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PRODUCING CARBON FOOTPRINTS THAT ARE CONSISTENT TO THE DUTCH NATIONAL AND ENVIRONMENTAL ACCOUNTS

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This paper contains the first preliminary calculations of a footprint for the Netherlands that is consistent to the national and environmental accounts published by Statistics Netherlands. We refer to this as a "single-country national accounts consistent footprint" ("SNAC-footprint"). The procedure is sufficiently robust that we are comfortable presenting them at conferences/workshops, but they are subject to a detailed review of the methodology. Results are therefore not to be cited.

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Summary: Since the early 1990's the concept of footprint indicators was popularized by the introduction of the "ecological footprint". In later years, carbon, water, material and land footprints were also developed. Initially these calculations were rarely done using input-output techniques or data, but recently the availability of multiregional input-output (MRIO) and environmental accounting data has changed this situation drastically. However, for some countries such as the Netherlands the MRIO-based footprints show substantially different levels and developments.

This paper explores first how carbon footprints can be calculated in such a way that they are consistent to official statistics of a single country. The paper shows an application for the Netherlands for the year 2009. The WIOD database is adjusted to conform to the Dutch national and environmental accounts that are published by Statistics Netherlands. Detailed trade data is also used to calculate the adjusted footprint which is referred to as a "single-country national accounts consistent" footprint ("SNAC-footprint"). The method is generic in the sense that other countries can re-use the procedure to adapt WIOD to their own official statistics.

The preliminary results show that the SNAC-footprint for the Netherlands is generally lower than the footprint of other MRIO-based studies estimates because of a significantly lower foreign footprint. The calculations also show a much lower fraction of the footprint is attributable to China. However, the methodology still has to undergo a detailed review before the results are definitive.

The paper also provides an overview of the challenges that lie ahead in bringing the footprint calculations within the realm of official statistics.

Keywords: multi-regional input-output analysis, carbon footprint, water footprint, ecological footprint, carbon leakage, pollution haven hypothesis, production perspective, consumption perspective, official statistics, MRIO, GTAP, EXIOPOL, EXIOBASE, CREEA, WIOD and EORA

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1. Introduction[2]

The term “footprint” became popular in the context of environmental issues in the early 1990s with the introduction of the “ecological footprint” (Rees, 1992, Wackernagel and Rees, 1996). Over the last two decades the ecological footprint has been the subject of countless journal articles and is being used by influential organisation to quantify the unsustainability of our society (e.g. WWF, 2010).[3]

The ecological footprint has also paved the way for other footprints or indicators that use similar philosophy. Examples include the carbon footprint (Peters, 2008; Peters and Hertwich, 2008), water footprint (Hoekstra, 2003; Hoekstra and Chapagain, 2008), land footprint (Weinzettel et al, 2013), biodiversity threats (Lenzen et al, 2012) and raw material equivalents (Schoer et al., 2012). All these indicators have in common that they relate consumption to environmental pressures.[4] It is therefore often referred to as the “consumption perspective” or the “consumption-based approach”. This is usually set against the “production perspective” where the environmental pressures generated by industries are measured.

The footprints are calculated by multiplying the products consumed by the environmental pressures per product for which direct estimates or estimates from life-cycle inventories are used. However, the use of input-output techniques to calculate footprints has increased significantly recently. The advantage of these calculations is that they quantify the direct and indirect pressures of the full supply chains.[5]

These adaptation of input-output techniques has been greatly enhanced because there is now abundant data to do these calculations. Several multiregional input-output (MRIO) databases have been developed recently (WIOD, EXIOPOL/CREEEA, EORA) or have been updated (OECD, GTAP). Most of these databases also include environmental data (see Annex I). The conceptual advantages and the availability of abundant data to perform these calculation’s has raised the prospect of creating a “family of footprints” based on the input-output calculations (Galli et al, 2011, Weinzettel et al., 2011).[6]

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[2] This introduction is mostly based on Hoekstra et al. (2013).

[3] The methodology used for the ecological footprint has also been criticized (van den Bergh and Verbruggen, 1999; Grazi et al., 2007; Fiala, 2008).

[4] Recently, the footprint concept has also been adopted to social areas such as modern slavery (www.slaveryfootprint.org).

[5] Note that the use of input-output techniques to attribute energy use and environmental pressure to consumption started in the late 60s and early 70s (Hoekstra, 2010, 2013). However, the term “footprint” was not yet used for these calculations. The results of these calculations were usually referred to as energy/emissions “embodied” in consumption.

[6] The increased use of input-output techniques is symbolized by the publication of a special issue on the carbon footprint in the *Economic Systems Research* (the journal of the international input-output association) in 2009 (ESR, 2009).

The above developments have taken place mostly in academic circles. However, national statistical institutes (NSI) are also increasingly looking at creating footprint indicators. Annex II provides an overview which shows that many NSIs have developed and published (experimental) calculations, particularly on carbon footprints.

This paper discusses a method to create a carbon footprints by combining MRIO data and data from official statistics. The following steps are taken:

- The paper argues for the calculation of footprints that are consistent to the national and environmental accounts produced by NSIs (Section 2)
- The differences between MRIO databases and official statistics are discussed (section 3).
- A method is described to combine MRIO data and official statistics in order to calculate an "SNAC-footprint" (where SNAC refers to Single-country National Accounts Consistent) (Section 4)
- The procedure is applied for the Netherlands for the year 2009. The results are presented and compared to other footprints (Section 5).
- Section 6 provides a discussion of some of the challenges to this work as well as the work of MRIO producers.
- Finally, section 7 concludes.

For the application in section 5 a carbon footprint is calculated although for the moment it only includes CO_2 (and not the other greenhouse gasses).

2. The need for a carbon footprint consistent to the official statistics

Nowadays many carbon footprint estimates are available that are either based on MRIO calculations or other methods. Policy makers and the general public therefore have an abundant choice of options to obtain footprint data. However, upon closer inspection the various sources do provide very different insights.

Figure 1 shows the carbon footprint estimates for the Netherlands of 6 sources that use 4 different MRIO databases (GTAP, EORA, GRAM, WIOD)[7]:

- GTAP[8]
    - PNAS (Proceedings of National Academy of Sciences). See: Peters et al (2011)
    - NCC (Nature Climate Change). See: Peters et al (2012)

[7] The data for figure 1 were supplied by Glen Peters (personal communication, June 2013).

[8] These three studies do use different vintages of the GTAP databases. Also in some cases the GTAP-data on refinery and entrepot trade has some issues (for the Netherlands) and is not dealt with in the same way. This are also the reasons for the large fluctuations in the ESSD figures (Peters, personal communication).

- ESSD (Earth System Science Data). See: Le Quéré et al. (2013).
- EORA. Source: www.worldmrio.org
- GRAM. See: Wiebe et al. (2012)
- WIOD. Source: www.wiod.org

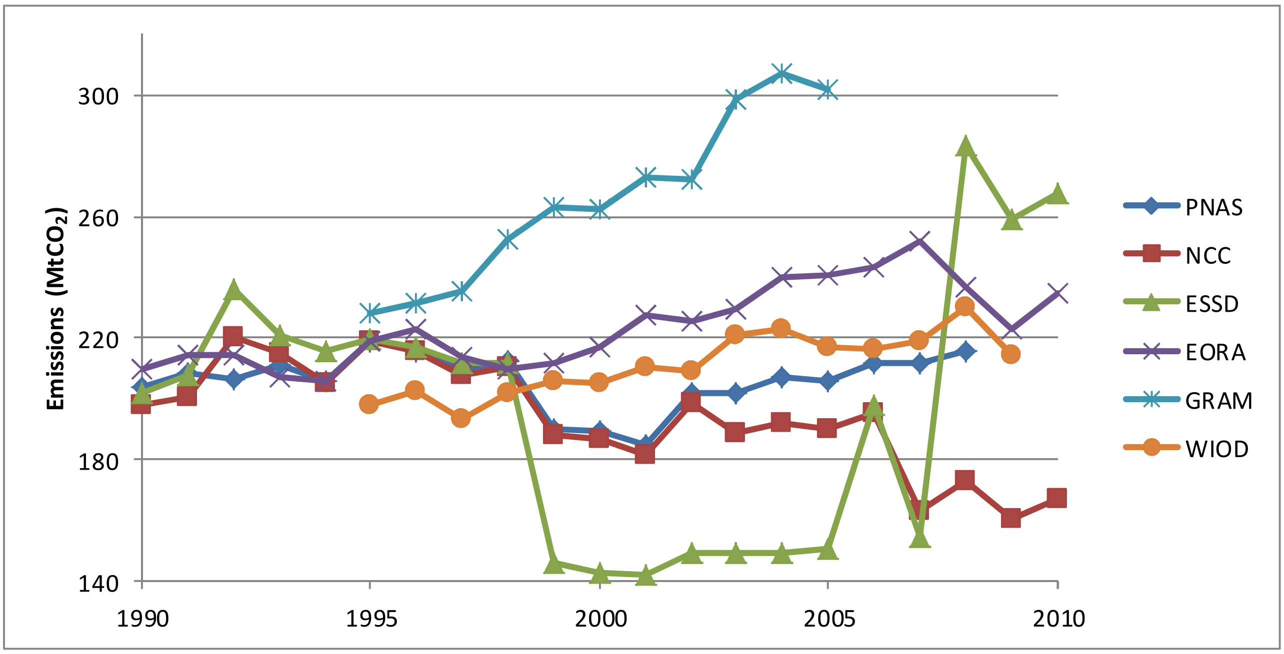

Figure 1. Dutch carbon (CO_2 only) footprint from 6 MRIO studies

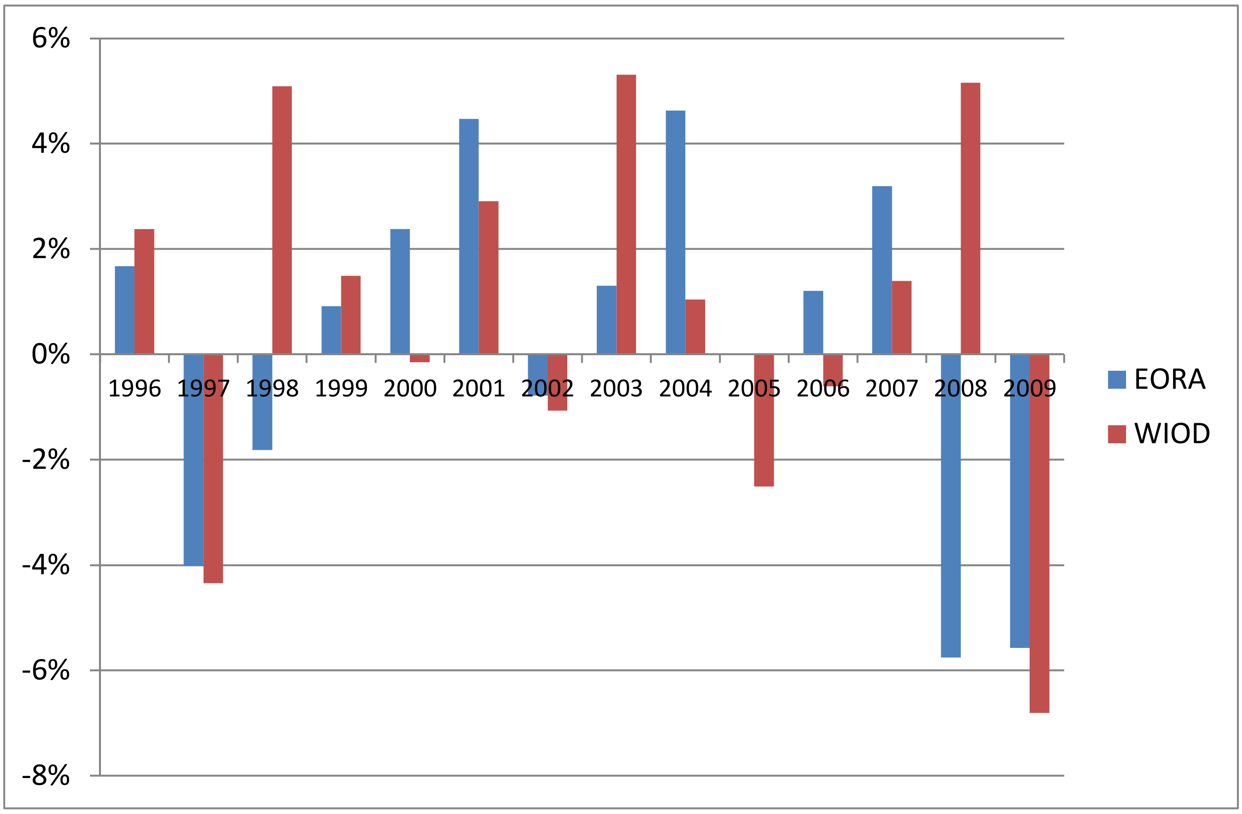

Figure 2. Year-on-year change in Dutch carbon (CO_2-only) footprint for WIOD and EORA

Figure 1 shows an enormous variation of the estimates, both in the size of footprint as well as the trend. Some show rapid increase in the footprint (GRAM) while others show a fairly rapid decrease (NCC).

In figure 2, the year-on-year development for two databases are shown: WIOD and EORA. The estimates of WIOD and EORA show a fairly similar development, although the level of the EORA footprint is higher. Figure 2 shows that the annual changes are sometimes very different in magnitude and in four out of the 14 years, the sign is even different.

Given these range of estimates for the footprint, what can a Dutch policy maker conclude? What is the true level and trend of the carbon footprint for the Netherlands? Did the carbon footprint increase or decrease since 1995? What is the absolute level of the carbon footprint? What impact did the crisis have on the footprint? It is clear that these questions cannot be answered conclusively using these results.

The underlying issue is that MRIO-based footprints do not aim (or claim) to provide conclusive results for individual countries. MRIO databases are produced to provide insight about global developments, but there are many reasons why an MRIO table will differ from official statistics (see next section).

One strategy would be to analyse all the differences in the calculations. A choice could then be made about the footprint calculations which is most appropriate for the Netherlands. This would be a second-best solution because it only answers which MRIO-based footprint gets closest to the “true” footprint.

In this paper we explore a more direct approach to calculate an SNAC-footprint (see section 4). The method uses the MRIO-methodology but rather than “getting it right from a global perspective”, the steps are geared towards making the results consistent to Dutch official statistics. In fact the method is a refinement of earlier approaches in which data of NSI’s were combined with data obtained from global MRIO databases. Wilting and Vringer (2007), e.g., combined the GTAP database with data from Statistics Netherlands to calculate the Dutch carbon and land footprint. In Section 5, the preliminary calculations of the SNAC-footprint for the Netherlands for the year 2009 is provided.

3. Differences between MRIO databases and official statistics

The most recent MRIO databases (EXIOPOL/CREEA, WIOD, EORA, OECD) stay close to official statistics.[9] Nevertheless, the methodology for producing MRIO databases leads to results that are inconsistent to the national accounts, trade

[9] NSIs are governed by the principles of official statistics, which regulate the quality standards, methodological soundness, institutional impartiality and consistency in the data production. The United Nations has laid down these guidelines in the “Fundamental principles of official statistics”.

statistics and environmental accounting data that are published by NSIs. To understand these differences, and what might be done to overcome them, it is important to understand the way in which MRIOs are produced. This section shows that differences in MRIO data and official statistics are inevitable.

Each of the MRIO projects has a unique set of assumptions to create a database, but there are some common methodological aspects to the most recent databases. All of them use statistical data from NSIs, usually stored in databases maintained by the United Nations, OECD and/or Eurostat. The data framework which is usually chosen is a supply and use table structure (SUT) but some also work directly with input-output tables. If these data are not available then macro-economic aggregates are used to estimate the MRIO tables.

In other respects there are other differences: some focus on providing value added data that are consistent to NSI data, while others focus on the consistency of international trade data.

Linking WIOD to the data from Statistics Netherlands.

In this section the difference between MRIO databases and official statistics is illustrated using the Netherlands as a case study. The WIOD database has been used as the MRIO database because it is completely transparent in terms of production of the data. The data of all the intermediary steps in the production process are available from the website, which allows us to choose at which stage to cut in to the process. Also WIOD had an explicit aim to stay close to the SUTs and environmental accounts provided by NSIs.

The Netherlands is an interesting example because of the “Rotterdam-effect”: this port acts as a gateway to Europe and the trade therefore consist of a sizeable amount of re-exports and transit trade. This is different to many countries where re-export and transit trade are very small or non-existent. However, it is very important for footprint calculations. For example, if Chinese products are imported by Germany, via Rotterdam, they will end up in the Dutch transit trade figures. If an MRIO table is created using a trade database which includes transit trade, it will overestimate the Dutch footprint in China. This may lead to different results for the Dutch footprint, depending on the trade database used.

Figure 3 shows the relationship between the data of Statistics Netherlands, international statistical databases and WIOD. To produce a carbon footprint input-output data are combined with the environmental statistics for greenhouse gases (see the dotted boxes on the left (CBS) and right side (WIOD) of the figure).

In essence the WIOD database is constructed using data from Statistics Netherlands, because it uses the Dutch data from international databases. The SUTs and environmental accounts data are derived from Eurostat. Trade in goods is derived from COMTRADE.

There are a number of reasons why the WIOD data might be different to the official CBS data:

1. Differences between official statistics within a country. Not all official statistics, even if they are produced by the same statistical institute, are consistent.

   - Imports/exports. The source data on trade in goods and services is collected by the trade statistics department of Statistics Netherlands. The data are then used by the national accounts department in the construction of supply and use tables and the rest of the national accounts. In principle these two statistics have different underlying concepts (territory vs. residence). Moreover, they are based on a different conception of statistical units. However, even when the trade data is adjusted for these conceptual aspects differences may still arise, because of the balancing procedures of the national accounts.

2. Differences between official statistics between countries. Official data of different countries may provide inconsistent data.

   - Trade asymmetries. One of the largest problems in the production of MRIO databases is the existence of asymmetries in trade statistics between countries i.e. statistics of country A about the imports from country B are inconsistent to the statistics of country B which show the exports to country A. This is known as a trade asymmetry.

3. Differences between the data at Statistics Netherlands and international databases.

   - Conceptual difference in the SUT. For example, there are conceptual differences in the treatment of margins between the SUT used by Statistics Netherlands and the SUT sent to Eurostat (see Hoekstra et al, 2012). Input-output analysis based on these two types of tables would therefore take place using a different conceptual basis.
   - Aggregation level. The SUT and IOT data delivered to Eurostat is far more aggregated than the SUT and IOT available at Statistics Netherlands.
   - The Environmental accounts are also available at a more detailed level (71 industries) at Statistics Netherlands than they are delivered to Eurostat.

4. Assumption in the compilation of the WIOD database

   - Resolving asymmetries. The WIOD project use import data of the trade statistics to calculate the share of imports coming from abroad. The export data from trade statistics are not used. Instead the exports are estimated by the mirror import statistics from other countries.
   - Conversion of the SUT to IOT. In the WIOD approach a simple mathematical procedure ("fixed product sales structure" -model D of the Eurostat (2008) manual) is used to produce input-output tables. In the case

of producing an input-output table at Statistics Netherlands, a manual method is used.

- International transport margins. In the compilation of the WIOD database special attention is paid to the derivation of international transport margins (which are part of the differences between imports (valued at (CIF) cost-insurance-freight) and exports (valued at (FOB) "free- on board" prices)). Only an aggregate estimate of the CIF/FOB adjustment is provided by Statistics Netherlands.

- Trade in goods data. Trade in goods in the COMTRADE database, which is used by WIOD to calculate trade shares per country, includes re-exports (but not transit trade).

Of course, each of these differences has an impact on the footprint calculations. For further details about the empirical differences between WIOD database and the official figures from Statistics Netherlands see Hoekstra et al (2013).

Peters et al (2012), when analysing MRIO results for all countries suggested that the environmental data makes the most difference to the eventual results. However, this is not likely to be a major factor in our case because WIOD uses the data from the environmental accounts. We have identified two specific issues which do however have a large impact on the calculations:

1. *The allocation of import and the calculation of re-exports*

WIOD departs from the official Dutch supply and use tables (Timmer et al, 2012). In a first step, the import vector from the supply table (e.g. agricultural products) is allocated using BEC (Broad Economic Categories) into imports going into intermediate consumption, investments, final consumption. In case the value of imports is higher than the value of intermediate consumption from the use table, the difference is recorded as a re-export (ibid p.34).

The Dutch National accounts however contain a lot more detailed information. For about 200 products (the SUTs are made at a more detailed level of 650 products) we have an IO table which summed over all products yields the Dutch IO table. Essentially, for each product we have a matrix which describes origin and destination disaggregated by all valuation layers (this database - in Dutch "eindbestand" we will refer to as the IO database).

2. *The treatment of margins*

A second source of differences pertains to the treatment of trade and transport margins. WIOD subtracts trade and transport margins from the Dutch use table in purchaser prices (ibid p.22) in order to obtain a use table in basic prices. In this process no trade and transport margins are subtracted from the export vector, which therefore essentially remains in fob valuation. As a results WIOD subtracts to much margins from intermediate consumption which causes a major difference with the Dutch National accounts.

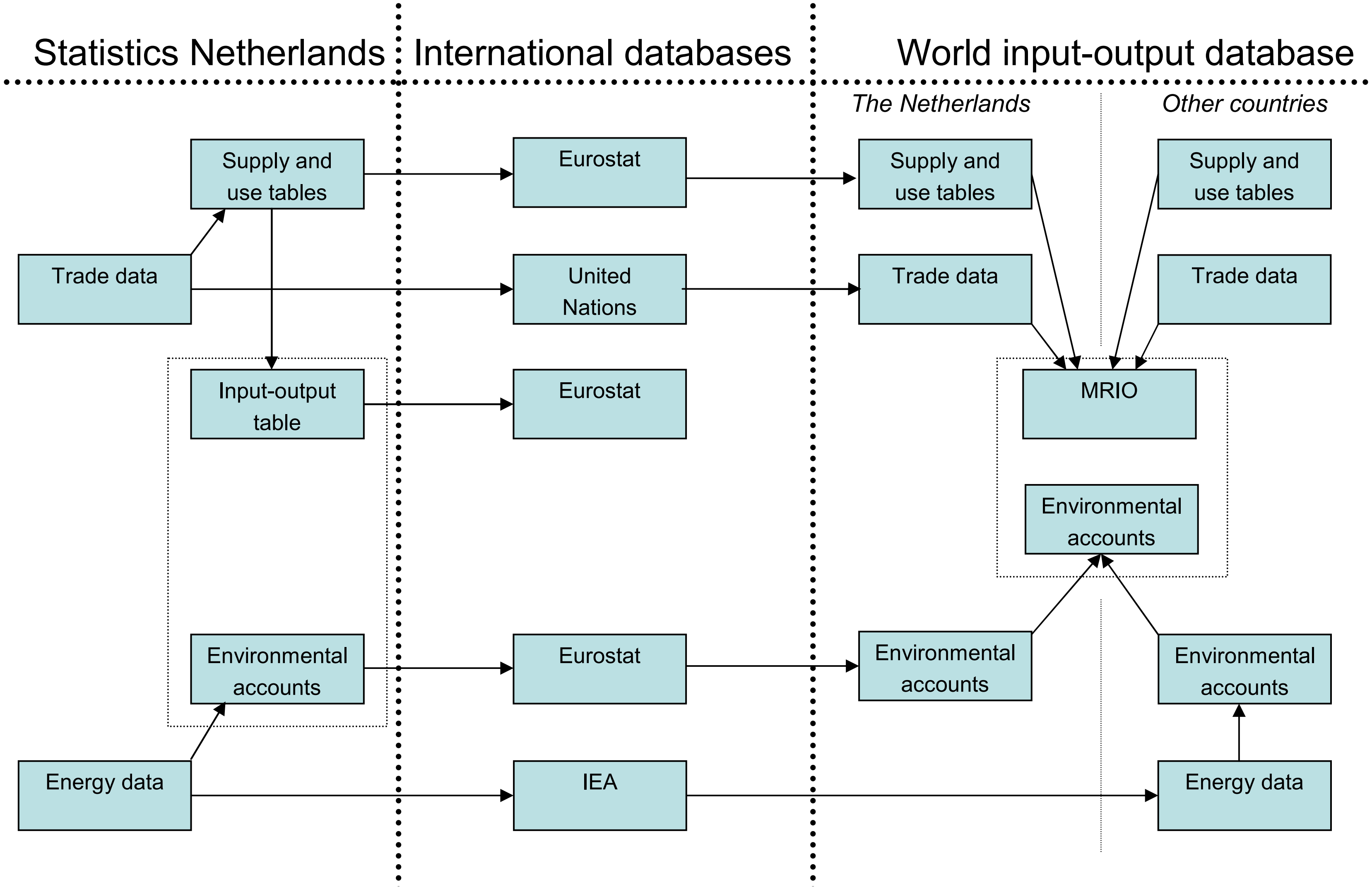

Figure 3. The production of the WIOD database from the perspective of Statistics Netherlands

4. Producing a SNAC-carbon footprint for 2009 for the Netherlands

In this section a method is described to calculate a footprint that is consistent to the Dutch national and environmental accounts: “single-country national accounts consistent” or “SNAC-carbon footprint” for the Netherlands. In section 5 some preliminary results will be shown for the year 2009.

The method is based on the WIOD methodology and data. The website of this database provides not only the definitive world input-output tables (WIOT) but also the intermediate steps in the production of the database.

Our method intervenes in the WIOD methodology at the stage of the “International SUTs” (IntSUT). In this stage, there is still an industry by commodity structure to the database which also means that the commodities can be linked to trade data. For 40 countries and regions the IntSUT data are used, however for the Netherlands data from Statistics Netherlands is used (SUT, trade data and environmental accounts). An WIOD balancing procedure is then followed to construct the WIOT from the intSUT tables, with one important difference: the data for the Netherlands is kept unaltered at every stage of the calculations. The end results is therefore an adjusted “WIOD database” that is entirely consistent to Dutch official statistics.

In the remainder of the section we will look at three aspects of the production process in some more detail. Firstly, the construction of the trade statistics which were tailor made for this project. Secondly, the production of the supply and use tables and finally the conversion of the intSUT to WIOT tables.

Preparation of the Dutch trade data

Compared to most other countries, the Netherlands have high re-exports. They form about one half of Dutch exports of commodities, and that is excluding transit trade (which are not part of the national accounting definition). This high share can be explained by several factors, for example a favourable position as the port to Europe, good infrastructure and skills in complex logistics (Kuypers et al. 2013).

To accurately attribute the CO_2 emissions to consumption, we need to split the imports for consumption from the imports for re-exports. To integrate this into the WIOD database the bilateral trade data is needed for each commodity, for each type of import. This is not yet available so a new method had to be constructed.

The data are created by taking into account the heterogeneity at firm level using micro data. It contains the variables re-exports, country of import, country of export and the eight digit commodity code according to the Combined Nomenclature.

First, we explain how we derived re-exports and the country they were exported to. For every trader (identified by his VAT-number), his exports are known by country of export and the eight digit commodity code. The percentage of re-exports is derived using the following guidelines:

- The trader can indicate in the trade survey which commodities are re-exports
- Statistics Netherlands profiles the larger traders, using information from visits and telephone calls
- Some commodities are not produced in the Netherlands (for example bananas), hence they must be re-exports.
- If, on the six digit level of the Combined Nomenclature, exports are less than twice the imports, these exports are considered to be re-exports. Results are robust to changes of the (arbitrary) factor 2.

If no extra information is available, re-exports are proportionally distributed among the countries of exports. For example, if a trader exports 50% of a given commodity to Germany, we assume that 50% of his re-exports of this commodity are exported to Germany as well.

Now we explain how to derive the country of import. Problems arise because it is not uncommon that one trader imports the commodities, and another one re-exports them. For example, the mother enterprise imports from Asia, and the Dutch daughter distributes the commodities over Europe. To address such cases, we considered the traders with re-exports that (on six digit level) were at least 100 million higher than the imports of these commodities. Using the information from the contacts and matching to firms in the same enterprise group, we clustered traders to match the re-exports to the corresponding imports. In this way, we found imports that corresponded to re-exports for about 200 large traders that previously had insufficient imports. Then we matched re-exports to imports in several steps:

- First match on the eight digit commodity level at the trader; if re-exports remain
- Match the remaining part on the six digit commodity level at the trader; if re-exports remain
- Match the remaining part on the six digit commodity level at national level; if re-exports remain
- Match the remaining part (always negligible) on two digit commodity level at national level

If no extra information is available, imports for re-exports are proportionally distributed among the countries of imports. For example, if a trader has re-exports of a given commodity, and imports 25% of this commodity from Germany, we assume that 25% of his imports for re-exports of this commodity are imported from Germany as well.

Production of the Dutch SUT data

The production of the SUT requires the following steps[10] (see also Edens et al., 2011):

- Based on the information in the IO database we first of all exclude the value of re-exports;
- The imports and exports of goods are split across countries using trade shares from trade in good statistics (see previous paragraphs)
- The imports and exports of services are split across countries using trade shares from international trade in services statistics
- A novel aspect is that import and exports due to processing and merchanting obtain a specific treatment. These import and export values are divided by using the SUTs at the more detailed level, where we make the assumption that the allocation of processing services over countries follows the distribution of trade in products that are being processed.
- We treat the supply and use of margins as a service. The fob export value of products is split into the export of product in basic prices and the export of a service that rests on the exported product. The distribution of exported services follows the distribution of the goods they rest upon
- With this information we are able to compile a Dutch international SUT, as well as the Dutch part of the IntSUTs of the other WIOD countries.

Balancing procedure

A WIOT can be computed from an international use and supply table (IntSUT). Therefore, in order to create a WIOT that is consistent with Dutch statistics (C-WIOT), one first requires an IntSUT that is consistent with Dutch statistics. Here 'consistent with Dutch statistics' implies that an IntSUT contains exactly the data that is used in the Dutch system of national accounts to determine official economic

[10] In the official IO tables in basic prices, the trade and transport margins are kept outside the intermediate demand block; they are provided as an additional row and an additional final demand column, which is obtained by calculating the row and column sums of the respective valuation layers.
In the Eurostat tables, the trade and transport margins are treated as the production of services and therefore consolidated with the wholesale and retail trade and transport industries. That is, the wholesale trade industry is depicted as producing wholesale services that are consumed by industries or final demand rather than depicted as the producers of margins. As we do not know the destination of the margins/services that are being produced, this calculation is performed using a proportionality assumption (margins/services used are distributed evenly over the producers). For our own environmental input-output analyses we have treated the production of margins as a pseudo-activity i.e. an additional activity that produces only margins but without emissions. This practice is however not compatible with an MRIO framework, since this is not the way which other countries classify margins.

indicators like GDP growth. Such a consistent IntSUT is obtained by incorporating official Dutch statistics with the IntSUT data as it is provided by WIOD. WIOD provides use and supply tables for 40 countries and specifies the import and export flows between these countries on the industry level. Furthermore, WIOD provides estimates of import flows of these 40 countries from the Rest of the World (RoW). Here it is important to note that WIOD does neither provide estimates for the RoW exports, nor estimates for a RoW intermediate use and supply table, so before one wants to use the IntSUT to compute a WIOT, one needs to derive these one selves. After the creation of the remaining parts for RoW, which is explained in more detail in annex III, the resulting IntSUT from WIOD is the starting point to create an IntSUT that is consistent with Dutch statistics.

In order to incorporate official Dutch statistics in the IntSUT, the Dutch industry columns, Dutch final demand columns, Dutch goods and services rows and value added and margins rows in the IntSUT from WIOD are replaced with corresponding, more detailed official statistics as they are denoted in the Dutch national accounts. This table is referred to as the Consistent IntSUT (C-IntSUT). However, since the IntSUT from WIOD constitutes a balanced system, where both global demand for each good in each country is equal to global supply of each good in each country and global value added plus margins is equal to global final demand, the C-IntSUT is unlikely to be still balanced. One example of such a source of imbalance, is that a share of the export, which was part of final demand in the national account setting, is suddenly part of the intermediate use of an industry in another country. This causes an imbalance, because the total final demand is no longer equal to the total value added. A second source of imbalance is due to the incorporation of Dutch imports and exports. The difference between old and new exports causes the column totals of the international use table to become different from the column totals of the international supply table, while the new Dutch imports cause the row totals of the international use table to differ from the international supply table. A third source of imbalance is simply a shift in the total Dutch value added and margins of Dutch industries. This causes a further imbalance between total value added plus margins and total final demand. The imbalanced C-IntSUT is balanced by first setting the consistent global final demand equal to consistent global value added plus margins. And then, by means of Stone's balancing method (Stone, 1942), the rows and columns from the use table are balanced with the rows and columns from the supply table, without altering the official Dutch statistics and the value added of the countries.

This balancing procedure provides a balanced C-IntSUT, which can be used to create a C-WIOT. To achieve this, there are numerous computation methods that all require different assumptions which all have pros and cons. For a more detailed discussion on these methods we refer to the Eurostat manual on Input-Output methods (Eurostat, 2008). One of the main computation methods that is discussed in this manual is the 'fixed product sales structure assumption' (Model D in the Eurostat manual), which has the advantage that is creates no negatives in the resulting input-output table. This method is applied to compute the C-WIOT.

5. Results

Please note that the results reported in this section are the first preliminary figures for the SNAC-footprint for the Netherlands. The procedure is sufficiently robust that we are comfortable presenting them at conferences and workshops, but they are subject to a detailed review of the methodology. Results are not to be cited.

The data preparation and balancing procedure was run for two versions of the WIOD database (September 2012). Table 1 shows the results for the SNAC-footprint using the latest release. In Annex the 4 the more detailed results are provided.

The SNAC-footprint calculations for the Netherlands for the year 2009 are compared to 4 other studies The column "%" show the difference between the SNAC-footprint and the MRIO in question. The results show that the SNAC-footprint is lower than most estimates (except for NCC). When we compare it to WIOD, for which we have a breakdown of the figures it is clear that this is largely caused by a significantly lower "foreign" footprint. When comparing WIOD to our own database, we found that WIOD imports were at a higher level, partly because too little had been attributed to re-exports. This proves that the additional wok of the trade data and the consistency to the national accounting totals lead to a marked improvement in the results.

Table 1. The SNAC-footprint of the Netherland for 2009 compared to MRIO studies

Name	**SNAC-footprint**	**WIOD**		**EORA**		**NCC**		**ESSD**	
Absolute/Percentage	$MtCO_2$	$MtCO_2$	%	$MtCO_2$	%	$MtCO_2$	%	$MtCO_2$	%
Total Footprint	**198**	**210**	**6%**	**223**	**13%**	**161**	**-19%**	**259**	**31%**
Domestic indirect emissions	77	71	-8%						
Domestic direct emissions	38	39	0%						
Total Domestic	**116**	**109**	**-6%**						
Total Foreign	**82**	**101**	**23%**						

Table 2 provides a country breakdown of SNAC-footprint and WIOD. A striking difference is the lower footprint of Dutch consumption in China. This is mostly due to the volume effect that the WIOD imports are simply higher, but also due to the fact that the country share that we obtained through the preparation of the trade statistics is about 2% lower.

Table 3 provides two sensitivity analyses. First, the influence of aggregation is measured by performing the calculations at 35 industries (WIOD classification) instead of 71 industries of the SNAC-footprint. This provides a significantly higher domestic footprint because the indirect emissions are 8% higher. Secondly, the influence of the CO2 data is analysed by using the WIOD data in the SNAC-footprint calculations. This leads to a further increase in the domestic footprint..

Table 2. The country breakdown of the SNAC-footprint and WIOD (kt CO_2)

Name	**SNAC-footprint**		**WIOD**		**Difference**
Absolute/Percentage	**ktCO_2**	**%**	**ktCO_2**	**%**	**%**
AUS	392	0,5%	558	0,6%	-0,1%
AUT	340	0,4%	410	0,4%	0,0%
BEL	3160	3,8%	4299	4,3%	-0,4%
BGR	319	0,4%	365	0,4%	0,0%
BRA	502	0,6%	902	0,9%	-0,3%
CAN	670	0,8%	1101	1,1%	-0,3%
CHN	15787	19,2%	21109	21,0%	-1,8%
CYP	54	0,1%	22	0,0%	0,0%
CZE	768	0,9%	989	1,0%	0,0%
DEU	7874	9,6%	8987	8,9%	0,7%
DNK	571	0,7%	620	0,6%	0,1%
ESP	932	1,1%	1311	1,3%	-0,2%
EST	596	0,7%	526	0,5%	0,2%
FIN	448	0,5%	589	0,6%	0,0%
FRA	1488	1,8%	2052	2,0%	-0,2%
GBR	3152	3,8%	4278	4,3%	-0,4%
GRC	207	0,3%	193	0,2%	0,1%
HUN	267	0,3%	328	0,3%	0,0%
IDN	667	0,8%	889	0,9%	-0,1%
IND	2397	2,9%	3541	3,5%	-0,6%
IRL	196	0,2%	274	0,3%	0,0%
ITA	1192	1,5%	1287	1,3%	0,2%
JPN	1282	1,6%	1775	1,8%	-0,2%
KOR	1099	1,3%	1414	1,4%	-0,1%
LTU	77	0,1%	80	0,1%	0,0%
LUX	46	0,1%	56	0,1%	0,0%
LVA	44	0,1%	37	0,0%	0,0%
MEX	299	0,4%	392	0,4%	0,0%
MLT	19	0,0%	10	0,0%	0,0%
POL	1774	2,2%	2423	2,4%	-0,2%
PRT	224	0,3%	382	0,4%	-0,1%
ROU	296	0,4%	440	0,4%	-0,1%
RUS	6827	8,3%	8220	8,2%	0,1%
SVK	267	0,3%	346	0,3%	0,0%
SVN	78	0,1%	77	0,1%	0,0%
SWE	378	0,5%	514	0,5%	-0,1%
TUR	686	0,8%	823	0,8%	0,0%
TWN	934	1,1%	1347	1,3%	-0,2%
USA	4974	6,1%	6060	6,0%	0,0%
Row	20874	25,4%	21624	21,5%	3,9%
Total	**82158**		**100648**		

Table 3. Sensitivity analyses (Mt CO_2)

	SNAC-footprint	Aggregation		CO_2 data	
No. industries (IO calculations)	71	35		35	
CO_2 data	CBS	CBS		WIOD	
Total Footprint	**198**	**205**	**3%**	**207**	**5%**
Domestic indirect emissions	77	84	8%	86	11%
Domestic direct emissions	38	38	0%	38	0%
Total Domestic	**116**	**122**	**5%**	**125**	**8%**
Total Foreign	**82**	**83**	**1%**	**83**	**1%**

For more results we refer to you to Annex IV, which also provides analysis of the two version of the WIOD database (April 2012 and September 2012). These two version of the database do not make much difference to the results. Only the Chinese footprint shows a marked difference because the trade data for China was revised significantly in the September version.

6. Challenges

In this section we describe some of the challenges, both in the short term, for our project and for the work on footprints at statistical offices in general.

Short term challenges

For our project we have the following aims for the short term:

- The methodology and scripts used will undergo a detailed review
- As figure 1 showed, it is very important to verify the trend in the footprint as well as the level. An official estimate will therefore also be created for 2003.
- More sensitivity analyses will have to show what makes the most difference in the calculations.
- A method will have to be created to update the WIOD database since there are no immediate plans to update the database beyond 2009 by the WIOD consortium themselves.
- Comparison of the domestic part of the SNAC-footprint calculated in this paper with the domestic part calculated with the Dutch official input-output table.
- Addition of non-CO_2 greenhouse gasses.

Longer term challenges

There are a number of longer term challenges that may have significant impact on MRIOs as well as this work at Statistical offices.

- Industry (ISIC/NACE) and Commodity (CPC/CPA) revisions. These classification have undergone revisions recently. The new classifications are now being processed by national accounting department. The main problem for MRIO work will be in the construction of time series since the revisions will have to be used in the SUT time series. It will take quite some time before these time series will be available.
- Conceptual revisions (SNA2008). The SNA2008 has introduced a number changes include the accounting rules for “goods for processing”. These changes have altered the way in which imports and exports are calculated in the national accounts and will therefore also affect footprint calculations.
- Common approach for NSI. The method proposed here is flexible in the sense that it could be used by any country. All that needs to be done is to collect the official SUT and trade data, and to use the same scripts developed in this project. It would be good if countries started to work together to see whether they can start to create a common methodology for calculating an SNAC-footprint.
- This procedure could be used to create other globalisation indicators such as “trade in value added” (see the work of the OECD) in a way that is consistent to national accounts.

7. Discussion and conclusion

This paper has shown that the carbon footprint calculations which currently exist in the MRIO literature show an enormous range of estimates for the CO_2 footprint of the Netherlands. The trend and level differ greatly between studies. There is therefore a demand to know what the best or most acceptable estimate of the “real” footprint is.

In this paper a new method is adopted in which an MRIO (WIOD) is adjusted to the Dutch national and environmental accounts in order to create an SNAC (“Single-country national accounts consistent”)-footprint. Of course, the results are still dependent on the WIOD estimates for foreign countries (economic structure and CO_2 emissions) but the domestic part and the trade shares have been adapted to the data from Statistics Netherlands.

The preliminary results show that the Dutch SNAC-footprint is generally lower than other MRIO estimates because of a significantly lower foreign footprint. Also the Dutch footprint in China is much lower. However, the methodology still has to undergo a detailed review before the results are definitive.

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Annex I. Overview of Multi-regional Input-Output (MRIO) databases

	GTAP	EXIOPOL/ CREEA	WIOD	EORA	OECD-WTO	
					Previous	New
Acronym	Global Trade Analysis Project	EXIOPOL: Externality data and input-output tools for policy analysis CREEA: Compiling and refining environmental and economic accounts	World Input-Output Database	-	-	
Institute	Purdue University	EXIOPOL: FP6 project lead by FEEM CREEA: FP7 project lead by TNO	FP7 project lead by the University of Groningen	University of Sydney	OECD	OECD
Website	www.gtap.agecon.purdue.edu	www.feem-project.net/exiopol/ www.creea.eu/	www.wiod.org	www.worldmrio.com	-	www.oecd.org/trade/valueadded
Years	1997, 2001, 2004, 2007 (years are not comparable)	2000 (EXIOPOL) 2007 (CREEA)	1995-2009	1990-2009	1995, 2000	2005, 2008 and 2009
Prices of previous year	-	-	1996-2009	-	-	-
Countries/ Regions	66-129 (depends on year)	43 (27 EU, 16 non-EU) (95% of the global GDP)	35 (27 EU and 12 non-EU) (80% of world GDP in 2006)	187	41 (90% of global GDP) (67% of global population in 2000)	40 (all OECD countries, Brazil, China, India, Indonesia, Russian Federation and South Africa)
Industries	57 sectors	130	37	100-500 sectors	17	18

Environmental data	Greenhouse gases (CO_2, NO_2, CH_4) Energy use Land use (split agro-ecological zone)	Emissions (56) Materials (96) Land use (15) Water use (14)	Energy use / several energy carriers Water consumption Land use Emissions of greenhouse gases Air pollutants Resource use/extraction Generation and treatment of various types of waste	Greenhouse gases Air pollution Water use Ecological Footprint	CO_2	None

Annex II. Overview of footprint calculations at NSI's and other government agencies

NSI/Other	Institute	Country	Type	Country specific IO	Time series or most recent year	Environmental	Regions	Industries	Data online	Household characteristics	Interactive
National Statistical Institutes	Australian Bureau of Statistics	Australia	SRIO	Y	2007/2008	GHG	1	40	N	N	N
	Statistics Canada	Canada	MRIO	Y	2002&2006	GHG	4	?	Y	N	N
	Statistics Denmark	Denmark	Partial	Y	2005	CO_2	13	60	N	Y	N
	INSEE	France	Partial	Y	2005	CO_2	±15	60	N	Y	N
	DESTATIS	Germany	Partial	Y	2007	CO_2	14	73	N	N	N
	Statistics Netherlands	Netherlands	Partial	N	2009	GHG (4)	17	60	N	Y	Y
	Statistics Sweden	Sweden	SRIO	N	1993-2008	Energy; materials; air emissions	2	134	Y	Y	Y
Other government agencies	PBL Netherlands Environmental Assessment Agency	Netherlands	Partial and MRIO	Y	2001	GHG (3) and land	13	57	N	N	N
	DEFRA	United Kingdom	MRIO	Y	1990-2009	CO_2 and GHG	4	123	Y	N	N
International institutes	OECD	OECD countries	MRIO								
	Eurostat	EU27	SRIO	N	2000-2007	8 pressures	2	64	Y	N	N

References: Australian Bureau of Statistics (Hao et al, 2012); Statistics Canada (Statistics Canada, 2012); Statistics Denmark (Rørmose et al, 2009);; INSEE (Lenglart, 2010); DESTATIS (DESTATIS, 2010); Statistics Netherlands (Edens et al, 2011; Statistics Netherlands, 2010; 2011); Statistics Sweden (Statistics Sweden 2003); PBL Netherlands Environmental Assessment Agency (Nijdam et al., 2005; Wilting and Vringer, 2009; Wilting, 2012); DEFRA (DEFRA, 2012; Wiedmann et al, 2008), Eurostat (Eurostat, 2012), OECD (Ahmad and Wyckoff, 2003; Nakano et al, 2009).

Annex III. Adjusting WIOD to Dutch data

In the steps below we describe how to transform the international supply and use table as they are available on www.WIOD.org, together with official Dutch statistics into a World Input-Output Table (WIOT) that is consistent with official Dutch statistics. This transformation procedure is performed in the statistical programming software RStudio.

Step 1: Read data

Read the 40 use and 40 supply tables from the IntSUT excel file, as available on the WIOD website.

Step 2: Pre-shape data

Remove subtotals from the use tables

Separate intermediate use and final demand for each country

Step 3: Create world use and supply table

Concatenate the 40 use tables into one large multi-regional use table (MRUT), with the intermediate use parts of all countries first, followed by the final demand parts.

Concatenate the 40 supply tables into one great multi-regional supply table (MRST), where the supply tables from WIOD are on a block diagonal and the remaining cells are zero's.

Step 4: Calculate export to Rest of the World (RoW)

Correct the export for each country by subtracting the retraceable exports from it (i.e. the exports that are given as part of the intermediate use or final demand in other countries). The remaining exports are classified as exports towards RoW. Here we should note that this procedure leads to some negative values for export to RoW, which is infeasible. This will be corrected in the next step.

Step 5: Correct negative exports to RoW

When, after step 4, the export to RoW of a certain good from a certain country became negative, replace this by zero.

Subtract the negative value proportionally from the rest of its row, unless the row total is insufficient to achieve this without creating new negatives. In that case, subtract the negative value proportionally from all the rows in its corresponding country.

Step 6: Distribute exports to RoW over industries and final demand categories within the RoW

Assume that RoW uses imports the same way as the average of BRICIM (Brazil, Russia, India, China, Indonesia, Mexico) countries. This implies that for each good we calculate the average distribution over industries and final demand categories for each imported good over the BRICIM countries. The export to RoW that was calculated in step 5 is distributed according to this 'BRICIM distribution' of the industries and final demand categories in RoW.

When none of the BRICIM countries imports a specific good while it is imported by the RoW, use the average distribution of non-BRICIM countries to determine how these goods are distributed over the industries and final demand categories.

Step 7: Create RoW use table

For each BRICIM country concatenate its intermediate use and value added part into one matrix and divide each of its cells with the matrix's total, such that the sum of the cells in each matrix sum op to one. Calculate the average of these (six) matrices, which serves as the distribution for the use table of RoW.

Retrieve the sum of intermediate use and value added of the RoW from the MRIO table as published by WIOD, and multiply the BRICIM use table distribution by this number. The result serves as the intermediate use and value added part of the RoW.

Calculate the BRICIM distribution of the RoW final demand part in the same way as the distribution of intermediate use and value added part, and multiply this BRICIM final demand distribution matrix by the total value added of the RoW, minus the RoW export and plus the RoW import. The result serves as the final demand matrix of RoW

Concatenate the intermediate use, value added and final demand parts of RoW to the MRUT from step 3, this serves as the MRUT for the whole world.

Step 8: Create RoW supply table

For each BRICIM country, divide each cell of its intermediate supply by the total of intermediate supply. Consecutively, take the average of these (six) distribution tables. This table serves as the distribution for the intermediate supply table of the RoW.

Multiply this distribution table by the total intermediate use plus total value added of RoW, as used in step 7.

Run a balancing procedure to assure that each row and column total in the supply table of the RoW is equal to the row and column total of the RoW in the use table.

Ad this supply table to the MRST from step 3, this gives a MRST for the whole world

Step 9: Incorporate official Dutch statistics

Replace the Dutch intermediate use and supply part and the Dutch import and export part in the MRUT and MRST from step 8 with their official Dutch statistics as they are available at Statistics Netherlands. The official statistics include re-exports, cif/fob adjustments on exports, direct purchases abroad by residents, purchases on the domestic territory by non-residents, international trade margins (ITM) and taxes less subsidies (TLS).

This replacement increases the number of Dutch goods and service categories from 59 to 221 and the number of industry categories from 35 to 135. The Dutch import data is specified for each country and intermediate use or final demand category. The Dutch export of goods and services is specified per country, but not per industry.

In order to distribute the Dutch export over industries and final demand categories in their countries of destiny, the distribution for each good in the WIOD use tables is applied.

If, according to WIOD, there is no Dutch export of a certain good to a certain country, while according to official Dutch statistics there is, the average use distribution of this good in other countries is applied.

If, according to official Dutch statistics, there is Dutch import of a specific good from a specific country, while according to WIOD that row total equals zero, this import value is subtracted from ‘Changes in inventories and valuables’ of the concerning country, such that the row total remains zero.

Distribute TLS and ITM on exports over the respective countries, proportionally to their respective distributions in the MRUT.

Step 10: Balance the MRUT and MRST

Due to both the creation of a use and supply table for the RoW and the incorporation of official statistics, both the row and column totals of the use table have changed, plus the row and column totals of the RoW in the supply table are not yet equal to the row and column totals of the RoW in the use table. In order to correct this imbalance we apply the Stone method (Stone, 1942) balancing procedure on both the MRUT and the RoW part of the MSUT. The Stone method is attractive because it provides a unique solution with minimal adjustment in terms of least-squares differences. However, the Stone method does not guarantee that the balanced matrix contains no new negative values. Therefore, in an iterative Stone balancing procedure the (small number of) negatives are corrected. This method no longer has the advantage of minimising the least squares (although due to the small number of negatives, it’s probably very close), but the method does provide a unique answer.

During the balancing procedure, the rows and columns that contains merely official Dutch statistics, together with the rows that contain value added , cif/fob adjustments on exports, direct purchases abroad by residents, purchases on the domestic territory by non-residents, ITM and TLS are left unchanged.

Step 11: Create IO table

Step 10 provides a balanced use and supply table that contain the official Dutch statistics. These two tables can be used to compute an industry-by-industry world input-output table (WIOT). To achieve this, there are numerous computation methods that all require different assumptions which all have pros and cons. For a more detailed discussion on these methods we refer to the Eurostat manual on Input-Output methods (Eurostat, 2008). One of the main computation methods that is discussed in this manual is the ‘fixed product sales structure assumption’ (Model D in the Eurostat manual), which has the advantage that is creates no negatives in the resulting input-output table. This method is applied to compute the WIOT that is consistent with official Dutch statistics.

Annex IV. Detailed results (ktCO_2)

WIOD version	WIOD (version: april 2012)				WIOD (version: september 2012)			
WIOD data adjusted?	**Original**	**Adjusted**			**Original**	**Adjusted**		
No. industries (IO calculations)	**35**	**71**	**35**	**35**	**35**	**71**	**35**	**35**
CO_2 data	**WIOD**	**CBS**	**CBS**	**WIOD**	**WIOD**	**CBS**	**CBS**	**WIOD**
Total Footprint	**213578**	**198577**	**205218**	**207820**	**210102**	**198000**	**204633**	**207239**
Domestic indirect emissions	70809	77438	83601	86203	70951	77452	83614	86220
Domestic direct emission	38503	38389	38389	38389	38503	38389	38389	38389
Total Domestic	**109312**	**115827**	**121990**	**124592**	**109454**	**115841**	**122003**	**124609**
Total Foreign	**104266**	**82750**	**83228**	**83228**	**100648**	**82158**	**82629**	**82629**
AUS	521	396	400	400	558	392	396	396
AUT	390	342	344	344	410	340	341	341
BEL	4335	3243	3261	3261	4299	3160	3177	3177
BGR	324	283	285	285	365	319	321	321
BRA	903	478	498	498	902	502	525	525
CAN	1148	660	666	666	1101	670	676	676
CHN	27607	16369	16300	16300	21109	15787	15703	15703
CYP	11	54	54	54	22	54	54	54
CZE	872	758	758	758	989	768	767	767
DEU	8703	7845	7929	7929	8987	7874	7958	7958
DNK	605	560	571	571	620	571	582	582
ESP	1241	937	940	940	1311	932	935	935
EST	514	598	628	628	526	596	627	627
FIN	572	447	454	454	589	448	455	455
FRA	1799	1492	1490	1490	2052	1488	1486	1486
GBR	4154	3175	3205	3205	4278	3152	3183	3183
GRC	142	207	204	204	193	207	204	204
HUN	305	267	268	268	328	267	268	268
IDN	792	645	649	649	889	667	672	672
IND	2961	2353	2358	2358	3541	2397	2401	2401
IRL	218	197	197	197	274	196	196	196
ITA	1221	1187	1190	1190	1287	1192	1195	1195
JPN	1562	1252	1256	1256	1775	1282	1287	1287
KOR	1381	1102	1103	1103	1414	1099	1099	1099
LTU	76	78	78	78	80	77	78	78
LUX	63	46	46	46	56	46	47	47
LVA	37	44	44	44	37	44	45	45
MEX	413	305	301	301	392	299	296	296
MLT	10	19	19	19	10	19	19	19
POL	2143	1772	1776	1776	2423	1774	1779	1779
PRT	329	222	225	225	382	224	227	227
ROU	337	298	300	300	440	296	298	298
RUS	8257	6784	6926	6926	8220	6827	6970	6970

SVK	277	267	268	268	346	267	268	268
SVN	67	75	76	76	77	78	79	79
SWE	430	376	381	381	514	378	384	384
TUR	701	642	642	642	823	686	686	686
TWN	1438	974	973	973	1347	934	932	932
USA	6285	5005	5018	5018	6060	4974	4985	4985