Comparing the use of GTAP-MRIO and WIOD for carbon footprint analysis

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Abstract

In this paper we explore the use of two different global multiregional input-output databases (GTAP-MRIO and WIOD) for the calculation of the global carbon emissions embodied in the final demand of nations (carbon footprint). We start our analysis with a description of the main characteristics of the databases and comparing their main components. Then, we calculate the carbon footprint with both databases and identify (from a global perspective) the most relevant factors underlying the resulting differences using structural decomposition analysis. The main conclusion that can be drawn is that, on average, certain elements of both databases can be said to be similar in around 75% to 80%, being only a few elements in each table the main drivers of the major differences. The divergences in the datasets of four countries explain almost 50% of the differences in the carbon footprint (USA 19.7%, China 18.1%, Russia 6.4% and India 4.3%). Industry wise, 50% of the differences can be explained by the divergences in three industries: (electricity 32.7%, refining 9.9% and inland transport 7.1%).

1 Introduction

In recent years there has been an increasing interest in the use of input-output (IO) methods to calculate the global CO_2 emissions resulting from the final consumption of a given country or, in other words, its carbon footprint (CF) (Wiedmann, 2009a). This interest was preceded by a growing concern over different issues related to climate policy such as the debate on how to allocate the responsibility for emissions between producers and consumers (Munksgaard and Pedersen, 2001) (Peters, 2008), the transfer of emissions between countries through international trade (Peters and Hertwich, 2008) or the identification of the impacts of the consumption habits of a country (Hertwich and Peters, 2009) and (Baiocchi, et al., 2010).

Due to the lack of information, seminal studies used single-region environmentally extended IO models (Wiedmann, 2009b) to calculate countries' footprints and related emissions trade balance. These models are built on the assumption that the carbon content of imported goods equals that of domestic ones (the so-called domestic technology assumption). Some authors have pointed out the shortcomings of this seemingly strong hypothesis, concluding that this method would only be valid to estimate the hypothetical amount of emissions avoided through international trade and not the CF and emissions embedded in trade (Andrew et al, 2009), (Arto et al., 2014), (Lenzen et al, 2004) and

(Rueda-Cantuche, 2011). Moreover, this is a theoretical concept. The economy that produces its own imports does not exist, and would look structurally very different.

In order to overcome the limitations of single-region models, multiregional input-output models (MRIO) surfaced as a more robust method for the calculation of CFs. According to (Miller & Blair, 2009), MRIO models were first conceived in (Isard, 1951) for the purpose of modelling the spatial economy within the field of regional science. Many applications have since been devoted to multiregional analyses of countries like China, Japan and USA. However, it was not until the 2000s that MRIO models were progressively applied to other fields such as the economic, social and environmental impacts of globalisation. From the environmental perspective, these models cover a set of countries or regions interlinked via trade flows, thus allowing a detailed assessment of the CF of countries by taking into account the different production technologies across regions. Examples of these models can be found in (Minx et al., 2009) and (Wiedmann, 2009b).

In recent years, the development of global multiregional IO (GMRIO) databases covering the whole world has increased the potential of IO techniques for the calculation of countries' CFs in a consistent way. The first studies that attempted to develop and use multiregional IO tables were published by the OECD. After this, other multiregional IO analyses were published based on the Global Trade Analysis Project database (GTAP-MRIO) (Hertwich and Peters, 2009). More recently, the publication of free-access databases such as the World Input-Output Database (WIOD) has opened the door to the expansion of footprint analysis, and recently (Arto et al., 2012) published for the first time the calculated CF of nations resulting from the WIOD project.

As illustrated in the review of (Wiedmann, et al., 2011), there are other existing GMRIO databases such as Eora (Lenzen, et al., 2013), EXIOPOL (Tukker, et al., 2013) and the Asian International IO Tables (Meng, et al., 2013). However, the selection of the GTAP-MRIO and the WIOD databases in this paper is due to the fact that these two databases are perhaps the two most commonly used databases in current policy-related studies: ECB (Mauro, et al., 2013), IMF (International Monetary Fund, 2013), UNIDO (UNIDO, 2012), OECD/WTO/UNCTAD (OECD-WTO-UNCTAD, 2013) and the European Union (European Commission, 2012).

A special issue on GMRIO frameworks published recently in Economic Systems Research pointed out the main features of different available GMRIO databases, including detailed information on the construction of the GTAP-MRIO (Andrew and Peters, 2013) and the WIOD (Dietzenbacher et al., 2013) input-output databases. In their contribution to this special issue, (Tukker and Dietzenbacher, 2013) highlight the need for an in-depth comparative analysis of databases to avoid comparing results that are based on different definitions for the extensions embodied in trade (EEBT vs GMRIO models), and instead to use similar and consistent system boundaries (territorial principle vs resident principle) and to use a harmonised dataset for extensions, most notably for emissions (IEA, EDGAR, etc.).

	GTAP-MRIO ($Mt\ CO_2$) (1)	WIOD ($Mt\ CO_2$) (2)	Difference ($Mt\ CO_2$) (3)=(1)-(2)	RPD (%)
LUX	18,8	9,5	9,3	65,8
AUS	348,8	455,7	-106,9	26,6
LTU	21,2	27,0	-5,8	24,1
CYP	14,9	11,9	3,1	22,8
ROM	96,2	119,7	-23,5	21,7
TWN	195,6	233,0	-37,5	17,5
BEL	175,3	148,0	27,2	16,9
IRL	60,9	71,9	-11,0	16,6
GRC	176,8	152,8	23,9	14,5
TUR	311,1	356,1	-45,0	13,5
MEX	434,5	496,6	-62,1	13,3
MLT	4,3	3,8	0,5	12,5
CZE	98,1	110,7	-12,6	12,0
DNK	86,8	77,2	9,6	11,7
LVA	17,3	15,5	1,8	11,3
SVN	19,3	21,4	-2,1	10,5
DEU	952,9	1.051,8	-98,8	9,9
IND	1.241,1	1.368,8	-127,7	9,8
KOR	502,8	553,5	-50,7	9,6
ESP	435,9	479,8	-43,9	9,6
POL	284,3	312,6	-28,3	9,5
World	27.391,1	29.218,2	-1.827,1	6,5

	GTAP-MRIO ($Mt\ CO_2$) (1)	WIOD ($Mt\ CO_2$) (2)	Difference ($Mt\ CO_2$) (3)=(1)-(2)	RPD (%)
RoW	4887,1	5.357,5	-470,4	9,2
HUN	65,4	71,7	-6,3	9,1
SWE	89,0	96,8	-7,8	8,4
ITA	571,5	621,1	-49,6	8,3
JPN	1311,2	1.405,9	-94,8	7,0
PRT	74,3	79,3	-5,0	6,5
World	27391,1	29.218,2	-1.827,1	6,5
EST	19,6	18,4	1,2	6,4
CHN	4308,8	4.572,6	-263,9	5,9
FIN	84,4	80,2	4,2	5,1
IDN	338,6	354,6	-16,0	4,6
NLD	208,7	218,0	-9,3	4,4
USA	6218,5	6.461,9	-243,4	3,8
AUT	98,8	102,6	-3,8	3,7
CAN	560,8	580,6	-19,8	3,5
SVK	39,7	38,3	1,3	3,4
FRA	570,9	589,6	-18,7	3,2
BGR	40,3	41,5	-1,2	2,8
RUS	1266,5	1.293,5	-27,1	2,1
GBR	774,7	790,8	-16,1	2,1
EU-27	11.160,1	11.917,0	-757,0	6,6

Source: own elaboration based on (Arto et al., 2012) and (Andrew and Peters, 2013).

Note: RPD = Relative Percentage Difference defined as: $RPD = \frac{|c_{iG} - c_{iW}|}{|c_{iG} + c_{iW}|/2} \times 100$, where c_{iG} and c_{iW} denote the CF of country *i* using GTAP-MRIO and WIOD, respectively. The GTAP-MRIO figures are based on the full version of GTAP-MRIO, aggregated to WIOD regions.

Table 1. Countries' carbon footprints calculated with GTAP-MRIO and WIOD ($MtCO_2$), and Relative Percent Difference (%), 2007

These authors show that, for CFs of the same nations, quite different values can be calculated with different GMRIO databases (Peters et al., 2012; Tukker et al., 2012). This can be clearly evidenced from the comparison of the results of the CFs calculated with GTAP-MRIO and WIOD (see Table 1). If we define the Relative Percent Difference (RPD) as the deviation of the national CF value in each database with respect to the mean of both (MRIO-GTAP and WIOD), then the aggregated results reveal that for 29 out of the 41 regions the relative difference is greater than 5%. This includes some key regions in the climate policy arena like the European Union (with a RPD of 6.7% or 757 million tonnes CO_2 ($MtCO_2$) in absolute terms) or China (RPD of 5.7%; 263 $MtCO_2$ in absolute terms). Moreover, the total CO_2 emissions in WIOD are higher than in GTAP-MRIO (29,218 $MtCO_2$ versus 27,391 $MtCO_2$). To some extent this is due to the fact that WIOD reports not only the CO2 emissions related to the combustion of fossil fuels but also the CO2 emissions from industrial processes, while the emissions used together with GTAP-MRIO for the calculations reported in Table 1 are exclusively those derived from the energy data of GTAP. Consequently, global emissions in WIOD are 6.7% greater than in GTAP-MRIO. Finally, Table 1 reports only aggregated figures of national CFs and it is likely that these differences become even larger when looking at the detailed results (e.g. the CF by commodity) (Lenzen, et al., 2010).

At this point different questions arise: 1) which are the main structural data differences between the GTAP-MRIO and the WIOD databases in relation to the CF? 2) to what extent do these discrepancies affect the results of the CF?; 3) which database would be preferable for each of the different policy questions to be addressed?

In order to answer these questions, this paper develops the first quantitative analysis of the differences in the CF values resulting from the GTAP-MRIO and WIOD databases. Our contributions can be summarised in four different aspects:

a) This paper fills the gap in the literature about the comparison of GTAP-MRIO and WIOD based carbon footprint results using homogenous industry classifications;
b) This paper uses a normalised coefficient (likelihood coefficient) based on weighted RPD indicator s as a measure of similarity between the values of two different outcomes, be they intermediate uses, final demand, carbon footprint…;
c) This paper identifies the main factors affecting the difference in the estimation of CFs of the two GMRIO models using structural decomposition analysis, which is a tool initially thought to be used in time series rather than in cross-sectional data, as we do;
d) As it will be shown throughout the paper, we will prove that the overall difference between the two GMRIO models can be allocated to only a few regions and specific industries (e.g. trade).

We start out our analysis by describing the main characteristics of both databases (Section 2). Afterwards, in Section 3 we develop the methodological framework. In section 4 we present the results of the comparison of the databases and CFs, and identify the factors underlying these differences in the CFs of countries. Finally, we discuss the suitability of these two GMRIO databases for the calculation of CFs of nations.

2 Description of GTAP-MRIO and WIOD databases

Table 2 shows the main features of GTAP-MRIO and WIOD, including the country and time coverage, the description of the main economic and environmental data sources and the approach for the construction of the databases.

The GTAP-MRIO model is an MRIO model constructed using the GTAP database (Narayanan et al., 2012a). GTAP compiles a global database describing bilateral trade patterns, production, consumption and intermediate use of commodities and services. While the original background of the GTAP database was computable general equilibrium analysis of trade policies, the dataset is also ideal for constructing an MRIO table. The GTAP database contains all the necessary components to construct an MRIO table, without the need for any additional balancing (Peters et al., 2011). However, to construct the GTAP database itself means dealing with inconsistencies in definitions and between data sources, requiring a balancing process to harmonise the database (McDougall, 2006). The GTAP-MRIO model used in this paper, however, takes a rather different approach to constructing an MRIO table, in that the GTAP balances the components required to construct an MRIO table without ever constructing an MRIO table (Andrew and Peters, 2013). The utility of the GTAP approach has never been assessed in comparison to the conventional approach of constructing MRIOTs.

The GTAP database construction process draws heavily on involving the community of database users to compile and submit the necessary data to GTAP. Input-output tables for individual countries are submitted by GTAP members following a well-developed protocol (Huff et al., 2000). The tables are checked by GTAP for inconstancies, and when necessary, disaggregated to the 57 industries of the GTAP classification using (i) structures from other IO tables within regional groupings for non-agricultural industries, and (ii) a more sophisticated approach for agricultural industries using country-level commodity quantity and price data from FAO and other sources (Peterson, 2008). International trade data are collected and harmonised separately, using a method that gives more reliable data points more weighting in a balancing procedure (Gehlhar et al., 2008). The GTAP database places more weight on the harmonised trade flows, and uses these data directly in the IOTs to replace the original data source. Energy data are collected from the International Energy Agency, harmonised to be consistent with the GTAP database, linked to price data, and used to replace the energy industries in the original IOTs (McDougall and Lee, 2006). A variety of other adjustments are performed based on external data sources (barriers to trade, subsidies, etc.) to ensure consistent valuation across the datasets. The resulting (adjusted) IO tables are in a range of currencies and generally not consistent with the desired base year. The GTAP database then uses what they call 'entropy-theoretic methods' to harmonise all data sources, in essence a generalised, minimum cross-entropy balancing process that allows a number of constraints to be applied (James and McDougall, 1993; McDougall, 1999; McDougall, 2006), e.g. GDP national values from the World Bank.

	GTAP-MRIO	WIOD
Countries	128+RoW	40+RoW
Industries	57	35 (industry by industry WIOT)
Time	1990, 1992, 1995, 1997, 2001, 2004, 2007	1995-2009
IO data	IO data: based on GTAP database. Country IOTs are submitted by voluntary contributors following guidelines on definitions and industry classification.	Official data reported by national Statistics Institutes and publicly available
Trade data	UN COMTRADE database	UN COMTRADE database
GHG data	The GTAP-MRIO model can be linked to a variety of externalities. In this paper we have used CO_2 emissions based on the GTAP energy data (which is derived from the IEA). It is also possible to link with other data sources, such as NAMEA, CDIAC, EDGAR, UNFCCC, etc.	CO_2, CH_4, N_2O EU Member States: official data reported by national Statistics Institutes consistent with national accounts. Non-EU countries: International Energy Agency, UNFCCC inventories, EDGAR database manipulated to be consistent with national accounts
Approach	Harmonise trade; use IOTs to link trade sets; IOT balanced with trade and macro-economic data	Harmonise SUTs; create bilateral trade database for goods and services; adopt import shares to split use into domestic and imported use; trade information for RoW is used to reconcile bilateral trade

Source: own elaboration based on (Tukker and Dietzenbacher, 2013)

Table 2. Main features of GTAP-MRIO and WIOD

GTAP compiles externality data for energy, CO_2 and other long-lived GHGs, and land use. The CO_2 data are based on energy flow data from the International Energy Agency. The energy flow data are made consistent with the GTAP requirements (McDougall and Lee, 2006) and then converted to CO_2 emissions using a variety of relatively standard assumptions (Lee, 2008). However, it is possible to link a variety of alternative datasets to the GTAP database, and this has been done for a range of alternative emission datasets and the differences compared (Andrew and Peters, 2013). It was found that differences between emission datasets may be an important cause of differences between different MRIOTs (Peters et al., 2012).

In this analysis, we use GTAP version 8.0 for the year 2007, which consists of 57 industries (GTAP industry classification (Table A 1) and 129 countries and regions (GTAP country classification, Table A 2). Most of the input-output tables in GTAP are product by product tables at current prices.

Detailed information on the compilation and construction of WIOD can be found in (Dietzenbacher et al., 2013). The WIOD database comprises a set of harmonised supply, use, and symmetric IO tables, linked through trade flows, and valued at current and previous year prices. The WIOD database covers the period 1995–2007 (and estimates for 2008 and 2009), 35 industries, 59 products and 40 countries (27 Member States of the European Union (EU-27), Australia, Brazil, Canada, China, India, Indonesia, Japan, South Korea, Mexico, Russia, Turkey, and the United States of America (USA)), and the Rest of the World (RoW) as an aggregated region. All economic data in WIOD are obtained from official national statistics. Data from National Accounts, supply and use tables (SUTs) and international trade statistics have been harmonised, reconciled and used for estimation procedures to arrive at a consistent time series of industry by industry World Input-Output Tables (WIOTs), covering 35 industries (see Table A 3) and the 41 regions (see Table A 4). The WIOD database relies on harmonising the available country SUTs to a common format, tending to look for a classification forming the best common denominator across the countries covered, and therefore usually leading to a reduced industry resolution. In this first stage, WIOD also constructs its time series of national SUTs on the basis of the National Accounts. After this, it uses trade share information to identify the source countries of imports. Reconciliation with export data is done via the RoW.

The WIOD also includes satellite accounts related to the environment, including greenhouse gas (GHG) emissions, energy, land, materials and water. In the case of GHGs, it covers the emissions of the three main global warming pollutants: CO_2, CH_4 and N_2O. The data for the EU-27 countries come from the official national accounting matrix including environmental accounts (NAMEA) for air emissions published by Eurostat. For non-EU countries, emissions have been calculated to be consistent with the National Accounts framework (i.e. following the resident principle). The main data sources for the calculation of GHG emissions in non-EU countries are the energy balances of the International Energy Agency, the inventory from the United Nations Framework Convention on Climate Change (UNFCCC), the Emissions Database for Global Atmospheric Research (EDGAR) and the SUTs. For further information on the construction of the satellite accounts see (Genty et al., 2012)

3 Methodology

The starting point of the methodology is two GMRIO tables for n industries and m countries with a common classification and a common currency unit (i.e. from the GTAP and WIOD databases). These GMRIO tables are created using three components: a $(n \times m) \times 1$-dimension vector of output ($\mathbf{x}$), a $(n \times m) \times (n \times m)$ transaction matrix ($\mathbf{Z}$) and a $(n \times m) \times m$ final demand matrix ($\mathbf{F}$). In addition to the economic transactions, the GMRIO tables also include information on the $(n \times m) \times 1$ vector of carbon dioxide emissions of producing industries ($\mathbf{e}$) and the $m \times 1$ vector of direct carbon dioxide emissions from households ($\mathbf{h}$). The vector $\mathbf{i}$ denotes the unitary vector with the appropriate dimension.

As shown schematically in Figure 1, the comparative analysis consists of three stages (see the three boxes of dotted lines):

a) Stage 1 describes how different the GTAP-based and the WIOD-based GMRIO tables are in terms of **Z**, **F**, **x, e** and **h**. Here, we propose to use the so-called Weighted Relative Percentage Difference (WRPD) and the newly derived ***ρ-likelihood*** coefficient as measures of dissimilarities.

b) Stage 2 describes the methodology used for the calculation of the CFs of countries using the main components of the GMRIO tables (**Z**, **F**, **x**, **e** and **h**) and compares them using the same indicators as in the first stage.

c) Stage 3 tries to identify the main factors contributing to the differences in the results of Stage 2. We propose to use structural decomposition analysis (SDA) to explore how the differences in each component of the two databases affect the calculations of the CF.

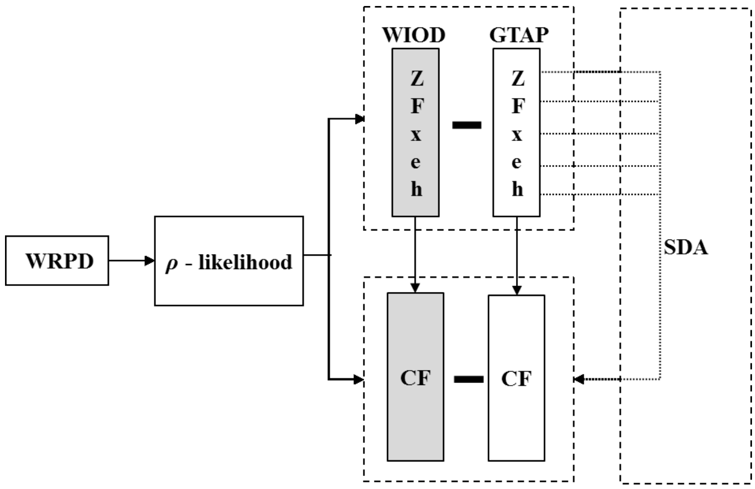

Figure 1. Comparison analysis

3.1 Method for comparing the main components of the database

The comparability between two matrices has been addressed by many authors in the literature and many articles often use the so-called Weighted Average Percentage Error (WAPE) for such a purpose (e.g. (Temurshoev et al., 2011)). The WAPE indicator is defined as a weighted average of the variation rates of the (*i,j*)-*th* element with respect to the same (*i,j*)-*th* element of the other matrix, which is usually considered as the true/official value[1]. The weights are taken from the one considered to be the true matrix. The mathematical expression of the WAPE indicator (e.g. for intermediate uses) would therefore be as follows:

$$WAPE = \sum_{i=1}\sum_{j=1}\left(\frac{\left|z_{T,ij}\right|}{\sum_{k}\sum_{l}\left|z_{T,kl}\right|}\right)\times\frac{\left|z_{E,ij}-z_{T,ij}\right|}{\left|z_{T,ij}\right|}\times 100$$

The subscripts *i* and *j* represent rows and columns (e.g. industries); the double sums are carried out across the rows (*i* and *k*) and columns (*j* and *l*) of the corresponding matrix (e.g. intermediate uses); and the subscripts *T* and *E* denote the true matrix and the estimated matrix, respectively.

[1] However, for comparison purposes in this paper we have taken WIOD as the sole reference database, thus disregarding the issue of whether or not this is truer than the alternative database.

However, this indicator does not have an upper bound, which is an important disadvantage. When the tables are very similar the WAPE will get close to zero (i.e. lower bound) but when the tables are quite different there is no way to measure the extent of the difference. Would a WAPE value of 10 indicate enough difference? Or would it be better to set a WAPE value of 25 as the threshold? Moreover, in our case the objective is not to compare an estimated matrix with the official one, but to compare the differences between two matrices. To solve these issues, we propose a new indicator based on the Relative Percentage Difference (RPD): the so-called Weighted Relative Percentage Difference (WRPD) index. It is defined[2] as follows:

$$WRPD = \sum_{i=1}\sum_{j=1}\left(\frac{\left|z_{G,ij}^{rs} + z_{W,ij}^{rs}\right|/2}{\sum_{k}\sum_{l}\left(\left|z_{G,kl}^{rs} + z_{W,kl}^{rs}\right|/2\right)}\right)\times RPD_{ij}^{rs} \text{ , being } RPD_{ij}^{rs} = \frac{\left|z_{G,ij}^{rs} - z_{W,ij}^{rs}\right|}{\left|z_{G,ij}^{rs} + z_{W,ij}^{rs}\right|/2}\times 100$$

The subscripts r and s stand for regions (e.g. flows from country r to s) and the subscripts G and W denote the GTAP-MRIO and WIOD databases respectively. The double sums are carried out across the rows (i and k) and columns (j and l) of the corresponding matrix (e.g. intermediate uses). We further assume that all elements in the tables are non-negative.

The RPD index is defined as the quotient between the absolute difference of the (i,j)*-th* elements of both matrices (i.e. numerator) and the arithmetic mean of the same two values. Then, the quotient is multiplied by 100 to express the index in percentage. One of the most interesting properties of the RPD index is that it is benchmarked within the range of [0-200]. So, the RPD is zero when the two values are equal; and 200 when the difference is evaluated with respect to the origin (i.e. $z_{W,ij}^{rs} = 0$), where the maximum deviation takes place (in absolute numbers).

However, the RPD index only refers to a pairwise comparison between the elements of the two targeted matrices so we propose the above WRPD index to provide a single value for the comparison of the fully-fledged matrices. Furthermore, we develop the so called ***ρ-likelihood*** coefficient, which is ranged between 0 and 1; 0 if the two matrices are likely to be very different and 1 if the two matrices are likely to be very similar. The ***ρ-likelihood*** coefficient[3] is defined as:

$$\rho - likelihood = 1 - \frac{WRPD}{200}$$

As a result, the description of the differences between the GTAP-MRIO and the WIOD databases on **Z**, **F**, **x**, **e** and **h** will be given in the next section on the basis of the WRPD and ***ρ-likelihood*** coefficients.

	WRPD	WAPE
Intermediates (Z)	51.12	51.42
Final demand (Y)	32.11	32.35
Output (X)	21.96	22.11
CO2 emissions (industries)	41.91	43.2
CO2 emissions (households)	14.36	15.1

[2] The definition is expressed only for intermediate uses, **Z,** but it can easily be extended to the other elements of comparison: **F**, **x**, **e** and **h**.

[3] The ***ρ-likelihood*** index is inspired by the concept of goodness of fit used in regression analysis.

Source: Own elaboration

Table 3. WRPD vs. WAPE

Table 3 shows the aggregated results of the WAPE and WRPD indices. They show evidence that the choice between WAPE or WRPD is irrelevant except for the fact that the WRPD allows us to calculate the ***ρ-likelihood*** coefficient without loss of information. For this important reason we will use the WRPD instead of the WAPE index in order to give a single measure of how likely the GTAP and WIOD databases are to be similar. Table 4 shows a summary of the different methods of comparison discussed and their main characteristics in terms of the upper and lower bounds that they take.

		Similar	**Different**
	Type	**Lower bound**	**Upper bound**
WAPE	Weighted	0	Infinite
RPD	Pair-wise	0	200
WRPD	Weighted	0	200
ρ-Likelihood	Weighted	0	1

Source: Own elaboration

Table 4. Methods of comparison

3.2 Method for comparing the CFs

In this subsection, we present the methodology used for the calculation of the CF of countries using the main components of the GMRIO models (**Z**, **F**, **x**, **e** and **h**). Then, we compare the resulting CFs of countries using WRPD and the ***ρ-likelihood*** coefficients).

Following the classical IO notation, from the GMRIO tables described above we can derive the vector of emissions from industries as:

$$\mathbf{e} = \hat{\mathbf{e}}\hat{\mathbf{x}}^{-1}\mathbf{x} = \hat{\mathbf{e}}\hat{\mathbf{x}}^{-1}\mathbf{LFi} \tag{1}$$

Replacing the vector of global final demand ($\mathbf{Fi}$) with the diagonal vector of domestic final demand of each region r ($\hat{\mathbf{f}}^{\mathbf{r}}$), we can calculate the emissions embedded in the domestic final demand of region r:

$$\mathbf{C}^{\mathbf{r}} = \hat{\mathbf{e}}\hat{\mathbf{x}}^{-1}\mathbf{L}\hat{\mathbf{f}}^{\mathbf{rr}} \tag{2}$$

where the element $c_{ij}^{r(st)}$ of $\mathbf{C}^{\mathbf{r}}$ denotes the emissions generated by industry i of region s in the production of the intermediate goods delivered to industry j of region t to satisfy region r's final demand for good j (e.g. the emissions generated by the iron industry (i) of China (s) in the production of the intermediate inputs for the Japanese (t) car industry (j), which would satisfy the German (r) final demand for cars). Therefore, the CF of region r due to the domestic final demand for commodity j in sum notation is:

$$c\_com_j^r = \sum_i \sum_s \sum_t c_{ij}^{r(st)} \tag{3}$$

Similarly, we can distinguish the domestic CF (i.e. the emissions generated in region *r* to satisfy its domestic final demand plus the direct emissions from households) and foreign CF (i.e. the emissions generated in region *s* to satisfy *r*'s domestic final demand):

$$c\_dom^{r(r)} = \sum_i \sum_j \sum_t c_{ij}^{r(rt)} + h^r \tag{4}$$

$$c\_for^{r(s)} = \sum_i \sum_j \sum_t c_{ij}^{r(st)}, \quad s \neq r \tag{5}$$

It follows that the total CF of region *r* is:

$$c^r = \sum_i \sum_j \sum_s \sum_t c_{ij}^{r(st)} + h^r \tag{6}$$

Thus, the contribution of the CF of region *r* to the sum of the emissions produced by all regions (global emissions) can be expressed as:

$$sc^r = \frac{c^r}{\sum_r c^r} \tag{7}$$

The share of the CF of region *r* due to the consumption of commodity *j* is:

$$sc\_com_j^r = \frac{c\_com_j^r}{c^r} \tag{8}$$

The share of the CF of region *r* due to household emissions is:

$$sc\_c\_h^r = \frac{h^r}{c^r} \tag{9}$$

The domestic share of the CF of region *r* is:

$$sc\_dom^{r(r)} = \frac{c\_dom^{r(r)}}{c^r} \tag{10}$$

And the share of the CF of region *r* that is emitted in region *s* is:

$$sc\_for^{r(s)} = \frac{c\_for^{r(s)}}{c^r} \tag{11}$$

We will apply expressions (7) to (11) to analyse the differences in the composition[4] of the CFs calculated using the GTAP-MRIO and WIOD databases.

[4] As the total emissions in both databases are different, the comparison of the absolute values of CFs can be problematic. Thus, we will focus on the composition of the CF. Note that we could also use the same emissions for both GMRIO databases and compare the absolute figures. However, in such a case, we could not assess the extent to which the differences in the environmental extensions affect the results.

3.3 Method for identifying the main factors contributing to deviations in the CFs of countries

In Stage 3, we show the methodology for quantifying the extent to which the differences in each component contributes to the discrepancy in the results of the CF. The SDA is a technique widely used in IO analysis to decompose the change of a variable over time in its determinants in order to analyse and understand historical changes in socio-economic or environmental indicators. In our case, we have adapted this technique to explore how the differences in each component in the two databases affect the calculations of the CF.

There are several ways of implementing a SDA (see (Su and Ang, 2012) for the different methods). We will follow the simplified method proposed (Dietzenbacher and Los, 1998), based on the average of the two polar decompositions. The starting point is the difference in the emissions embedded in the final demand of region *r* calculated using the two different databases:

$$\Delta\mathbf{C^r} = \mathbf{C^r_G} - \mathbf{C^r_W} \tag{12}$$

The two polar decompositions ($\Delta\mathbf{C^r_1}$ and $\Delta\mathbf{C^r_2}$) and the average of the two are:

$$\Delta\mathbf{C^r_1} = \Delta\hat{\mathbf{e}}\hat{\mathbf{x}}^{\mathbf{-1}}_{\mathbf{G}}\mathbf{L_G}\hat{\mathbf{f}}^{\mathbf{r}}_{\mathbf{G}} + \hat{\mathbf{e}}_{\mathbf{W}}\Delta\hat{\mathbf{x}}^{\mathbf{-1}}\mathbf{L_G}\hat{\mathbf{f}}^{\mathbf{r}}_{\mathbf{G}} + \hat{\mathbf{e}}_{\mathbf{W}}\hat{\mathbf{x}}^{\mathbf{-1}}_{\mathbf{W}}\Delta\mathbf{L}\hat{\mathbf{f}}^{\mathbf{r}}_{\mathbf{G}} + \hat{\mathbf{e}}_{\mathbf{W}}\hat{\mathbf{x}}^{\mathbf{-1}}_{\mathbf{W}}\mathbf{L_W}\Delta\hat{\mathbf{f}}^{\mathbf{r}}_{\mathbf{G}} \tag{13}$$

$$\Delta\mathbf{C^r_2} = \Delta\hat{\mathbf{e}}\hat{\mathbf{x}}^{\mathbf{-1}}_{\mathbf{W}}\mathbf{L_W}\hat{\mathbf{f}}^{\mathbf{r}}_{\mathbf{W}} + \hat{\mathbf{e}}_{\mathbf{G}}\Delta\hat{\mathbf{x}}^{\mathbf{-1}}\mathbf{L_W}\hat{\mathbf{f}}^{\mathbf{r}}_{\mathbf{W}} + \hat{\mathbf{e}}_{\mathbf{G}}\hat{\mathbf{x}}^{\mathbf{-1}}_{\mathbf{G}}\Delta\mathbf{L}\hat{\mathbf{f}}^{\mathbf{r}}_{\mathbf{W}} + \hat{\mathbf{e}}_{\mathbf{G}}\hat{\mathbf{x}}^{\mathbf{-1}}_{\mathbf{G}}\mathbf{L_G}\Delta\hat{\mathbf{f}}^{\mathbf{r}}_{\mathbf{W}} \tag{14}$$

$$\Delta\mathbf{C^r} = \frac{1}{2}\left(\Delta\mathbf{C^r_1} + \Delta\mathbf{C^r_2}\right) \tag{15}$$

Thus, the difference in the total CF would be given by

$$\Delta c^r = \Delta\mathbf{C^r}\mathbf{i} + \Delta c^r_h \tag{16}$$

where Δc^r_h denotes the divergence in the CF of region *r* due to the differences in the direct emissions from households and, as shown before, **i** denotes the unitary vector:

$$\Delta c^r_h = \Delta h^r = h^r_G - h^r_W \tag{17}$$

The third element of (13) and (14) can be further decomposed to distinguish between the effect of the differences in the matrix of intermediate consumption and in the vector of output. On the one hand, as $\mathbf{x} = \mathbf{Lf}$, and $\Delta\mathbf{L} = \mathbf{L_G}\Delta\mathbf{A}\mathbf{L_W} = \mathbf{L_W}\Delta\mathbf{A}\mathbf{L_G}$ [5], the third element of the two polar decompositions can be written as:

[5] $\Delta\mathbf{L} = \mathbf{L_G}\Delta\mathbf{A}\mathbf{L_W} \Rightarrow \mathbf{L_G} - \mathbf{L_W} = \mathbf{L_G}\left(\mathbf{A_G} - \mathbf{A_W}\right)\mathbf{L_W} \Rightarrow$
$\mathbf{L^{-1}_G L_G L^{-1}_W} - \mathbf{L^{-1}_G L_W L^{-1}_W} = \left(\mathbf{L^{-1}_G L_G}\right)\left(\mathbf{A_G} - \mathbf{A_W}\right)\left(\mathbf{L_W L^{-1}_W}\right) \Rightarrow \left[\mathbf{I} - \mathbf{A_W}\right] - \left[\mathbf{I} - \mathbf{A_G}\right] = \mathbf{A_G} - \mathbf{A_W}$

$\Delta\mathbf{L} = \mathbf{L_W}\Delta\mathbf{A}\mathbf{L_G} \Rightarrow \mathbf{L_G} - \mathbf{L_W} = \mathbf{L_W}\left(\mathbf{A_G} - \mathbf{A_W}\right)\mathbf{L_G} \Rightarrow$
$\mathbf{L^{-1}_W L_G L^{-1}_G} - \mathbf{L^{-1}_W L_W L^{-1}_G} = \left(\mathbf{L^{-1}_W L_W}\right)\left(\mathbf{A_G} - \mathbf{A_W}\right)\left(\mathbf{L_G L^{-1}_G}\right) \Rightarrow \left[\mathbf{I} - \mathbf{A_W}\right] - \left[\mathbf{I} - \mathbf{A_G}\right] = \mathbf{A_G} - \mathbf{A_W}$

$$\hat{\mathbf{e}}_{\mathbf{W}}\hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}}\Delta\mathbf{L}\hat{\mathbf{f}}_{\mathbf{G}}^{\mathbf{r}} = \hat{\mathbf{e}}_{\mathbf{W}}\hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{W}}\Delta\mathbf{A}\mathbf{L}_{\mathbf{G}}\hat{\mathbf{f}}_{\mathbf{G}}^{\mathbf{r}} \tag{18}$$

$$\hat{\mathbf{e}}_{\mathbf{G}}\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}}\Delta\mathbf{L}\hat{\mathbf{f}}_{\mathbf{W}}^{\mathbf{r}} = \hat{\mathbf{e}}_{\mathbf{G}}\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{G}}\Delta\mathbf{A}\mathbf{L}_{\mathbf{W}}\hat{\mathbf{f}}_{\mathbf{W}}^{\mathbf{r}} \tag{19}$$

The following step is to split the differences in the technical coefficients ($\Delta\mathbf{A}$) into the intermediate consumption and the output. Accordingly, the two polar decompositions of $\Delta\mathbf{A}$ and the average of the two are:

$$\Delta\mathbf{A}_{\mathbf{1}} = \Delta\mathbf{Z}\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}} + \mathbf{Z}_{\mathbf{W}}\Delta\hat{\mathbf{x}}^{\mathbf{-1}} \tag{20}$$

$$\Delta\mathbf{A}_{\mathbf{2}} = \Delta\mathbf{Z}\hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}} + \mathbf{Z}_{\mathbf{G}}\Delta\hat{\mathbf{x}}^{\mathbf{-1}} \tag{21}$$

$$\Delta\mathbf{A} = \frac{1}{2}\left(\Delta\mathbf{A}_{\mathbf{1}} + \Delta\mathbf{A}_{\mathbf{2}}\right) \tag{22}$$

Now, we can decompose the differences between the calculations of the emissions embedded in the domestic final demand of region r from both databases into the following four effects:

$$\Delta\mathbf{C}^{\mathbf{r}} = \Delta\mathbf{C}_{\mathbf{e}}^{\mathbf{r}} + \Delta\mathbf{C}_{\mathbf{Z}}^{\mathbf{r}} + \Delta\mathbf{C}_{\mathbf{f}}^{\mathbf{r}} + \Delta\mathbf{C}_{\mathbf{x}}^{\mathbf{r}} \tag{23}$$

where $\Delta\mathbf{C}_{\mathbf{e}}^{\mathbf{r}}$ is the difference in the CF due to divergences in the industry emissions reported by each database, $\Delta\mathbf{C}_{\mathbf{Z}}^{\mathbf{r}}$ is the difference due to divergences in the matrix of intermediate consumption, $\Delta\mathbf{C}_{\mathbf{f}}^{\mathbf{r}}$ is the difference due to divergences in the vector of final demand and $\Delta\mathbf{C}_{\mathbf{x}}^{\mathbf{r}}$ is the difference due to divergences in the vector of the output. From expressions (13) to (22), it follows that these effects can be calculated as:

$$\Delta\mathbf{C}_{\mathbf{e}}^{\mathbf{r}} = \frac{1}{2}\left(\Delta\hat{\mathbf{e}}\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{G}}\hat{\mathbf{f}}_{\mathbf{G}}^{\mathbf{r}} + \Delta\hat{\mathbf{e}}\hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{W}}\hat{\mathbf{f}}_{\mathbf{W}}^{\mathbf{r}}\right) \tag{24}$$

$$\Delta\mathbf{C}_{\mathbf{Z}}^{\mathbf{r}} = \frac{1}{2}\left(\hat{\mathbf{e}}_{\mathbf{W}}\hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{W}}\frac{1}{2}\Delta\mathbf{Z}\left(\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}} + \hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}}\right)\mathbf{L}_{\mathbf{G}}\hat{\mathbf{f}}_{\mathbf{G}}^{\mathbf{r}}\right) + \frac{1}{2}\left(\hat{\mathbf{e}}_{\mathbf{G}}\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{G}}\frac{1}{2}\Delta\mathbf{Z}\left(\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}} + \hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}}\right)\mathbf{L}_{\mathbf{W}}\hat{\mathbf{f}}_{\mathbf{W}}^{\mathbf{r}}\right) \tag{25}$$

$$\Delta\mathbf{C}_{\mathbf{f}}^{\mathbf{r}} = \frac{1}{2}\left(\hat{\mathbf{e}}_{\mathbf{W}}\hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{W}}\Delta\hat{\mathbf{f}} + \hat{\mathbf{e}}_{\mathbf{G}}\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{G}}\Delta\hat{\mathbf{f}}_{\mathbf{W}}^{\mathbf{r}}\right) \tag{26}$$

$$\begin{aligned}\Delta\mathbf{C}_{\mathbf{x}}^{\mathbf{r}} = {}& \frac{1}{2}\left(\hat{\mathbf{e}}_{\mathbf{W}}\hat{\mathbf{x}}_{\mathbf{W}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{W}}\frac{1}{2}\left(\mathbf{Z}_{\mathbf{G}} + \mathbf{Z}_{\mathbf{W}}\right)\Delta\hat{\mathbf{x}}\mathbf{L}_{\mathbf{G}}\hat{\mathbf{f}}_{\mathbf{G}}^{\mathbf{r}}\right) + \frac{1}{2}\left(\hat{\mathbf{e}}_{\mathbf{G}}\hat{\mathbf{x}}_{\mathbf{G}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{G}}\frac{1}{2}\left(\mathbf{Z}_{\mathbf{G}} + \mathbf{Z}_{\mathbf{W}}\right)\Delta\hat{\mathbf{x}}\mathbf{L}_{\mathbf{W}}\hat{\mathbf{f}}_{\mathbf{W}}^{\mathbf{r}}\right) \\ & + \frac{1}{2}\left(\hat{\mathbf{e}}_{\mathbf{W}}\Delta\hat{\mathbf{x}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{G}}\hat{\mathbf{f}}_{\mathbf{G}}^{\mathbf{r}} + \hat{\mathbf{e}}_{\mathbf{G}}\Delta\hat{\mathbf{x}}^{\mathbf{-1}}\mathbf{L}_{\mathbf{W}}\hat{\mathbf{f}}_{\mathbf{W}}^{\mathbf{r}}\right)\end{aligned} \tag{27}$$

where $\Delta c_{e(i)}^{r(s)} = \sum_t \sum_j \Delta c_{e(ij)}^{r(st)}$ is the difference in the CF of region r due to divergences in the emissions of industry i of region s reported by GTAP-MRIO and WIOD, $\Delta c_{Z(ij)}^{r(st)}$ is the difference in the CF of region r due to divergences in the intermediate consumption of products from industry i of region s by industry j of region t, $\Delta c_{f(j)}^{r(t)} = \sum_s \sum_i c_{f(ij)}^{r(st)}$ is the difference in the CF of region r due to divergences in the domestic final demand of region r for products from industry j of region t, and $\Delta c_{x(i)}^{r(s)} = \sum_t \sum_j c_{x(ij)}^{r(st)}$ is the difference in the CF of region r due to divergences in the output of industry i of region s.

Therefore, from expressions (16) and (23) to (27) we find that the total difference in the CF can be decomposed as:

$$\Delta c^r = \sum_s \sum_t \sum_i \sum_j \left(\Delta c_{e(ij)}^{r(st)} + \Delta c_{Z(ij)}^{r(st)} + c_{f(ij)}^{r(st)} + c_{x(ij)}^{r(st)} + \Delta c_h^r \right) \tag{28}$$

Taking the previous results as a starting point, we can explore in detail the extent to which each of the main components of the databases contributes to the absolute difference in the calculations of the CF from GTAP-MRIO and WIOD. For instance, the share of the difference in the CF of region r due to the divergence in emissions of industry i of region s would be given by:

$$\gamma_{e(i)}^{r(s)} = \frac{\left| \Delta c_{e(i)}^{r(s)} \right|}{\sum_s \sum_t \sum_i \sum_j \left(\left| \Delta c_{e(ij)}^{r(st)} \right| + \left| \Delta c_{Z(ij)}^{r(st)} \right| + \left| c_{f(ij)}^{r(st)} \right| + \left| c_{x(ij)}^{r(st)} \right| + \left| \Delta c_h^r \right| \right)} \tag{29}$$

Likewise, we can calculate the contribution of the other elements of the databases: $\gamma_{Z(ij)}^{r(st)}$[6], $\gamma_{f(j)}^{r(t)}$, $\gamma_{x(i)}^{r(s)}$ and γ_h^r.

4 Comparison of the GTAP and WIOD databases

In this section, we present the results of the comparison of the main components of the databases and the resulting CFs. For the sake of simplicity we have limited our analysis to CO_2 emissions. In order to facilitate the comparison we have aggregated both databases to a common 24 industry classification (see Table A 5 of the Annex). In addition, we have aggregated the GTAP-MRIO countries to match the 41 region disaggregation of WIOD (Table 4); this can generate a bias in the results of the CF due to spatial ((Andrew et al., 2009)(Su and Ang, 2010)) or industry aggregation (Su et al., 2010), especially in the case of GTAP. However, we have computed the differences in the results of the national CFs after the aggregation and found that, in the case of GTAP-MRIO, the aggregation bias is below 5% in all the countries, except Russia (5.3%) and Australia (7.5%) with an average difference of 0.4%, while in the case of WIOD the difference is below 5% in all the cases with an average of 0.2% (see Table A 6).

4.1 Comparison of the main components of GTAP-MRIO and WIOD

In this section, we first make some general comments on the results obtained from our comparative analysis and then we describe in more detail our findings in each element of comparison, i.e. **Z**, **F**, **x**, **e** and **h**.

Generally speaking, only a few cells have a significant impact on the WRPD values and, therefore, on the single WRPD value measuring the overall difference between the GTAP-MRIO and WIOD tables

[6] For simplicity, in the case of the effect of the differences in Z matrix we will focus in the total effect by rows, i.e. we will analyse $\gamma_{Z(i)}^{r(s)}$.

(Table 5). The 15 cells with the highest WRPD values accumulate 10.5% of the overall WRPD value for intermediate uses (**Z**); 41.8% for final demand (**F**); 40.1% for industry output (**x**); 35.4% for CO_2 emissions produced by industries (**e**); and 89.3% for total CO_2 direct emissions of households[7] (**h**).

Intermediate uses (Z)

The intermediate use matrix **Z** of the GTAP-MRIO table is 74% similar (ρ-likelihood coefficient) on average to that of the WIOD database (see Table 5). The top 15 WRPD values accumulate 10.5% of the overall WRPD value. They comprise nine transactions from six USA industries; four transactions from industries from the RoW region and two transactions from Japanese industries. In all the cases, these differences refer to transactions between industries in their own country (i.e. domestic transactions).

Nine of the top 15 transactions are related to the USA tables, involving industries like real estate and other business services (USA_23), financial intermediation (USA_22), electrical equipment and machinery (USA_12), construction (USA_16), air transportation (USA_20), and other services (USA_24).

	Z			F			x		e		h	
rank	**row**	**column**	**WRPD**	**row**	**column**	**WRPD**	**row**	**WRPD**	**row**	**WRPD**	**row**	**WRPD**
1	USA_23	USA_23	0,82	USA_24	USA	3,54	USA_23	2,76	USA_18	1,59	CHN	2,79
2	RoW_02	RoW_02	0,64	USA_23	USA	3,44	USA_24	1,76	RoW_08	1,56	USA	2,03
3	USA_22	USA_23	0,59	USA_17	USA	1,05	USA_12	0,56	CHN_08	1,28	ROW	1,87
4	USA_23	USA_24	0,51	JPN_23	JPN	0,89	USA_17	0,50	RoW_18	1,28	FRA	0,92
5	RoW_02	RoW_08	0,48	RoW_23	ROW	0,85	RoW_02	0,46	USA_24	1,20	DEU	0,84
6	USA_22	USA_22	0,40	JPN_24	JPN	0,80	JPN_24	0,41	RoW_09	1,12	ESP	0,78
7	USA_12	USA_12	0,37	USA_12	USA	0,47	RoW_23	0,32	USA_08	1,00	GBR	0,69
8	USA_16	USA_24	0,30	RoW_17	ROW	0,45	USA_22	0,29	CHN_10	0,92	JPN	0,64
9	USA_23	USA_22	0,25	RoW_16	ROW	0,41	USA_16	0,28	CHN_11	0,91	IND	0,48
10	JPN_11	JPN_11	0,19	RoW_24	ROW	0,33	RoW_08	0,27	USA_20	0,85	BRA	0,37
11	RoW_02	RoW_16	0,18	USA_22	USA	0,28	FRA_17	0,26	CHN_15	0,70	RUS	0,36
12	USA_20	USA_24	0,17	USA_02	USA	0,25	CHN_23	0,25	USA_15	0,64	IDN	0,29
13	JPN_17	JPN_23	0,16	CHN_23	CHN	0,24	ITA_17	0,25	RUS_11	0,63	NLD	0,27
14	USA_17	USA_12	0,16	FRA_17	FRA	0,22	JPN_23	0,23	USA_17	0,59	ITA	0,27
15	RoW_08	RoW_18	0,16	RoW_02	ROW	0,20	RoW_24	0,21	RoW_19	0,59	AUS	0,22
Sum	-	-	**5,4**	-	-	**13,4**	-	**8,8**	-	**14,9**	-	**12,8**
Total	-	-	**51,1**	-	-	**32,1**	-	**22,0**	-	**41,9**	-	**14,4**
ρ	-	-	**0,74**	-	-	**0,84**	-	**0,89**		**0,79**		**0,93**
Sum/Total	-	-	**10,5**	-	-	**41,8**	-	**40,1**	-	**35,4**	-	**89,3**

Note: WRPD = Weighted Relative Percentage Difference; ρ = likelihood coefficient; Z = intermediate uses; F = final demand; x = output; e = CO_2 emissions (industries); h = CO_2 emissions (households).

Table 5. Top 15 and overall summary of findings

The RoW suffers from big differences as well. Actually, the greatest of all refers to the outputs of mining and quarrying from the rest of the world (RoW_02). This might well indicate that this region has been used as a closure region for balancing purposes in the WIOD database, thus leading to significant deviations from the GTAP-MRIO tables. Incidentally, the RoW in our GTAP-MRIO is made up of a group of countries that had to be aggregated in order to make it comparable to the WIOD database. Other relevant transactions in the RoW that reported big deviations in **Z** were the

[7] Notice that in this case, the total number of cells is 41, thus it is not surprising that the top 15 accumulate so much.

intermediate uses of refined petroleum products (RoW_08) consumed by inland transportation (RoW_18).

The top 15 list of transactions with bigger differences is completed with the Japanese intermediate inputs of trade, hotel and restaurant services (JPN_17) consumed by their domestic real estate industry (JPN_23) and the inputs of Japanese basic and fabricated metals (JPN_11) purchased by the industry itself.

Final demand (F)

The final demand matrix **F** of the WIOD table is 84% similar (ρ-likelihood coefficient) on average to that of the GTAP-MRIO database (see Table). The top 15 WRPD values accumulate 41.8% of the overall WRPD value. In this case the country distribution is formed by domestic transactions: six transactions from the USA; five transactions from the Rest of the World region; two transactions from Japan, one from China and one from France.

In the USA, the bigger deviations relate to the US final demand for domestically produced other services activities (USA_24); real estate and other business services (USA_23); trade, hotel and restaurant services (USA_17); electrical equipment and machinery (USA_12); financial intermediation services (USA_22); and mining (USA_04). The final demand for real estate services presents big deviations in the four countries with the top 15 highest transaction values, i.e. USA, Japan, the RoW and China, while other services activities also present significant deviations with the exception of China.

Total industry output (x)

The total industry output of all countries (**x**) in the GTAP-MRIO table is 89% similar (ρ-likelihood coefficient) on average to that of the WIOD database (see Table 5). This time, the top 15 WRPD values accumulate almost 40.1% of the overall WRPD value and the country distribution is very similar to that of final demand. The highest differences in total output include six industries from the USA, four industries from the RoW, two from Japan and one each from France, China and Italy.

The other services activities and real estate show big differences in the three regions, i.e. USA, Rest of the World and Japan. The mining and quarrying industry (RoW_02) together with the petroleum refining industry (RoW_08) outputs present significant deviations in the RoW. The remaining cases relate mostly to the US tables, reporting remarkable gaps in the following industries: manufacturing industry of electrical equipment and machinery (USA_12); trade, hotel and restaurant services (USA_17); construction (USA_16); financial intermediation services (USA_22).

Carbon dioxide emissions by industries (e)

The GTAP-MRIO carbon dioxide emission by industry is 79% similar (ρ-likelihood coefficient) on average to that of the WIOD database (see Table 5). The top 15 WRPD values accumulate just under 36% of the overall WRPD value. The country distribution is again dominated by the USA (six industries) and the RoW (four industries). China is also included (four industries) and the list is completed with Russia (one industry).

It is very important to note that the petroleum refining industry (08) shows big differences in three of the top 15 countries (USA, China, and RoW) while inland transportation services (18) present significant deviations in the USA and the RoW. The gap in the emissions produced by electricity, gas and water supply (15) is sizeable in the USA and China. As a last remark, there are also important deviations in other services (USA_24), air transport (USA_20) and trade, hotels and restaurants (USA_17) in the USA; the chemical industry (RoW_09) and water transport (RoW_19) of the RoW; the Chinese industries of other non-metallic minerals (CHN_10) and basic metals (CHN_11); and basic metals in Russia (RUS_11).

Carbon dioxide emissions by households (h)

The WIOD carbon dioxide emissions by households figure is 93% similar on average to that of the GTAP-MRIO database (see Table 5). The top 15 WRPD values accumulate nearly 90% of the overall WRPD value. The high accumulated WRPD value is closely linked to the reduced number of elements considered in the WRPD single index (i.e. 41 countries). The biggest differences in the total direct carbon dioxide emissions emitted by households are seen in China, the USA and the RoW.

4.2 Comparison of CFs from GTAP-MRIO and WIOD

In this section, we compare the results obtained from the GTAP-MRIO and WIOD databases across countries (see Table 6); across commodities driving the carbon footprint of countries, i.e. percentage of the CF of country r due to its domestic final demand for product i (see Table 7); and across exporting countries where the emissions originate, i.e. percentage of the CF of country r that it is emitted in region s (see Table 7).

The CF derived from the GTAP-MRIO table is 98% similar (ρ-likelihood coefficient) on average to that of the WIOD database (see Table 6) with a total WRPD of 3.6%. In absolute terms, the differences in the country shares of the global footprint are quite low (i.e. low WRPDs[8]), with figures below 1 percentage point in all countries. The USA and the RoW region accumulate 41.2% of the total deviations. Moreover, adding Australia and India would raise this figure to more than half.

For 24 countries, the contribution to the global CF calculated with GTAP-MRIO is greater than that calculated with WIOD (see positive terms in the third column of Table 6). Within this group of countries, we find the largest difference in the USA, Great Britain and Belgium. Regarding the other 17 countries for which the CF shares estimated with GTAP-MRIO are lower than the ones calculated with WIOD, the RoW region, Australia, India and China are the noteworthy countries.

[8] Note that the WRPD by country equals the absolute value of the difference in the shares of nations' CFs of the global CF.

	GTAP (%)	WIOD (%)	GTAP-WIOD	WRPD (%)	Cumm. WRPD
USA	22.94	22.11	0.84	0.84	23.46
RoW	17.60	18.23	-0.63	0.63	41.17
AUS	1.38	1.57	-0.19	0.19	46.51
IND	4.55	4.72	-0.17	0.17	51.27
CHN	15.46	15.62	-0.16	0.16	55.73
GBR	2.83	2.69	0.14	0.14	59.57
MEX	1.57	1.70	-0.14	0.14	63.37
BEL	0.63	0.51	0.12	0.12	66.81
GRC	0.65	0.54	0.11	0.11	69.82
BRA	1.37	1.27	0.10	0.10	72.66
FRA	2.13	2.03	0.09	0.09	75.30
TUR	1.14	1.22	-0.08	0.08	77.59
CAN	2.07	1.99	0.07	0.07	79.66
TWN	0.72	0.80	-0.07	0.07	81.68
ROM	0.35	0.41	-0.06	0.06	83.49
RUS	4.39	4.45	-0.06	0.06	85.25
ESP	1.59	1.65	-0.06	0.06	86.93
JPN	4.86	4.81	0.06	0.06	88.51
DNK	0.32	0.27	0.05	0.05	89.99
NLD	0.80	0.75	0.05	0.05	91.33
LUX	0.07	0.03	0.04	0.04	92.43
FIN	0.31	0.27	0.04	0.04	93.42
DEU	3.60	3.63	-0.03	0.03	94.33
KOR	1.85	1.88	-0.03	0.03	95.18
CZE	0.36	0.38	-0.02	0.02	95.79
IRL	0.22	0.24	-0.02	0.02	96.35
AUT	0.37	0.35	0.02	0.02	96.92
LTU	0.07	0.09	-0.02	0.02	97.45
POL	1.04	1.05	-0.02	0.02	97.93
CYP	0.05	0.04	0.01	0.01	98.31
IDN	1.23	1.22	0.01	0.01	98.62
SVK	0.14	0.13	0.01	0.01	98.90
LVA	0.06	0.05	0.01	0.01	99.16
EST	0.07	0.06	0.01	0.01	99.39
ITA	2.14	2.15	-0.01	0.01	99.61
SVN	0.07	0.07	0.00	0.00	99.70
MLT	0.02	0.01	0.00	0.00	99.79
HUN	0.24	0.24	0.00	0.00	99.87
SWE	0.33	0.33	0.00	0.00	99.93
BGR	0.14	0.14	0.00	0.00	99.97
PRT	0.27	0.27	0.00	0.00	100.00
Total	-	-	-	**3.6**	-
ρ	-	-	-	**0.98**	-

Note: WRPD = Weighted Relative Percentage Difference;
ρ = likelihood coefficient; Cumm. = Cummulative.

Table 6. Difference in the share of countries' CFs in the global footprint, 2007

	Carbon footprint of countries					Carbon footprint of countries			
	Across commodities		Across exporting countries originating the emissions			Across commodities		Across exporting countries originating the emissions	
	WRPD	ρ	WRPD	ρ		WRPD	ρ	WRPD	ρ
AUS	22.87	0.77	11.53	0.94	ITA	22.06	0.78	7.23	0.96
AUT	35.99	0.64	20.33	0.90	JPN	22.69	0.77	8.70	0.96
BEL	43.41	0.57	15.95	0.92	KOR	32.45	0.68	6.91	0.97
BGR	33.42	0.67	6.89	0.97	LTU	67.35	0.33	31.01	0.84
BRA	31.71	0.68	6.45	0.97	LUX	65.20	0.35	28.76	0.86
CAN	24.98	0.75	13.45	0.93	LVA	39.25	0.61	12.63	0.94
CHN	24.51	0.75	2.00	0.99	MEX	32.04	0.68	9.06	0.95
CYP	58.58	0.41	25.78	0.87	MLT	65.17	0.35	20.98	0.90
CZE	33.34	0.67	10.59	0.95	NLD	42.51	0.57	12.50	0.94
DEU	28.94	0.71	8.48	0.96	POL	19.42	0.81	6.83	0.97
DNK	40.76	0.59	12.86	0.94	PRT	33.16	0.67	10.85	0.95
ESP	24.92	0.75	8.33	0.96	ROM	20.40	0.80	10.47	0.95
EST	29.30	0.71	9.88	0.95	RoW	31.01	0.69	10.58	0.95
FIN	25.15	0.75	11.56	0.94	RUS	42.22	0.58	3.08	0.98
FRA	38.74	0.61	10.20	0.95	SVK	36.31	0.64	32.39	0.84
GBR	25.94	0.74	6.82	0.97	SVN	44.24	0.56	12.85	0.94
GRC	54.11	0.46	10.87	0.95	SWE	37.70	0.62	12.95	0.94
HUN	33.03	0.67	15.23	0.92	TUR	34.81	0.65	7.11	0.96
IDN	26.17	0.74	4.53	0.98	TWN	30.42	0.70	6.50	0.97
IND	33.55	0.66	6.85	0.97	USA	25.06	0.75	7.08	0.96
IRL	33.62	0.66	11.10	0.94					

Note: WRPD = Weighted Relative Percentage Difference; ρ = likelihood coefficient

Table 7. Difference in the carbon footprint of countries across industries and across exporting countries where the CO_2 emissions originate, 2007

Looking at the (more disaggregated) level of commodities driving the CFs of countries, we found that differences between the two databases increase with the disaggregation.

Table 7 shows a maximum likelihood coefficient equal to 0.85 (with an average of 0.65) and WRPD values always over 15% (with an average of 35%).

Conversely, the results of the CFs of GTAP-MRIO and WIOD across the exporting countries where the CO_2 emissions originate do not show significant divergence between the two databases. They are 94% similar on average (ρ-likelihood coefficient) with a WRPD value equal to 12%. However, this result should be taken with caution because the domestic component of the CF, which is by far the most important, is very similar in both databases.

4.3 Impacts of the differences in the structures in the CFs

Next, using the results from the SDA and the indicators derived from expression (29), we analyse how the differences in the components of the databases affect the calculations of the CF using the two GMRIO models. Now, for each of the countries we have 3,937 results: 4 factors (**e, Z, f, x**)×24 industries× 41 countries, plus direct emissions from households.

	Z	f	x	e	h	Total
AUS	20.9	27.8	23.5	26.2	1.7	100
AUT	27.1	22.2	23.9	25.1	1.6	100
BEL	24.7	27.2	18.6	26.9	2.6	100
BGR	23.7	25.2	28.0	20.0	3.1	100
BRA	21.2	18.8	17.9	39.3	2.8	100
CAN	24.2	21.6	19.7	34.2	0.3	100
CHN	31.1	18.0	31.1	17.9	1.9	100
CYP	25.0	28.8	17.8	26.5	1.9	100
CZE	23.0	31.6	19.3	25.3	0.8	100
DEU	23.7	23.0	21.5	29.5	2.2	100
DNK	19.8	26.1	24.0	29.4	0.8	100
ESP	25.8	15.6	25.3	29.2	4.1	100
EST	22.2	29.8	19.8	25.2	3.0	100
FIN	25.2	18.6	25.2	30.3	0.7	100
FRA	21.9	21.0	20.5	32.8	3.8	100
GBR	24.1	22.0	26.3	25.5	2.0	100
GRC	21.4	21.0	21.3	35.2	1.0	100
HUN	21.9	26.3	21.2	28.5	2.1	100
IDN	29.1	19.4	23.4	26.0	2.0	100
IND	28.9	19.6	25.8	24.5	1.1	100
IRL	23.6	24.9	23.4	23.5	4.7	100
ITA	22.1	22.4	22.8	31.6	1.1	100

	Z	f	x	e	h	Total
JPN	21.5	23.1	19.3	34.8	1.3	100
KOR	24.0	23.6	21.1	31.1	0.3	100
LTU	21.2	31.0	21.4	22.3	4.0	100
LUX	30.1	20.7	28.0	18.4	2.9	100
LVA	26.3	27.1	23.1	23.4	0.1	100
MEX	20.4	23.5	18.1	37.8	0.2	100
MLT	28.5	26.3	27.7	16.8	0.8	100
NLD	22.7	29.5	21.3	23.8	2.7	100
POL	22.9	28.8	24.8	23.6	0.0	100
PRT	27.1	18.5	26.9	26.2	1.3	100
ROM	22.9	19.6	18.8	37.4	1.3	100
RoW	23.9	27.0	20.8	27.2	1.0	100
RUS	19.2	32.0	29.6	18.5	0.8	100
SVK	26.7	26.7	23.7	21.7	1.2	100
SVN	23.7	27.4	18.8	24.7	5.4	100
SWE	22.6	25.2	20.0	30.9	1.3	100
TUR	26.7	23.1	22.9	26.3	1.0	100
TWN	22.7	17.9	20.1	37.0	2.3	100
USA	27.7	19.5	25.7	26.2	0.9	100
Mean	24.1	23.2	22.7	27.8	2.1	100
Stdev	2.8	4.1	3.3	4.8	1.1	

Note: Z = intermediate uses; f = final demand; x = output; e = CO_2 emissions (industries); h = CO_2 emissions (households)

Table 8. Contribution of the different components of the GMRIO databases to the differences in the country shares of the global carbon footprint (%), 2007

Table 8 reports the aggregate share of the difference in the CFs due to the differences in each component of the database: the industry emissions **e**, the direct emissions from households **h**, the intermediate matrix **Z**[9], the final demand **f**, and the output **x**. For 24 countries, most of the divergences in the estimations of the CF are related to the components of the GMRIO table: in 12 countries the main factor is final demand, in 9 countries it is the intermediate matrix and in 3 it is the output. In the other 17 countries, the main source of divergences is the industry emissions. As an average (last row of Table 8), 27.8% of the differences are due to the industry emissions, 24.1% due to the matrix of intermediates, 23.2% due to the final demand, 22.7% due to the output and 2.1% due to the direct emissions from households. Further details on specific industries are shown in the Annex.

4.4 A good summary

The main finding that can be drawn from the comparative analysis carried out between the GTAP-MRIO and the WIOD inter-country tables (**Z**, **F**, **x**) and their associated carbon dioxide emissions (**e**, **h**) is that, on average, the elements of matrices **Z**, **F**, **x**, **e** and **h** of both databases can be said to be

[9] For simplicity, in the case of the effect of the differences in **Z** matrix we show the total effect by rows, thus this factor should be interpreted as the difference due to divergences in the sales structure.

around 75% to 80%[10] similar, with only a few elements in each table being the main drivers of the major differences. It must be clear that our comparative analysis has been made from a global perspective where countries like the USA, China and the RoW region weigh more than other countries and, thus, will play a prominent role in the key differences encountered between the two databases. The same applies to industries and commodities.

Concerning economic transactions (**Z**, **F**, **x**), the most significant differences between GTAP-MRIO and WIOD tables relate to the USA, the RoW and Japanese tables. To a lesser extent, France and China also play a role in some industries.

In terms of industries, there is a list of key industries that often report the biggest differences between these GMRIO databases. They could actually be seen as an advanced indicator of one of the driving factors leading to major differences in the carbon footprint calculated. In particular, some of these industries suffer from specific accounting rules that may vary from one country to another, thus making the estimation of GMRIO tables more difficult (e.g. real estate and financial intermediation services, as well as other services; trade, hotels and restaurants; mining; and petroleum refining products).

As regards carbon dioxide emissions, the USA, the RoW and China really make a difference, both in emissions produced by industries (**e**) and emissions emitted by households (**h**). In terms of direct emissions of households, those are followed by some of the biggest countries in Europe (i.e. France, Germany, Spain and the United Kingdom). As for industrial emissions, the biggest deviations pivot around the petroleum refining products (08), the inland transportation services (18) and the electricity, gas and water supply activities (15), which might be one of the reasons for the potential deviations encountered in the calculation of the carbon footprint of nations using both databases. This means that we need to detail these industries, or understand why they are different in different datasets.

These differences in the components of the GMRIO tables clearly affect the results of the calculations of countries' CFs. For instance, in 21 out of the 41 countries analysed the difference in the share of nations' CFs in the global carbon footprint is greater than 5%; in 12 countries it is greater than 10% and in 5 countries it is greater than 20%. However, the 20 countries in which the RPD is lower than 5% represent 90% of the global footprint (70% if we exclude the RoW region). These differences increase significantly when comparing the detailed results of the CFs.

By country, most of the differences in the calculations of the CF can be explained by the divergences in the components of the databases corresponding to the USA, China, the RoW, Russia and India. Among these countries, the USA, China, and the RoW are also the ones for which we found the main differences in all the components of databases. However, the results by industry do not match those resulting from comparing the components of the databases. In terms of CFs, the most relevant differences are due to electricity, gas and water supply (15), petroleum refining products (08), inland transportation services (18), basic and fabricated metals (11), and air transport (20).

5 Discussion and conclusion

The results show that some specific countries and industries exert the most significant difference on the carbon footprint results. The question is which database might be preferable for global carbon

[10] The figure is 0% if the two matrices are likely to be very different and 100% if the two matrices are likely to be very similar (see the so-called ***p-likelihood*** coefficient described in Section 3).

footprint analysis. One way of assessing the suitability of the databases for the calculation of the CF is to make a comparison with the original source data from some parts of the MRIO tables, focusing on those countries and industries for which, according to the SDA, the differences have the greatest impacts on the results.

On the one hand, we have compared the sales structures of the electricity, gas and water supply industry in China, the USA, India and Spain from both databases with the original data reported by the corresponding National Statistical Institutes. The results clearly show that the sales structure of WIOD is closer to the original data than that of GTAP-MRIO (Table 9Table). In the four countries analysed, the mean absolute error (MAE) resulting from comparing the sales structure of WIOD and the official data is lower than 0.5% (0.45% for China, 0.78% for India, 0.32% for Spain and 0.21% for the USA). Meanwhile, in the case of the GTAP-MRIO, the MAE is in all the cases over 1.5% (2.45% for China, 2.37% for India, 1.85% for Spain and 2.75% for the USA), and is more than 3 times higher than the MAE of WIOD. On the other hand, the CO_2 emissions reported by WIOD for the EU countries are the same as the ones reported by Eurostat, while for GTAP we observe many differences in all countries (see Table Table 9), mainly due to the fact that the emission databases are not the same. However, it must be highlighted that CO_2 emissions are not strictly part of a MRIO framework, but rather of a satellite system next to it. In this sense, different emissions datasets can be used to conduct the analysis (e.g. the WIOD environmental extensions can be used together with the GTAP-MRIO).

Besides, these differences in the IO structures with respect to the official data could be due to the harmonisation procedure. Given that WIOD prioritises the structures of the SUTs and GTAP prioritises the trade structure, one would expect that WIOD structures would be closer to official data. Moreover, these differences could also stem from the reference year of the datasets. WIOD uses, whenever available, data from official time series of the SUT, while GTAP uses data from IO tables for reference years. For instance, for the USA, the IO tables underlying GTAP8 are those of 2002, for Spain those of 2000, for India those of 2003 and China those of 2007 (Narayanan et al., 2012b).

The differences in the calculations of the CF are particularly significant in terms of the commodity composition of the CF and the country of origin of the emissions (Table 7). This issue is very relevant when the results of the CF are going to be used to assess the environmental impacts of the consumption patterns of a country (Hertwich and Peters, 2009) or the shift of emissions between countries through international trade (Peters and Hertwich, 2008).

Although the differences in detailed figures are notable, it is important to highlight that the differences in the total CFs of the countries representing most of the global CF are relatively small (Table 6). In this sense, the higher geographical and commodity resolution of the GTAP-MRIO offers an advantage to calculate aggregated national footprints of countries not covered by WIOD and for assessing the CF of specific products. Anyhow, when using GTAP-MRIO, we would suggest the revision of the factor and input structure of the electricity, gas and water supply industry of some key countries like China and the emissions of the EU countries.

From a practical viewpoint, WIOD shows some advantages in comparison to GTAP-MRIO. Access to the WIOD is free of charge and the IO tables are ready to use without any further manipulations. In contrast, in order to access the GTAP database a fee must be paid unless the user is a contributor to the database. Furthermore, when a time series is relevant for the analysis, the use of WIOD would be preferable due to its higher temporal coverage and availability of data at previous year prices, although future availability of updated data is not ensured. Besides, the GTAP database does not include a GMRIO table, which should be constructed by the user. However, according to the 2013 background paper for the GTAP Advisory Board Meeting (Walmsley, 2013), a GTAP-MRIO table is currently being developed for analysis of supply chain issues.

	China			India			Spain			USA		
Industry	GTAP	WIOD	Official	GTAP	WIOD	Official	GTAP	WIOD	Official	GTAP	WIOD	Official
01	2,43	1,37	1,39	14,35	4,10	5,10	3,32	1,61	1,76	0,30	1,30	1,36
02	4,76	7,12	7,28	2,03	1,40	1,27	0,91	0,81	0,88	0,91	2,37	2,35
03	2,52	1,49	1,49	2,07	1,76	1,35	4,49	2,92	3,05	2,34	3,18	3,01
04	4,68	2,14	1,80	1,33	4,39	3,70	1,07	0,58	0,60	0,64	0,33	0,29
05	0,27	0,12	0,37	0,05	0,19	0,13	0,22	0,16	0,17	0,04	0,01	0,06
06	0,61	0,69	0,78	0,44	0,41	0,10	0,79	0,42	0,44	0,64	0,51	0,48
07	2,40	1,25	1,15	2,44	1,16	0,85	2,65	2,27	2,42	2,64	2,49	2,10
08	2,87	1,35	1,58	0,83	3,33	1,86	0,97	0,31	0,32	1,17	0,78	0,39
09	13,46	10,34	9,38	8,23	5,13	4,17	4,33	4,08	4,30	5,29	5,17	4,82
10	5,16	4,84	4,42	2,32	4,50	3,48	3,99	3,47	3,73	1,21	1,32	1,27
11	20,08	12,62	11,42	11,05	13,23	10,16	9,97	4,30	4,56	4,15	3,69	3,44
12	4,50	6,19	5,24	3,64	2,51	3,73	1,68	1,63	1,61	2,01	1,48	1,33
13	1,41	1,25	1,19	1,06	2,89	2,11	1,49	1,60	1,60	1,20	1,14	1,13
14	0,26	0,22	0,43	2,35	0,35	0,14	0,24	0,30	0,30	0,04	0,29	0,35
15	8,53	30,32	34,73	11,59	20,68	27,93	4,58	20,93	22,89	11,05	0,07	0,07
16	1,00	3,22	2,54	0,97	6,61	6,55	1,43	1,74	1,27	0,33	1,00	0,94
17	2,87	2,93	2,78	6,74	1,37	1,53	6,37	10,80	11,42	10,06	6,29	6,75
18	0,93	1,23	1,21	2,34	5,48	5,03	2,17	2,31	2,52	1,55	0,53	0,51
19	0,03	0,08	0,00	0,22	0,09	0,12	0,06	0,15	0,15	0,13	0,04	0,04
20	0,02	0,06	0,00	0,04	0,03	0,02	0,03	0,06	0,06	0,21	0,00	0,01
21	0,82	0,75	0,75	1,54	1,12	0,71	2,34	2,15	2,20	0,46	0,96	1,01
22	0,61	0,48	0,54	2,92	0,69	0,64	0,83	0,78	0,69	1,74	1,28	0,89
23	0,68	1,15	0,89	1,46	1,05	0,89	5,92	3,57	3,54	1,96	5,22	5,99
24	4,04	3,65	3,20	0,39	0,27	0,33	12,06	8,90	8,41	16,86	11,44	12,70
f	14,48	4,82	5,31	19,57	17,24	17,13	24,92	23,11	20,45	32,57	48,85	48,45
Exports	0,56	0,33	0,19	0,04	0,01	0,00	3,17	1,02	0,63	48,44	25,96	25,95
MAE	**2,45**	**0,45**		**2,37**	**0,78**		**1,85**	**0,32**		**2,75**	**0,21**	

Note: the mean absolute error (MAE) is defined as: $MAE_D = \frac{1}{26}\sum_k \left| s_{D,k} - s_{O,k} \right|$, where s denotes the reported sales structures of the total product output (market share) of the electricity, gas and water supply industry (k), with D being either the GTAP-MRIO or the WIOD databases or the official statistics.

Table 9. Sales structure of the electricity, gas and water supply industry in China, the USA, India and Spain in GTAP, WIOD and official IO tables and the mean absolute error (%), 2007.

To sum up, GTAP-MRIO gives priority to the trade structures, while WIOD places the focus on the National Accounts structures in some parts of the MRIO tables and the official environmental accounts. In a sense, GTAP implicitly recognises that they will move away from official national statistics. Besides, WIOD is also aggregated at the region and industry level, so the 130 region, 57 industry calculations by GTAP may lead to more detailed estimates than WIOD. However, we cannot test this.

Overall, given the different priorities of different aspects of each database, it is difficult to make definitive assertions concerning the accuracy of the GTAP-MRIO versus WIOD CF estimates. It may happen that we were comparing apples and oranges. Indeed, the GTAP-MRIO model aims to analyse international trade and serves the purpose of getting the most accurate register of flows of goods passing over the frontiers of countries. Conversely, WIOD serve the purpose to give the most accurate estimate of the use of primary inputs and the release of pollutants in relation to production, consumption and trade, as National Accounts also do (e.g. GDP). And not surprisingly, sometimes, the accounting rules may differ since the purposes are different. For instance, the new European System of Accounts (2010) determines that the goods sent abroad for processing (and owned by the sender) will not be registered any more as an export but rather as an imported service, while trade statistics will keep reporting them as exports. There is no doubt that this will likely enlarge the differences in the CF values calculated with the two GMRIO models but interestingly, no one would be wrong.

Therefore, to what extent does the analysis support the selection of one database over the other? From our point of view, there is not a clear answer to this question, since there is a trade-off between the use of the two databases: WIOD is closer to the official structures from the National Accounts while GTAP has a different philosophical approach where trade statistics prevail over the official domestic structures, and it has more detailed structures of regions and industries. On balance, the user should make a judgement on what is best for their particular research question.

6 Acknowledgements

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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Annex

Code	Industry	Cor.
pdr	Paddy rice	01
wht	Wheat	01
gro	Cereal grains nec	01
v_f	Vegetables, fruit, nuts	01
osd	Oil seeds	01
c_b	Sugar cane, sugar beet	01
pfb	Plant-based fibers	01
ocr	Crops nec	01
ctl	Cattle,sheep,goats,horses	01
oap	Animal products nec	01
rmk	Raw milk	01
wol	Wool, silk-worm cocoons	01
frs	Forestry	01
fsh	Fishing	01
coa	Coal	02
oil	Oil	02
gas	Gas	02
omn	Minerals nec	02
cmt	Meat: cattle,sheep,goats,horse	03
omt	Meat products nec	03
vol	Vegetable oils and fats	03
mil	Dairy products	03
pcr	Processed rice	03
sgr	Sugar	03
ofd	Food products nec	03
b_t	Beverages and tobacco products	03
tex	Textiles	04
wap	Wearing apparel	04
lea	Leather products	05

Code	Industry	Cor
lum	Wood products	06
ppp	Paper products, publishing	07
p_c	Petroleum, coal products	08
crp	Chemical,rubber,plastic prods	09
nmm	Mineral products nec	10
i_s	Ferrous metals	11
nfm	Metals nec	11
fmp	Metal products	11
mvh	Motor vehicles and parts	13
otn	Transport equipment nec	13
ele	Electronic equipment	12
ome	Machinery and equipment nec	12
omf	Manufactures nec	14
ely	Electricity	15
gdt	Gas manufacture, distribution	15
wtr	Water	15
cns	Construction	16
trd	Trade	17
otp	Transport nec	18
wtp	Sea transport	19
atp	Air transport	20
cmn	Communication	21
ofi	Financial services nec	22
isr	Insurance	22
obs	Business services nec	23
ros	Recreation and other services	24
osg	PubAdmin/Defence/Health/Educat	24
dwe	Dwellings	24

Table A 1. Industry classification of GTAP and correspondence with the common industry classification of GTAP and WIOD

Code	Country	Cor.	Code	Country	Cor.	Code	Country	Cor.
CRI	Albania	RoW	OMN	India	IND	XEE	Rest of Eastern Africa	RoW
BGD	Argentina	RoW	KWT	Indonesia	IDN	PAN	Rest of Eastern Europe	RoW
BEL	Armenia	RoW	EST	Iran IR	RoW	XSM	Rest of EFTA	RoW
AZE	Australia	AUS	XCF	Ireland	IRL	SLV	Rest of Europe	RoW
XWS	Austria	AUT	FIN	Israel	RoW	AUT	Rest of Former Soviet Union	RoW
CYP	Azerbaijan	RoW	XAC	Italy	ITA	MLT	Rest of North Africa	RoW
DNK	Bahrain	RoW	BHR	Japan	JPN	XSE	Rest of North America	RoW
MYS	Bangladesh	RoW	XCA	Kazakhstan	RoW	NZL	Rest of Oceania	RoW
GTM	Belarus	RoW	NOR	Kenya	RoW	XSU	Rest of South African CU	RoW
EGY	Belgium	BEL	IRN	Korea	KOR	XNA	Rest of South America	RoW
IND	Bolivia	RoW	FRA	Kuwait	RoW	VNM	Rest of South Asia	RoW
XER	Botswana	RoW	XCB	Kyrgyzstan	RoW	LAO	Rest of Southeast Asia	RoW
ARE	Brazil	BRA	KOR	Lao PDR	RoW	ARM	Rest of the World	RoW
NAM	Bulgaria	BGR	ETH	Latvia	LVA	ESP	Rest of Western Africa	RoW
JPN	Cambodia	RoW	KEN	Lithuania	LTU	ITA	Rest of Western Asia	RoW
NLD	Cameroon	RoW	MDG	Luxembourg	LUX	ZAF	Romania	ROM
QAT	Canada	CAN	XEF	Madagascar	RoW	XSC	Russian Federation	RUS
PER	Caribbean	RoW	ALB	Malawi	RoW	HUN	Saudi Arabia	RoW
SWE	Central Africa	RoW	MNG	Malaysia	RoW	SVN	Senegal	RoW
NPL	Chile	RoW	MWI	Malta	MLT	XEA	Singapore	RoW
GEO	China	CHN	BGR	Mauritius	RoW	UGA	Slovakia	SVK
PAK	Colombia	RoW	TUR	Mexico	MEX	ZMB	Slovenia	SVN
ARG	Costa Rica	RoW	CHN	Mongolia	RoW	KGZ	South Africa	RoW
POL	Cote d'Ivoire	RoW	LTU	Morocco	RoW	GBR	South Central Africa	RoW
HND	Croatia	RoW	BLR	Mozambique	RoW	ZWE	Spain	ESP
MAR	Cyprus	CYP	KAZ	Namibia	RoW	THA	Sri Lanka	RoW
TUN	Czech Republic	CZE	PHL	Nepal	RoW	XEC	Sweden	SWE
XNF	Denmark	DNK	MUS	Netherlands	NLD	URY	Switzerland	RoW
LKA	Ecuador	RoW	AUS	New Zealand	RoW	ISR	Taiwan	TWN
LVA	Egypt	RoW	CHL	Nicaragua	RoW	HRV	Tanzania	RoW
ECU	El Salvador	RoW	SVK	Nigeria	RoW	KHM	Thailand	RoW
CMR	Estonia	EST	VEN	Norway	RoW	LUX	Tunisia	RoW
CHE	Ethiopia	RoW	DEU	Oman	RoW	XTW	Turkey	TUR
CIV	Finland	FIN	SGP	Pakistan	RoW	ROU	Uganda	RoW
GHA	France	FRA	COL	Panama	RoW	NIC	Ukraine	RoW
CZE	Georgia	RoW	XSA	Paraguay	RoW	IRL	United Arab Emirates	RoW
NGA	Germany	DEU	CAN	Peru	RoW	BWA	United Kingdom	GBR
PRT	Ghana	RoW	TWN	Philippines	RoW	SAU	United States of America	USA
SEN	Greece	GRC	MOZ	Poland	POL	USA	Uruguay	RoW
BOL	Guatemala	RoW	TZA	Portugal	PRT	MEX	Venezuela	RoW
BRA	Honduras	RoW	GRC	Qatar	RoW	IDN	Viet Nam	RoW
XOC	Hong Kong	RoW	PRY	Rest of Central America	RoW	RUS	Zambia	RoW
XWF	Hungary	HUN	HKG	Rest of East Asia	RoW	UKR	Zimbabwe	RoW

Table A 2. Country classification of GTAP and correspondence with the common country classification of GTAP and WIOD

Industry	Cor.
Agriculture, Hunting, Forestry and Fishing	01
Mining and Quarrying	02
Food, Beverages and Tobacco	03
Textiles and Textile Products	04
Leather, Leather and Footwear	05
Wood and Products of Wood and Cork	06
Pulp, Paper, Paper , Printing and Publishing	07
Coke, Refined Petroleum and Nuclear Fuel	08
Chemicals and Chemical Products	09
Rubber and Plastics	09
Other Non-Metallic Mineral	10
Basic Metals and Fabricated Metal	11
Machinery, Nec	12
Electrical and Optical Equipment	12
Transport Equipment	13
Manufacturing, Nec; Recycling	14
Electricity, Gas and Water Supply	15
Construction	16
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	17
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	17
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	17
Hotels and Restaurants	17
Inland Transport	18
Water Transport	19
Air Transport	20
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	18
Post and Telecommunications	21
Financial Intermediation	22
Real Estate Activities	23
Renting of M&Eq and Other Business Activities	23
Public Admin and Defence; Compulsory Social Security	24
Education	24
Health and Social Work	24
Other Community, Social and Personal Services	24
Private Households with Employed Persons	24

Table A 3. Industry classification of WIOD and correspondence with the common industry classification of GTAP and WIOD

Code	Country
AUS	Australia
AUT	Austria
BEL	Belgium
BGR	Bulgaria
BRA	Brazil
CAN	Canada
CHN	China
CYP	Cyprus
CZE	Czech Republic
DEU	Germany
DNK	Denmark
ESP	Spain
EST	Estonia
FIN	Finland
FRA	France
GBR	United Kingdom
GRC	Greece
HUN	Hungary
IDN	Indonesia
IND	India
IRL	Ireland

Code	Country
ITA	Italy
JPN	Japan
KOR	South Korea
LTU	Lithuania
LUX	Luxembourg
LVA	Latvia
MEX	Mexico
MLT	Malta
NLD	Netherland
POL	Poland
PRT	Portugal
ROM	Romania
RoW	Rest of the World
RUS	Russia
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
TUR	Turkey
TWN	Taiwan
USA	United States of America

Table A 4. Country classification of WIOD and common country classification of GTAP and WIOD

Code	Industry
01	Agriculture, Hunting, Forestry and Fishing
02	Mining and Quarrying
03	Food, Beverages and Tobacco
04	Textiles and Textile Products
05	Leather, Leather and Footwear
06	Wood and Products of Wood and Cork
07	Pulp, Paper, Paper , Printing and Publishing
08	Coke, Refined Petroleum and Nuclear Fuel
09	Chemicals and Chemical Products, Rubber and Plastics
10	Other Non-Metallic Mineral
11	Basic Metals and Fabricated Metal
12	Electrical and Optical Equipment, Machinery, Nec
13	Transport Equipment
14	Manufacturing, Nec; Recycling
15	Electricity, Gas and Water Supply
16	Construction
17	Trade, Hotels and Restaurants
18	Inland Transport, and supporting Activities
19	Water Transport
20	Air Transport
21	Post and Telecommunications
22	Financial Intermediation
23	Real Estate Activities, Renting of M&Eq and Other Business Activities
24	Other services

Table A 5. Common industry classification of GTAP-MRIO and WIOD

	GTAP			WIOD		
	Before aggregation	After aggregation	Difference (%)	Before aggregation	After aggregation	Difference (%)
AUS	348.8	377.0	-7.5	455.7	457.8	-0.4
AUT	98.8	102.2	-3.3	102.6	103.1	-0.5
BEL	175.3	173.2	1.2	148.0	148.9	-0.6
BRA	365.3	374.5	-2.5	365.9	369.9	-1.1
BGR	40.3	39.4	2.5	41.5	41.6	-0.3
CAN	560.8	565.7	-0.9	580.6	581.9	-0.2
CHN	4,308.8	4,234.3	1.8	4,572.6	4,563.2	0.2
CYP	14.9	14.6	2.3	11.9	11.6	2.5
CZE	98.1	98.1	0.1	110.7	110.9	-0.2
DNK	86.8	87.1	-0.3	77.2	77.5	-0.4
EST	19.6	19.5	0.5	18.4	18.4	-0.1
FIN	84.4	84.3	0.2	80.2	79.5	0.9
FRA	570.9	583.2	-2.1	589.6	594.6	-0.8
DEU	952.9	986.0	-3.4	1,051.8	1,061.2	-0.9
GRC	176.8	177.0	-0.1	152.8	157.5	-3.0
HUN	65.4	66.1	-1.1	71.7	71.4	0.5
IND	1,241.1	1,245.8	-0.4	1,368.8	1,378.4	-0.7
IDN	338.6	336.0	0.8	354.6	355.3	-0.2
IRL	60.9	61.5	-0.9	71.9	71.4	0.7
ITA	571.5	585.5	-2.4	621.1	626.9	-0.9
JPN	1,311.2	1,332.0	-1.6	1,405.9	1,404.4	0.1
KOR	502.8	508.0	-1.0	553.5	550.7	0.5
LVA	17.3	16.9	2.3	15.5	15.3	1.0
LTU	21.2	20.2	4.8	27.0	27.2	-0.6
LUX	18.8	19.6	-3.9	9.5	9.5	0.2
MLT	4.3	4.4	-2.9	3.8	3.8	-0.3
MEX	434.5	429.6	1.1	496.6	497.8	-0.3
NLD	208.7	218.5	-4.5	218.0	219.0	-0.5
POL	284.3	284.1	0.1	312.6	308.1	1.5
PRT	74.3	74.0	0.4	79.3	79.3	0.0
ROM	96.2	94.9	1.4	119.7	120.1	-0.4
RUS	1,266.5	1,202.7	5.3	1,293.5	1,301.2	-0.6
SVK	39.7	39.0	1.7	38.3	38.7	-0.8
SVN	19.3	19.4	-0.8	21.4	21.6	-1.2
ESP	435.9	435.3	0.1	479.8	481.9	-0.4
SWE	89.0	91.2	-2.5	96.8	96.7	0.1
TWN	195.6	198.2	-1.3	233.0	232.4	0.3
TUR	311.1	312.3	-0.4	356.1	357.0	-0.3
GBR	774.7	775.2	-0.1	790.8	786.9	0.5
USA	6,218.5	6,284.7	-1.1	6,461.9	6,459.8	0.0
RoW	4,887.1	4,819.9	1.4	5,357.5	5,325.8	0.6
World	27,391.1	27,391.1		29,218.2	29,218.4	

Table A 6. Countries' carbon footprint calculated with GTAP-MRIO and WIOD ($MtCO_2$) before and after aggregation and difference (%), 2007

Supplementary information

Detailed industry decomposition analysis of the different CFs of countries

Table 7 depicts detailed results on the share of the total difference in the CF from GTAP-MRIO and WIOD due to the differences in the specific components (cells) of the database. For each country, the table reports the top 10 components (out of 3,937[11]) affecting the absolute difference in the CF, while the last row shows the most relevant components over the absolute difference in the global CF (the top 10 out of 161,417 components). According to our calculations, at the global level (last row of Table 7), the top 10 components explain 17% of the difference in the global CF. These top 10 components are related to only four countries (China, the USA, India and Russia) and three industries: electricity, gas and water supply (15), inland transport (18) and other services (24).

At the country level, in all the cases the top 10 components explain more than 20% of the difference in the CF, with an average of 35%: 9.5% due to differences in the industry emissions, 9.1% due to the components of the final demand, 7.7% due to output, 7.4% due to intermediate sales and 1.3% due to direct emissions from households. For 20 countries out of 41 the top 10 figures explain between 30% and 40% of the difference, and for eight countries more than 40%. These are China (66%), Russia (59.9%), India (57.3%), Bulgaria (53.4%), the USA (49.1%), Spain (43.2%), Portugal (42.3%) and Mexico (40.2%). Of these, four representative countries merit further comment: two emerging economies (China and India), and two developed countries: one EU country (Spain) and one non-EU country (USA).

- In the case of China, 66% of the difference in the CF is due to differences in these top 10 components, with 50.5% due to the differences in one single industry: the “Electricity, Gas and Water Supply” industry (22.9% due to differences in the intermediates, 20.2% due to the output, 5.3% due to the final demand and 2.2% due to the emissions of the industry). Moreover, the differences in the Chinese “Electricity, Gas and Water Supply” industry are among the top 10 causes of differences in the CF of 15 countries.
- In India, the top 10 components explain 57.3% of the difference in the CFs. In this country, the differences in the intermediate sales, the output, and the final demand of the “Electricity, Gas and Water Supply” industry explain 41.9% of the total difference in the CF.
- The results of the USA are similar to those of China and India. In this case, the top 10 components explain 49.1% of the difference, and with the differences in the components of the “Electricity, Gas and Water Supply” industry explaining a significant share of the total difference in the CF (31.2%).

[11] Corresponding to the difference in the country's direct emissions from households, plus the difference in each of the 4 factors in the 24 industries of the 41 regions.

	Rank top-10																				
	1		2		3		4		5		6		7		8		9		10		Top 10
CHN	Z_CHN_15	22.9	x_CHN_15	20.2	f_CHN_15	5.3	e_CHN_08	3.8	e_CHN_10	3.4	e_CHN_11	2.4	f_CHN_16	2.4	e_CHN_15	2.2	h	1.9	f_CHN_23	1.6	66.0
RUS	x_RUS_15	19.7	f_RUS_15	16.2	Z_RUS_15	8.8	e_RUS_11	4.2	e_RUS_10	2.9	f_RUS_24	2.2	e_RUS_18	1.5	Z_RUS_02	1.5	f_RUS_23	1.4	f_RUS_18	1.4	59.9
IND	Z_IND_15	18.5	x_IND_15	17.7	f_IND_15	5.6	e_IND_18	3.2	e_IND_10	2.5	e_IND_02	2.3	e_IND_11	2.3	f_IND_03	2.0	e_IND_15	1.6	e_IND_17	1.6	57.3
BGR	x_BGR_15	17.5	Z_BGR_15	11.8	f_BGR_15	9.3	h	3.1	e_BGR_18	2.5	f_BGR_16	2.2	f_BGR_18	2.0	e_BGR_15	2.0	e_BGR_16	1.7	f_BGR_03	1.2	53.4
USA	x_USA_15	13.3	Z_USA_15	12.8	f_USA_24	5.1	e_USA_18	3.8	e_USA_24	3.3	f_USA_23	2.7	e_USA_08	2.3	Z_USA_20	2.2	e_USA_20	1.9	e_USA_15	1.7	49.1
ESP	x_ESP_15	11.0	Z_ESP_15	9.1	e_ESP_18	6.3	h	4.1	e_ESP_10	3.9	f_ESP_15	2.7	Z_CHN_15	1.8	x_CHN_15	1.5	e_ESP_08	1.5	x_ESP_10	1.3	43.2
PRT	x_PRT_15	12.6	Z_PRT_15	10.4	e_PRT_18	4.6	f_PRT_15	3.2	e_PRT_10	2.7	e_PRT_24	1.9	x_PRT_10	1.8	Z_PRT_10	1.7	f_PRT_16	1.7	f_PRT_17	1.6	42.3
MEX	e_MEX_18	8.0	Z_MEX_15	6.0	f_MEX_15	5.9	x_MEX_15	4.2	f_MEX_08	3.5	e_MEX_17	2.8	e_MEX_15	2.8	e_MEX_08	2.5	e_MEX_10	2.4	e_MEX_24	2.1	40.2
GRC	e_GRC_18	9.1	x_GRC_15	6.4	Z_GRC_15	5.4	e_GRC_15	4.9	e_GRC_08	2.8	e_GRC_03	2.6	f_GRC_17	2.5	e_GRC_02	2.4	f_GRC_15	1.7	f_GRC_16	1.7	39.7
POL	x_POL_15	9.5	Z_POL_15	8.1	f_POL_17	4.8	f_POL_15	4.0	f_POL_18	2.8	e_POL_15	2.7	e_POL_18	2.4	f_POL_16	2.0	e_POL_10	1.7	f_POL_01	1.7	39.6
AUS	f_AUS_15	7.7	x_AUS_15	7.5	Z_AUS_15	4.6	f_AUS_23	4.1	e_AUS_18	3.7	e_AUS_08	2.6	Z_CHN_15	2.5	x_CHN_15	2.3	f_AUS_24	2.2	f_AUS_16	1.8	39.1
IDN	Z_IDN_11	7.1	Z_IDN_15	6.2	x_IDN_11	5.8	e_IDN_08	3.8	x_IDN_15	3.3	f_IDN_24	2.7	e_IDN_02	2.4	f_IDN_17	2.1	h	2.0	e_IDN_20	1.8	37.3
ROM	e_ROM_15	8.2	Z_ROM_15	5.6	e_ROM_08	4.7	e_ROM_10	3.9	x_ROM_18	3.3	e_ROM_16	2.6	f_ROM_15	2.3	f_ROM_03	2.2	f_ROM_17	2.1	Z_ROM_18	1.8	36.6
MLT	x_MLT_15	11.5	Z_MLT_15	10.5	x_MLT_18	2.3	f_MLT_24	1.9	e_MLT_20	1.9	Z_CHN_15	1.8	Z_MLT_18	1.8	x_CHN_15	1.7	f_MLT_20	1.6	f_MLT_16	1.5	36.5
TUR	x_TUR_15	7.4	Z_TUR_15	6.5	e_TUR_18	5.1	f_TUR_15	3.0	f_TUR_23	2.6	e_TUR_10	2.5	f_TUR_04	2.4	Z_TUR_18	2.1	x_TUR_18	1.9	f_RUS_15	1.9	35.6
GBR	x_GBR_15	10.4	Z_GBR_15	6.4	f_GBR_15	5.6	e_GBR_18	3.7	h	2.0	f_GBR_19	1.8	f_GBR_03	1.6	Z_CHN_15	1.5	e_RoW_08	1.3	x_CHN_15	1.2	35.4
DNK	e_DNK_19	8.6	x_DNK_19	7.3	f_DNK_19	4.9	f_DNK_17	3.4	e_DNK_18	2.7	f_DNK_16	1.9	f_DNK_18	1.8	e_RoW_08	1.6	x_DNK_18	1.4	f_DNK_20	1.4	35.0
BRA	e_BRA_18	7.7	e_BRA_08	5.3	e_BRA_24	3.2	Z_BRA_08	3.0	Z_BRA_18	3.0	x_BRA_08	2.9	h	2.8	e_BRA_15	2.3	f_BRA_08	2.3	e_BRA_20	2.3	34.9
FIN	e_FIN_08	6.1	x_FIN_15	5.3	e_FIN_18	4.1	Z_FIN_08	3.4	x_RUS_15	3.1	Z_RUS_15	2.9	f_FIN_15	2.5	x_FIN_08	2.3	f_FIN_17	2.1	Z_FIN_15	2.1	34.1
JPN	e_JPN_18	4.7	e_JPN_08	4.4	f_JPN_24	4.3	f_JPN_19	3.7	f_JPN_23	3.0	e_JPN_15	3.0	Z_JPN_15	2.9	e_JPN_11	2.8	x_JPN_15	2.8	Z_CHN_15	2.2	33.8
EST	f_EST_15	5.1	Z_EST_15	4.2	x_EST_15	3.6	e_EST_18	3.4	f_EST_19	3.4	f_EST_17	3.3	h	3.0	Z_RUS_15	2.5	e_EST_19	2.4	f_EST_16	2.2	33.2
LTU	f_RUS_08	4.2	h	4.0	f_RoW_08	3.9	e_RoW_08	3.6	x_RUS_15	3.2	x_RoW_08	3.2	f_LTU_18	3.2	f_LTU_08	2.9	e_LTU_08	2.8	x_LTU_15	1.9	33.1
CZE	f_CZE_15	9.8	Z_CZE_15	4.5	x_CZE_15	3.0	e_CZE_08	2.8	f_CZE_18	2.5	e_CZE_18	2.5	f_CZE_17	2.4	f_CZE_03	2.3	x_RUS_15	1.6	Z_CHN_15	1.6	33.0
TWN	e_TWN_02	5.4	Z_TWN_15	4.2	e_TWN_15	3.9	e_TWN_19	3.3	x_TWN_15	3.2	e_TWN_10	2.6	e_TWN_08	2.5	Z_TWN_02	2.5	f_TWN_12	2.5	Z_CHN_15	2.4	32.3
KOR	f_KOR_19	4.3	Z_KOR_15	4.1	x_KOR_15	4.0	e_KOR_08	3.4	e_KOR_11	3.1	Z_CHN_15	3.1	x_CHN_15	2.8	e_KOR_18	2.5	e_KOR_10	2.3	f_KOR_15	2.3	31.9
AUT	x_AUT_15	7.9	Z_AUT_15	6.7	e_AUT_18	3.7	f_AUT_18	3.0	f_AUT_16	2.2	f_AUT_15	1.9	e_AUT_08	1.7	h	1.6	e_DEU_08	1.6	Z_CHN_15	1.4	31.6
NLD	x_NLD_15	5.3	f_NLD_15	3.8	f_NLD_19	3.8	e_NLD_18	3.6	Z_NLD_15	3.2	h	2.7	f_NLD_16	2.1	f_NLD_17	2.1	e_NLD_24	2.1	e_NLD_08	1.9	30.7
CAN	e_CAN_18	5.5	e_CAN_08	4.3	e_CAN_24	4.3	f_CAN_24	3.2	Z_USA_15	2.9	x_USA_15	2.3	x_CAN_18	2.3	Z_CHN_15	2.0	Z_CAN_18	1.9	Z_CAN_15	1.8	30.6
DEU	f_DEU_15	4.8	x_DEU_15	4.5	e_DEU_08	3.3	e_DEU_15	3.1	Z_DEU_15	2.9	e_DEU_18	2.9	h	2.2	Z_CHN_15	2.2	x_CHN_15	1.7	f_DEU_19	1.6	29.2
ROW	f_RoW_15	3.8	e_RoW_18	3.7	x_RoW_15	3.5	Z_RoW_15	3.3	Z_RoW_08	3.0	x_RoW_20	2.5	f_RoW_19	2.3	e_RoW_08	2.2	f_RoW_16	2.2	f_RoW_23	1.9	28.5
ITA	e_ITA_18	5.5	x_ITA_15	4.0	x_ITA_18	2.9	f_ITA_15	2.8	Z_ITA_15	2.6	e_ITA_10	2.2	f_ITA_17	2.1	f_ITA_16	2.0	e_ITA_17	1.9	Z_ITA_18	1.7	27.8
CYP	f_CYP_19	4.6	f_CYP_17	4.5	e_CYP_19	3.3	Z_CYP_15	2.6	Z_RoW_08	2.3	e_CYP_18	2.2	e_CYP_15	2.1	f_CYP_03	2.1	h	1.9	f_CYP_16	1.8	27.5
IRL	x_IRL_15	5.3	h	4.7	Z_IRL_15	3.8	e_IRL_20	2.3	x_CHN_15	2.1	Z_CHN_15	1.9	f_IRL_15	1.9	f_IRL_18	1.7	f_IRL_17	1.5	f_IRL_23	1.5	26.6
SVK	x_SVK_15	3.7	f_SVK_15	3.6	Z_SVK_15	3.1	f_SVK_03	2.4	e_SVK_18	2.3	Z_SVK_08	2.3	f_SVK_16	2.3	Z_CZE_15	2.0	f_SVK_18	1.9	x_RUS_15	1.8	25.6
LUX	Z_RoW_19	4.4	x_RoW_19	4.3	e_LUX_18	4.1	h	2.9	f_LUX_19	1.9	e_BEL_08	1.9	f_LUX_16	1.8	f_LUX_15	1.6	x_LUX_15	1.3	Z_RoW_15	1.3	25.5
HUN	e_HUN_08	5.2	e_HUN_24	3.3	f_HUN_15	2.6	f_HUN_03	2.3	x_HUN_15	2.1	h	2.1	f_HUN_24	2.0	e_HUN_17	2.0	x_RUS_15	1.9	f_HUN_08	1.8	25.3
LVA	f_LVA_03	4.4	f_LVA_18	4.2	e_RoW_08	2.4	e_LVA_18	2.3	x_LVA_15	2.1	Z_LVA_15	2.0	x_RUS_15	2.0	x_RoW_08	2.0	Z_RUS_15	1.9	Z_RoW_08	1.7	24.9
SVN	h	5.4	f_SVN_15	4.2	f_SVN_18	2.7	Z_SVN_15	2.0	e_SVN_18	1.9	f_SVN_13	1.7	f_SVN_12	1.7	e_SVN_15	1.6	Z_SVN_18	1.5	Z_RoW_15	1.4	24.2
FRA	e_FRA_18	6.6	h	3.8	e_FRA_24	2.5	f_FRA_17	2.2	x_FRA_15	1.7	f_FRA_16	1.5	e_FRA_23	1.5	f_FRA_15	1.4	e_RoW_08	1.3	Z_RoW_15	1.3	23.9
BEL	f_BEL_19	4.0	e_BEL_08	3.6	f_BEL_16	2.8	h	2.6	e_BEL_18	2.0	f_BEL_17	1.7	f_BEL_15	1.5	f_BEL_03	1.2	Z_CHN_15	1.2	f_BEL_24	1.2	22.0
SWE	f_SWE_19	5.2	e_SWE_18	3.5	f_SWE_17	1.8	f_SWE_18	1.8	e_SWE_15	1.8	e_RoW_08	1.4	x_CHN_15	1.3	h	1.3	Z_CHN_15	1.3	x_RUS_15	1.3	20.7
World	Z_CHN_15	3.2	x_USA_15	3.0	Z_USA_15	2.9	x_CHN_15	2.8	f_USA_24	1.2	x_RUS_15	0.9	e_USA_18	0.8	Z_IND_15	0.8	x_IND_15	0.7	f_CHN_15	0.7	17.0

Note: the components of the database are defined by a letter (Z = intermediate uses; f = final demand; x = output; e = CO_2 emissions (industries); h = CO_2 emissions (households)), a three-letter country code and a two-number industry code. The numbers represent for each country the share of the difference in the CFs due to the corresponding component. The last row represents the share of the difference in the global carbon footprint due to the corresponding component.

Table A 7. Share of the difference in the CFs due to the differences in each component of the database (%), 2007. Top 10 differences.

- The differences in the top 10 components of the databases explain 43.2% of the divergences in the calculations of the Spanish CF, with the differences in the "Electricity, Gas and Water Supply" industry amounting to 22.8%. The differences in the satellite accounts of CO_2 emissions account for 15.8% of the total: 6.3% due to "Inland transport", 4.1% due to direct emissions from households, 3.9% due to "Other Non-Metallic Mineral" and 1.5% due to "Coke, Refined Petroleum and Nuclear Fuel". In the case of Spain, the differences in the Chinese "Electricity, Gas and Water Supply" industry explain 3.3% of the divergences in its CF.

In general, the differences in the components of the "Electricity, Gas and Water Supply" industry are the main source (32.7%) of divergences in the estimations of the CF: almost two thirds of all the differences in the CF (Table A 8). The other three main sources of differences are "Coke, Refined Petroleum and Nuclear Fuel" (9.9% of differences), "Inland Transport, and supporting activities" (7.8% of differences) and "Basic Metals and Fabricated Metal" (5.6% of differences). Country wise, the differences in the components of four countries explain almost 50% of the differences in the CFs: the USA (19.7%), China (18.1%), Russia (6.4%) and India (4.3%); the differences in the RoW represent 19.2% of the total.

Sector	(%)
15	31.7
08	9.9
18	7.8
11	5.6
20	5.0
19	4.6
24	4.4
09	4.2
10	4.2
02	3.6
Total	81.1

Country	(%)
USA	19.7
RoW	19.2
CHN	18.1
RUS	6.4
IND	4.3
JPN	4.0
DEU	2.7
GBR	2.5
KOR	1.9
ITA	1.8
Total	80.5

Table A 8. Contribution of the top ten industries and countries to the differences in the global carbon footprint (%), 2007