing employment?

The right hand side of

Figure 4 depicts the number of jobs generated worldwide by each country's imports. The EU-27 is the leading geographical area in creating jobs elsewhere through its imports. In 2008, almost 28% (165 M-job) of the total employment generated by international trade was due to the EU-27 imports. The imports of the RoW generated 19.8% of the total employment embodied in international trade (118 M-job) while the USA generated 19.7% (118 M-job); China, 7% (42 M-job) and Japan 6.6% (39 M-job). Between 1995 and 2008, the RoW showed the highest increase in terms of employment generated by imports (+73 M-job), followed by the EU-27 (+65 M-job), the USA (+44 M-job), China (+34 M-job) and Russia (+16 M-job).
Comparing the employment generated abroad by each country´s imports and its total employment, Australia (97.3%), Canada (91.7%), the USA (77.6%), the EU-27 (72.1%) and South Korea (66.5%) ranked among the highest. On the contrary, India (3.2 %), China (5.6 %), Indonesia (6.3 %), Brazil (9.1 %) and the RoW (13.4%) showed the lowest rate of imported employment over their national totals.
Table A2 of the appendix shows a matrix of bilateral flows of employment embodied in trade for the year 2008. The RoW, China, and India were the regions that most benefitted from the EU-27 imports, being the number of jobs generated in those countries 70, 55, and 18 M-job, respectively. The employment generated by trade in the RoW is mainly linked to exports to the EU-27 (35.9%), the USA (21.3%), China (13.1%) and Japan (7.9%). In China, exports to the RoW amounted to 28.3% of the Chinese embodied employment in exports, while the exports to the EU-27 and the USA amounted 24.7% and 19.6%, respectively. Almost 50% of the employment generated by international trade in the EU-27 was linked to exports to the RoW, 17% to the USA, and 9.8% to China. The main trade partners of the USA in terms of embodied employment in exports were the RoW (34.8%), the EU-27 (23.1%), Canada (10.9%), China (8.3%) and Mexico (6.6%). Finally, exports to the USA generated 59.2% of the jobs linked to trade in Mexico and 55%, in Canada.

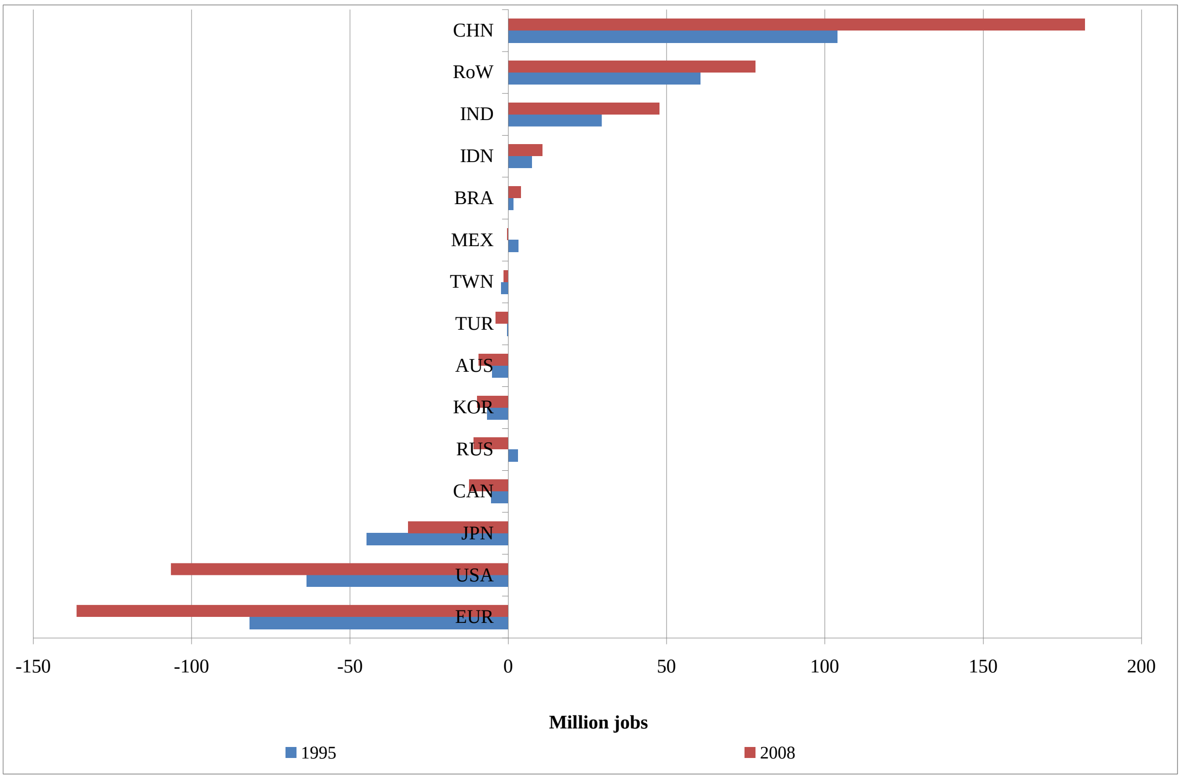
3.2.3. Who is net exporter and net importer of employment?

Figure 6 shows the employment trade balance for the years 1995 and 2008. In 2008, the EU-27 and the USA were the largest net employment importers through international trade, with a negative employment trade balance of 136 and 107 M-job, respectively. Japan, Canada, Russia, South Korea, Australia, Turkey and Taiwan are also net employment importers, though their trade deficits are lower in absolute terms than those of the EU-27 and the USA. Conversely, China led the group of countries that benefitted most from international trade in terms of net employment. In 2008, China was the world's largest net employment recipient, with 182 M-job (23.5% of its total employment), followed by the RoW (78 M-job and 8.8% of its total employment), India (48 M-job, 10.3%), and Indonesia (11 M-job, 10.2).

Between 1995 and 2008, the employment trade balance (in absolute values) has increased, especially in the case of the EU-27 and the USA. The net transfers of employment from the EU-27 and the USA to other regions have increased since 1995 by a factor of 1.7 each (with a growth of 55 and 43 M-job, respectively). [5]At the same time, the net employment transfers received by China have increased by a factor of 1.8 (+78 M-job).

[5] At this point, the reader should be aware that a shift moving into the direction of replacing imports by domestic production would not necessarily bring the same amount of jobs as those actually created in the exporting countries. It is self-evident that this is fully dependent on many factors such as productivity, efficiency and technological differences between exporting and importing countries

Figure 6. Employment trade balance, 1995 and 2008. (M-job)



4. Discussion

4.1. Relevance of the results

The international community is currently involved in a negotiation process for a new implementation agreement of the United Nations Framework Convention on Climate Change. The agreement currently in force, the Kyoto Protocol, only establishes emissions targets for a limited group of developed countries (Annex B countries[6]), while the remaining countries do not have limits to their GHG emissions. In this sense, Annex B countries can benefit from the consumption of goods and services imported from non-Annex B countries, and at the same time reduce their emissions by "shifting" these emissions to non-Annex countries. Moreover, since the climate legislation is more lax in non-Annex countries, there is a risk of carbon leakage from Annex-B to non Annex-B countries.

[6] The list of Annex B countries of the Kyoto protocol includes: Australia, Bulgaria, Canada, Croatia, Czech Republic, Estonia, the EU-15, Hungary, Iceland, Japan, Latvia, Liechtenstein, Lithuania, Monaco, New Zealand, Norway, Poland, Romania, Russian Federation, Slovakia, Slovenia, Switzerland, Ukraine, the USA.

International trade eases these processes of relocation of pollution, allowing the accomplishment of emission targets at the national level; however, at the global level, the emissions do not necessarily decrease. Indeed, one of the key elements of the post-Kyoto debate is the question of the allocation of the responsibilities for emissions among countries and the "transfers" of emissions between countries via internationally. According to the consumer responsibility principle, emission importer countries should bear more responsibility for those emissions. This position is supported by some emerging economies that have been leading the growth of global emissions during the last decade and a half, such as China. These countries argue that, as it has been demonstrated by several studies (Weber et al., 2008, Davis and Caldeira, 2010, Peters et al., 2011), an increasing part of their emissions are released when producing goods and services that are consumed by developed countries (Zhang, 2011). However, this approach ignores that exporting countries simultaneously obatin important economic benefits from the production of those goods, and, therefore, from releasing GHGs to the atmosphere. Hence, negotiation positions claiming a raise of the share of the burden of climate change of the developed countries (as net emission importers or consumers), should bear in mind that this may lead to a reduction in their imports from developed countries and, therefore, could have negative economic consequences on developing countries. Indeed, this argument is supported by our calculations: in the year 2008, 24% of global GHG emissions and 20.1% of total worldwide employment were linked to international trade. Those figures definitely lead to the conclusion that employment, environment and trade must go hand in hand and their joint importance should not be ignored when allocating the responsibilities of GHG emissions embodied in international trade.

4.2. Who are the key players of this game?

China, the EU-27, and the USA are key players of trading jobs for emissions due to:

(a) *Their quantitative importance as top exporters/importers of GHG emissions and employment*; in the case of China, this relevance derives from its role as both top emission and top employment exporter (jobs receiver). China exports 30% of the GHG emissions embodied in international trade and hosts 37.5% of the employment generated through international trade. On other hand, the EU-27 and the USA take advantage from the GHG emitted abroad to satisfy their domestic final demands, but they also create employment in other countries through their imports. The EU-27 and the USA were the destination of 25% and 18.4% of the GHG emissions embedded in international trade. They also were the regions that contributed most to the creation of employment abroad through their imports (28% and 19.7% of the employment generated by trade worldwide, respectively).

(b) *The quantitative importance of export/import related GHG emissions and employment over national totals*; China shows a high dependence on its exports: 28.9% of Chinese employment and 33.6% of its national emissions are devoted to the production of exports to satisfy the final demand of other countries. Conversely, the EU-27 is highly dependent on its imports: the emissions embodied in the EU-27 imports are equivalent to 46.3% of its domestic emissions. China and the EU-27 should therefore pay especial attention to issues related to trade, employment and emissions, since their socio-economic structures seem to be very sensitive to them.

4.3. A possible way forward

Different options for including trade issues in climate polices have been suggested. These measure include, among others, the use of trade-based mechanisms -such as border-tax adjustments- or the adjustment of the emissions inventories to trade (Peter and Hertwich, 2008). Policy options can have economic consequences that should be analysed carefully. When assessing these options for reducing the emissions linked to international trade and their economic implications, it is important to analyze not only the countries where emissions and employment are generated, but also the sectors involved. According to our analysis, the most emission intensive sectors do not necessarily have to be the most employment intensive. This can be observed by comparing the landscapes of Figure 2 and Figure 5 and by looking at Table 1.

Table 1. GHG emission and employment embodied in exports: 2008.

	Share of GHG emissions embodied in exports		Share of employment emissions embodied in exports		Employment in exports / Emissions in exports (jobs / 1000 tCO_2e)	
	Goods	Sectors	Goods	Sectors	Goods	Sectors
Electrical and Optical Equipment	12.4%	0.8%	11.7%	4.1%	55	297
Mining and Quarrying	11.6%	13.6%	6.3%	6.6%	32	29
Basic Metals and Fabricated Metal	10.9%	10.0%	4.5%	2.9%	24	17
Chemicals and Chemical Products	9.6%	7.0%	4.3%	1.7%	26	14
Agriculture, Hunting, Forestry and Fishing	6.3%	12.6%	13.8%	34.9%	129	163
Coke, Refined Petroleum and Nuclear Fuel	5.8%	4.0%	2.0%	0.2%	20	3
Transport Equipment	4.6%	0.4%	4.0%	1.3%	51	189
Textiles and Textile Products	4.5%	0.7%	10.8%	5.1%	140	448
Machinery, Nec	4.4%	0.4%	3.8%	1.8%	51	278
Food, Beverages and Tobacco	4.3%	0.5%	8.7%	1.6%	118	180
Water Transport	3.3%	3.9%	1.0%	0.5%	18	7
Manufacturing, Nec; Recycling	2.8%	1.2%	4.5%	2.6%	94	127
Inland Transport	2.7%	4.0%	1.7%	3.6%	37	52
Renting of M&Eq and Other Business Activities	2.6%	0.8%	4.6%	4.2%	104	317
Other Non-Metallic Mineral	2.1%	3.5%	0.6%	0.7%	18	11
Air Transport	2.0%	2.2%	0.8%	0.3%	23	8
Rubber and Plastics	1.8%	1.2%	1.8%	1.9%	58	94
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	1.4%	0.3%	2.4%	3.4%	99	582
Electricity, Gas and Water Supply	1.3%	28.7%	0.1%	0.7%	6	1
Other Community, Social and Personal Services	1.0%	2.0%	2.4%	6.3%	141	188
Rest	4.5%	2.2%	10.3%	15.5%	135	423
Total	100.0%	100.0%	100.0%	100.0%	59	59

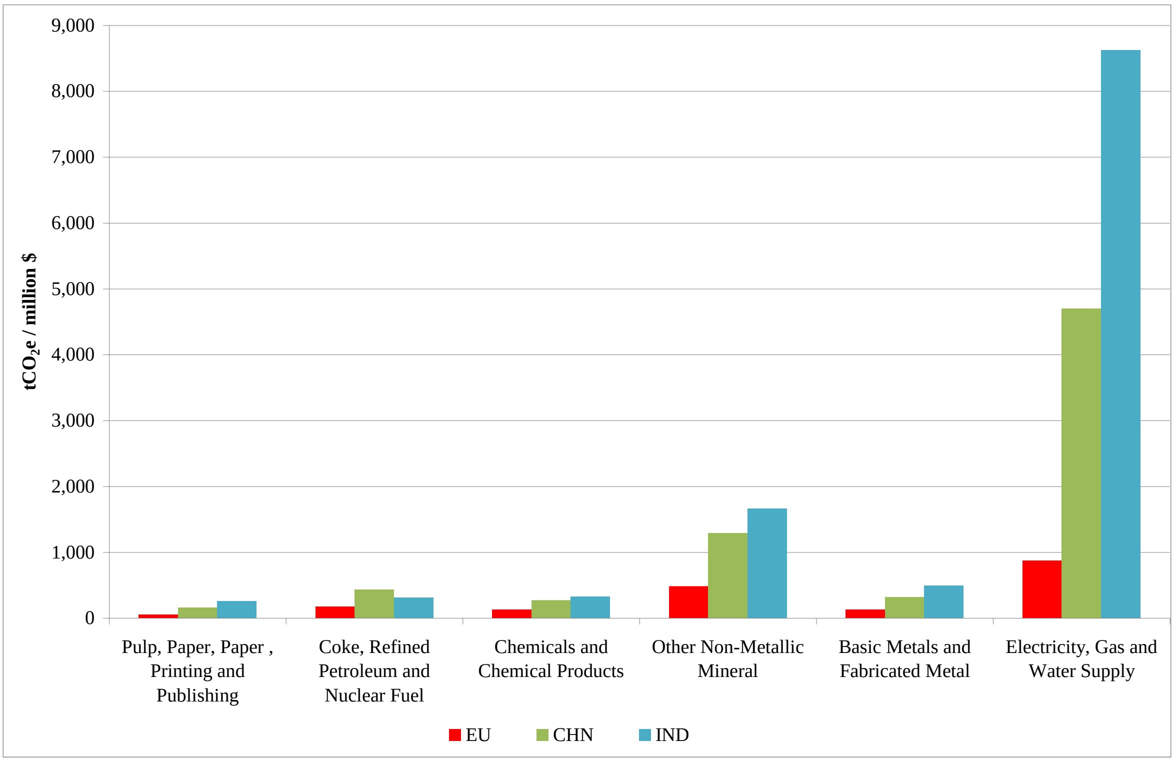
Source: Own elaboration.

Table 1 shows that electrical and optical equipment goods were responsible in 2008 for 12.4% of the emissions and for 11.7% of the total employment embedded in global exports. However, manufacturing industry producing such goods only contributed to 0.8% of the emissions and 4.1% of the employment. Using such information, it is estimated that a reduction in the exports/imports of electrical and optical equipment which decreases the emissions by 1000 tCO_2e, would bring a reduction of 55 jobs in the whole economy. However, policy measures focused on emission reductions in the electricity, gas and water supply industries would involve, *ceteris paribus*, only 1 job less per 1000 tCO_2e reduction in emissions. Additionally, the benefits in terms of emission reductions would be really significant as this industry is responsible for nearly 30% of the total emissions embedded in trade. Therefore, policy measures aiming to reduce the emissions generated in the electricity products industry are rather more recommendable than reducing directly the imports of other goods, such as electrical and optical equipment. To sum up, from a global perspective, it would be better to prioritise measures oriented to those commodities/sectors with the greatest potential for reducing the emissions and the least impact on employment or, in other words, with the highest emission intensities per job.

One way of favouring the reduction of the emissions embodied in trade but minimising the economic impact on exporting countries, would be sharing the responsibility among the trade partners. For instance, the Clean Development Mechanism (CDM) of the Kyoto Protocol seems to be a good tool for sharing the efforts for reducing emissions (IPCC, 2007). CDM allows Annex I countries to meet part of their reduction targets by investing in projects that reduce the emissions in developing countries. In this sense, the reduction of emissions embodied in exports at the sectorial level could be based on the improvement of the production technologies. Although technological change has contributed notably to offset the growth in GHG emissions during the last years, there is still room for progress in this direction. The change in the emissions due to technological change is closely related to the reduction of the emission intensity of an economy, measured as the quotient between the emissions and total output.

Figure 7 shows emission intensities in the EU-27, China and India for the most emission intensive industries of the manufacturing sectors. For all sectors analysed, China and India showed a ratio of GHG emissions per unit of output much higher than in the EU-27. The gap existing between China and India with respect to the EU-27 could be interpreted as an improvement potential (in terms of cleaner technologies) of these emerging economies. This gap is especially relevant for the electricity sector.

Figure 7: Gap of the sectorial GHG emissions per unit of output in China and India with respect the EU, 2008. (tCO_2e/million $)



5. Conclusions

During the last two decades, developed countries have obtained environmental benefits in the form of reductions of greenhouse gas emissions by displacing them outside their national borders. This situation has led developing countries to argue in climate change international negotiations that developed countries were actually one of the main contributors to their emissions provided for those goods and services produced and mostly conveyed to developed countries' markets. This so-called consumer responsibility argument is becoming increasingly important in international policy negotiations and has led recently to policy proposals aimed at includes trade issues in climate change mitigation. So, the rules of the game are changing progressively and a new global perspective should be envisaged, so that worldwide emissions are reduced at the least cost.

In our view, far from them being effective, we argue that such reductions in the emissions embedded in international trade could lead as well to losses in associated employment, especially in developing countries, which incidentally also gain economic benefits from the displacement of emissions made by developed countries. As a result, we support in this paper the idea of including both the economic benefits of developing countries and the environmental benefits of developed countries in international negotiations, so that global emissions are reduced effectively and with the least cost in exporting countries. In this sense, it is important to highlight that whenever policy measures shall be discussed with the purpose of reducing emissions, their repercussions on employment must be taken into account in order to decide whether to affect the production/consumption of products or directly conceive policy measures affecting the specific sectors producing them.

Our arguments have been supported by a detailed quantitative analysis throughout the paper. Our results show the importance of policies oriented to share the emissions responsibilities embodied in trade between producers and consumers countries. On the one hand, importing countries obtain environmental benefits by displacing emissions outside their national borders; on the other hand, exporting countries benefit from employment generation and economic growth. For this reason, it is even more important to extend the scope of the emission reduction debate by including both the environmental benefits obtained by importing countries and the economic benefits obtained by exporting countries into the analysis. We think that our suggestions would greatly improve global environmental and economic benefits within the context of international climate change negotiations.

Disclaimer

The views expressed in this paper belong to the authors and should not be attributed to the European Commission or its services.

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Table A1. GHG emissions embodied in exports and imports by country, 2008. (Million tCO2e)

	AUS	BRA	CAN	CHN	EU-27	IND	IDN	JPN	KOR	MEX	RUS	TWN	TUR	USA	RoW	Total Exports
AUS	0.5	1.2	2.8	29.9	21.3	4.5	4.2	23.3	7.4	1.4	1.9	2.9	1.0	17.8	45.5	165.6
BRA	1.3	0.3	3.5	30.7	61.1	1.6	1.4	8.3	3.5	2.3	6.1	1.0	1.5	23.3	64.3	210.2
CAN	2.6	4.9	1.7	16.2	38.4	3.4	1.6	11.7	2.8	6.5	2.1	1.2	1.3	131.4	36.3	262.0
CHN	65.2	40.2	84.5	19.3	651.6	79.5	36.6	212.7	93.9	41.7	77.5	27.8	26.8	579.2	807.2	2,843.7
EU-27	14.7	17.5	21.3	66.0	20.4	16.3	6.1	30.1	12.3	13.8	34.1	6.4	19.9	144.4	380.0	803.4
IND	4.9	4.8	15.7	33.1	93.9	0.8	4.7	14.5	5.7	3.5	6.3	3.1	3.9	68.3	111.1	374.4
IDN	4.1	1.3	1.8	14.7	25.1	5.5	0.2	19.6	5.7	1.1	1.9	2.4	1.4	17.3	35.3	137.3
JPN	4.8	2.6	5.0	40.1	37.4	3.2	4.8	1.8	11.0	3.8	6.2	7.1	1.5	38.1	87.8	255.2
KOR	3.2	2.4	3.5	37.5	34.2	3.6	3.6	14.1	0.5	3.3	5.8	2.3	2.2	28.0	69.7	213.9
MEX	0.5	0.9	4.4	2.2	10.7	0.6	0.2	2.1	0.5	0.5	0.5	0.2	0.3	54.9	10.2	88.5
RUS	7.9	10.6	7.8	49.5	332.0	12.9	6.7	31.7	14.0	6.7	3.6	4.6	27.0	80.1	182.7	777.9
TWN	2.8	2.0	3.2	31.2	28.1	2.1	1.8	18.4	3.1	2.2	1.9	0.3	1.1	30.1	33.0	161.3
TUR	0.4	0.3	0.7	1.4	22.9	0.6	0.3	0.7	0.3	0.3	3.4	0.1	0.1	4.4	19.1	54.9
USA	10.8	12.7	80.0	64.0	152.3	11.6	6.0	49.0	17.8	62.8	8.6	9.8	5.7	24.7	216.0	731.7
RoW	49.7	56.5	44.3	295.7	843.9	117.8	36.4	209.1	70.3	31.2	72.9	27.5	45.0	520.0	76.0	2,496.2
Total Imports	173.4	158.3	280.2	731.6	2,373.3	264.0	114.4	647.0	248.7	181.0	232.8	96.7	138.7	1,762.0	2,173.9	9,575.9

Table A2. Employment embodied in exports and imports by country, 2008. (Thousands of jobs)

	AUS	BRA	CAN	CHN	EU-27	IND	IDN	JPN	KOR	MEX	RUS	TWN	TUR	the USA	RoW	Total Exports
AUS	5	12	48	305	244	50	43	190	89	14	20	29	8	195	480	1,733
BRA	87	22	227	1,338	4,276	92	75	419	164	193	339	55	82	1,496	3,903	12,769
CAN	35	62	26	213	518	34	19	130	34	93	34	23	13	1,964	396	3,594
CHN	5,211	2,533	6,979	1,143	55,313	5,839	2,797	16,611	7,828	2,540	7,748	1,694	1,781	43,907	63,321	225,244
EU-27	549	668	768	2,828	748	620	239	1,077	524	446	1,559	314	689	4,893	13,647	29,570
IND	854	542	1,449	4,635	17,803	107	740	1,930	757	465	1,307	540	571	12,722	18,204	62,626
IDN	638	177	245	1,895	3,881	865	21	1,507	488	123	271	164	192	2,337	4,697	17,500
JPN	150	84	173	1,321	1,246	87	133	56	290	119	250	285	46	1,332	2,186	7,757
KOR	77	67	95	950	1,065	78	81	327	13	87	189	53	54	752	1,875	5,763
MEX	44	73	423	175	995	36	13	186	39	30	47	16	19	4,194	827	7,118
RUS	124	149	109	847	4,532	197	107	582	273	92	51	67	369	1,129	3,025	11,653
TWN	105	51	160	787	745	54	47	292	79	63	51	9	27	870	681	4,018
TUR	21	18	34	67	1,580	28	18	42	16	15	249	7	5	202	950	3,252
USA	182	174	1,226	936	2,602	217	73	580	279	739	137	136	65	411	3,916	11,673
RoW	3,037	4,122	3,963	25,614	70,358	6,504	2,269	15,521	4,801	2,487	10,395	2,003	3,285	41,775	5,028	201,164
Total Imports	11,119	8,752	15,924	43,054	165,908	14,809	6,672	39,450	15,673	7,506	22,648	5,395	7,207	118,181	123,135	605,434