"European Framework for Measuring Progress"

e-Frame

www.eframeproject.eu

SP1-Cooperation
Coordination and support actions (Coordinating actions)
FP7 SSH-2011-3

Grant Agreement Number 290520
SSH.2011.6.2-1

Deliverable 6.2

Dissemination level: PU

Environmental footprints: An methodological and empirical overview from the perspective of official statistics

Authors: Rutger Hoekstra, Bram Edens, Daan Zult, Ronghao Wu and Harry Wilting[1,2]

11 March 2013

This project is funded by the European Union under the 7th Research Framework Programme (Theme SSH-2011-3)
Grant Agreement nr 290520

[1] A previous version of this paper was presented at the final conference of the WIOD conference in May 2012 (Hoekstra et al, 2012).

[2] Rutger Hoekstra, Bram Edens and Daan Zult are affiliated to Statistics Netherlands. Harry Wilting is affiliated to PBL Netherlands Environmental Assessment Agency. Ronghao Wu is an MSc. student at Wageningen University who did her internship at Statistics Netherlands. The authors are grateful by comments from Oscar Lemmers (Statistics Netherlands) and Marcel Timmer (University of Groningen).

Deliverable 6.2

Environmental footprints: An methodical and empirical overview from the perspective of official statistics

Summary

The concept of environmental footprints emerged at the beginning of the 1990's through the introduction of the "ecological footprint". This indicator has achieved a large amount of media coverage and impact on policy discussion. In later years, carbon, water, material, land and biodiversity footprints were also developed. Footprint calculations are valuable because they directly link environmental pressures to consumption. Furthermore, this type of work can also help to answer other environment-economic questions related to the shifts in environmental burdens between countries (sometimes referred to as "carbon leakage" or the "pollution haven hypothesis").

So far academia and research institutes are doing the bulk of the work in this field, but National Statistical Institutes (NSI) are also increasingly producing footprint indicators. For the most part, the calculations at NSIs are experimental.

Footprint calculations, both in the academic and statistical world, are increasingly using multiregional input-output (MRIO) databases. Over the last few years quite a number of these databases have emerged (e.g. GTAP, OECD, EXIOBASE/CREEA, WIOD and EORA). These databases are increasingly relying on official statistics. This raises the prospect that these databases can start to be used in the production of "official" footprints by NSI's.

This paper aims to answer the question: what prospect is there to introduce MRIO-based "official" footprints at NSI's? This is done by providing an inventory of the academic work as well as the work that is currently being done at NSIs. Furthermore, the MRIO databases that have been created, are reviewed.

Following these overviews, the paper explores the differences between these database and NSI data are illustrated by taking the WIOD database and contrasting it to the data of Statistics Netherlands. The paper also discusses the problems associated with revisions of the national accounts which are currently taking place. Finally, this paper will show how the WIOD database can be adapted to Dutch statistics to arrive at an "official" footprint for the Netherlands.

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

Table of Contents

1. Introduction

A footprint quantifies the environmental pressures that are related to the consumption[3] of a country[4]. However, footprint calculations are also used to answer other environmental-economic questions. To fully appreciate the value of footprint calculations it is important to distinguish three interrelated questions in the academic literature: *footprint calculations*, *producer and consumer responsibility* and *global shifts in environmental pressures*.

Footprint calculations

The calculation of "footprints" started with the work on "ecological footprints" in the early 1990s (Rees, 1992, Wackernagel and Rees, 1996).[5] The ecological footprint calculates the amount of land and water (surface area) that is necessary in the production of a certain consumption bundle. For example, the amount of land that is required to produce food is a component. An important, but often criticised part of the calculation, is the fictive amount of forest that would be required to sequester the human CO_2 emissions (van den Bergh en Verbruggen, 1999).

The ecological footprint is capable of directly linking human consumption to environmental pressures. It also shows the "overshoot" i.e. the difference between the ecological footprint and the actual area of productive land available to us. This communicative power has led influential institutes such as the World Wildlife Fund to adopt it in their Living Planet Report (WWF, 2010). On the other hand, the methodology of the ecological footprint has also been criticized (van den Bergh and Verbruggen, 1999; Grazi et al., 2007; Fiala, 2008).

The ecological footprint has also inspired researchers to develop other footprint indicators such as the carbon footprint (Peters, 2008; Peters and Hertwich, 2008) and water footprint (Hoekstra, 2003; Hoekstra and Chapagain, 2008).[6] Although the methodologies are currently quite different, there are efforts to harmonise their calculations. For example, in the OPEN-EU project an effort was made to identify a "family of footprints" by defining the similarities and differences in methodologies and data (Galli et al, 2011). The overall conclusion was that footprint calculations should converge towards the use of MRIO data and input-output analysis (Weinzettel et al., 2011).[7]

Most of the above developments have taken place in the academic realm. However, NSIs are also increasingly looking at these issues. As we will show, quite a few NSIs have developed and published (experimental) calculations, particularly on carbon footprints.

---

[3] In footprint calculations consumption is mostly defined as domestic final demand i.e. consumption expenditures and gross capital formation.

[4] Footprints are also calculated for other levels of consumption such as cities, regions, universities or individuals. The focus of this paper is on the national level.

[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). 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] Recently, the footprint concept has also been adopted in other areas as well. It has been linked to land (Weinzettel et al, 2013), "biodiversity threats" (Lenzen et al, 2012) and raw materials (through the so-called raw-material equivalents (RME) (Schoer et al., 2012). The term "footprint" has even been used to focus attention on slavery (www.slaveryfootprint.org).

[7] 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).

Production versus consumption perspective

Footprint indicators make explicit the environmental pressures that are caused by consumer behaviour. However, their calculation is often used to prove another point as well. It is a strand of the literature which is often referred to as the "production versus consumption perspective" (Peters, 2008; Peters and Hertwich, 2008).

Underlying this discussion is the question: Which environmental pressures should a country be held responsible for? Put differently, who is the polluter in the polluter-pays-principle? On the one hand you could say that industries, which are directly emitting the pollutants (and creating value added), are responsible. This is commonly referred to as the production perspective.[8] International agreements, such as the Kyoto Protocol, have a similar basis[9] because all greenhouse gas emissions within a country's geographical boundaries are included. On the other hand, the consumption perspective is based on the premise that the "polluter" is the final consumer of the products. In the consumer perspective all environmental pressures in the production cycle are included, whether the production takes place in the country itself or abroad.

Global shifts in environmental pressures

In an autarkic country, the total environmental pressures from the producer and consumer perspective will be the same. However, due to trade relations between countries both perspectives lead to different results. One could say that all countries have an "environmental trade balance" which is similar to the economic "balance of trade". This environmental trade balance, which is the difference between the environmental pressures embodied in exports and imports, may be changing over time. This may be the result of economic developments as well as institutional agreements such as the Kyoto Protocol or WTO agreements on trade liberalisation.

Various hypotheses have been proposed to characterize these global shifts. For example, the term "carbon leakage" is used to label studies that investigate whether the emissions (from the producer perspective) of Kyoto-signatories are being reduced by increasing imports of emission-intensive products for non-signatories (Peters, 2008, Weber et al, 2008; Peters and Hertwich, 2006/2008; Babiker, 2005). A related field of research is the "pollution haven hypothesis" that investigates the same shifts from developed to developing countries, resulting from differences in environmental regulation (Eskeland and Harisson, 2003; Cole, 2004).

Multiregional input-output (MRIO) analysis

Research that involves the above three issues increasingly concerns multiregional input-output (MRIO) data and analysis. An MRIO table shows all intercountry trade, including a breakdown by industry and final demand categories. The last few years have seen the emergence of a large amount of MRIO databases (See section 3). Many of them have environmental modules that make it possible to calculate environmental footprints.

The advantage of the MRIO approach is that the three above questions can be answered simultaneously from a set of consistent calculations. Also the input-output methodology allows quantification of the indirect effects of consumption (see annex 1).

[8] Note that in the production perspective the direct emissions from final consumption are also included.

[9] The production perspective and Kyoto definition of emissions are similar but not identical. The Kyoto definition starts from the principle of territorial emissions, although there is a special treatment for transport and short-cyclical emissions. The production perspective is based on the "residency principle" which implies that all pollutants emitted by companies and households that are resident of a country are counted.

The demand for an "official" footprint

The MRIO databases that are based largely on the official data from NSIs. However, in the production of the MRIO a number of assumptions have to be made to balance the flows in the global economic structure. As a result the MRIO databases will show inconsistencies to the official statistics. For instance, aggregates such as Gross Domestic Product (GDP), or total amount of CO_2 emitted or the trade of goods and services may differ from the official figures published by NSIs.[10]

The source data and the balancing methodologies vary per MRIO database. As Figure 1 shows this may lead to very different outcomes for the footprint calculation. Three carbon footprint calculations for the Netherlands are shown in the figure: two based on GTAP studies (Peters et al, 2011; Wiebe et al., 2012) and one based on the WIOD database (Boitier, 2012). From these results it is show that the databases create different levels and, perhaps more importantly, trends in the footprint. See Peters et al. (2012) for further comparisons.

But what is the best footprint for the Netherlands? Since there are no "official" footprint available it is unclear which of levels or trends are correct.

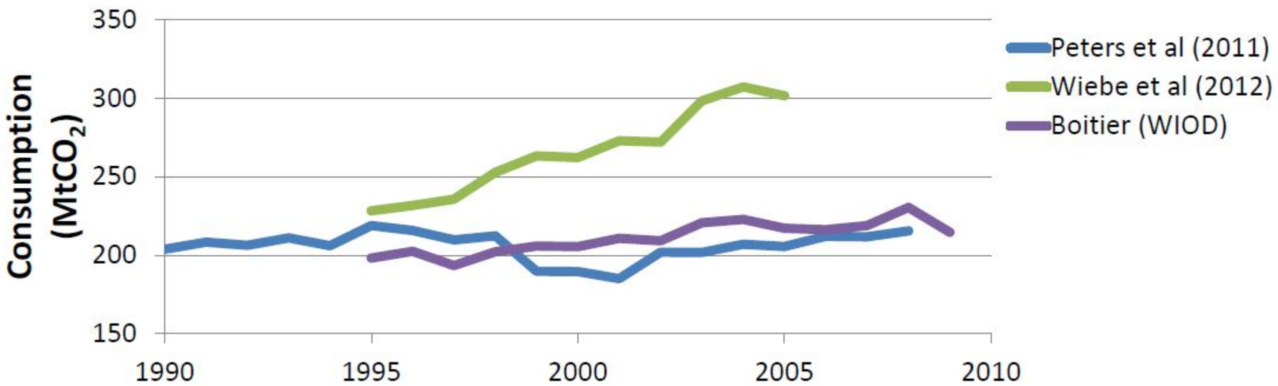


Figure 1. Differences in consumption-based estimates for the Netherlands
Source: Keynote speech by Glen Peters at the WIOD conference in May 2011

Towards an "official" footprint

The aim of this paper is to show what steps need to be taken to move towards "official" footprints. The following issues will be covered in this paper:

1. An overview work on footprints at NSIs will be provided.
2. An overview of characteristics of the various MRIO databases is shown.
3. The methodological and empirical differences between MRIO databases and official statistics are illustrated using a case study. The difference between a major MRIO database (WIOD) and corresponding Dutch official statistics data is analysed.
4. The issue of revisions in the industry and goods classifications and the implication of the revision of the System of National Accounts (2008) are discussed. These revisions are challenges for the production of MRIO databases in future.
5. A method is proposed to adapt MRIO data to official statistics thereby producing an "official" footprint.

[10] 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".

6. The paper will provide guidance for the next steps.

Note that the remainder of this paper focuses on footprint calculations, despite the fact that the introduction stressed that there are other relevant research issues (production vs. consumption perspectives, global shifts in environmental burdens). Footprints calculations are however the most visible at NSIs. Nevertheless, it should be emphasised that the calculations yield valuable information beyond the footprint.

2. Overview of work at NSIs

Table 1 provides an overview of work done on footprints by NSI's, other government agencies and international institutes. This overview is not exhaustive, but it does provide a good overview of the NSIs and related government institutes that are active in this field.

Several statistical offices (Canada, Denmark, Netherlands) started experimenting with environmentally extended input-output (IO) analysis in the late 1990s (see for example de Haan, 2004). This was often due to the availability of time series of IO tables in combination with emerging environmental accounting programs. These initial efforts were not based on MRIO data, but instead relied on the "domestic technology assumption", which assumes that imports are produced with the same production technology as domestic products. In the table we refer to this as the Single Region Input-Output (SRIO) model.

The table shows that several other statistical offices have followed suit. Some use the SRIO approach (Sweden, Eurostat), but the table shows that many of them have started to use partial MRIO models. Partial MRIO models can exist in many forms, but what distinguishes them from comprehensive MRIO tables is that interregional trade flows (at the industry to industry level) are partially accounted for or not accounted for at all. Some countries add additional information about country specific emissions but apply the domestic IO table (e.g. Netherlands, Germany) others add information about country specific IO tables (e.g. Denmark).[11]

Only Statistics Canada, DEFRA and PBL have used full-MRIO models. PBL has used GTAP (see section 3), DEFRA and Statistics Canada have constructed their own MRIO databases, often with less regions (4) than the most recent MRIO databases (which distinguish at least 40 countries/regions). Overall conclusion is that there is wide range of methods that are used.

The focus of NSI work is clearly on carbon footprints, although many only look at CO_2 and not the broader range of greenhouse gasses. Some NSIs also include a wider range of environmental issues such as energy or material flows. Note that a lot of the work is on CO_2 The level of detail used is often 60 industries due to the availability of IO tables in that format.[12] There is also clear interest in additional breakdowns of household consumption into household characteristics such as income; household composition (family members etc.); location (rural / urban) (4 out of 9 institutes);

Finally, the dissemination practices of the institutes show that the results are not always presented as "official statistics". Data are often disseminated in the form of experimental analysis, but not available as official data sets (with exception of Canada, United Kingdom and Eurostat). This

[11] The German method is an example of a hybrid method where physical details from the German energy flow account is used to add greater detail to the monetary IO table to ensure consistency with the actual physical energy consumption of industries.

[12] As there is no official IO time series for Sweden it was developed from the SUTs.

reflects the uneasiness that is often felt in the statistical community to present statistics that are based on input-output modeling assumptions and MRIO databases. In Sweden and the Netherlands interactive tools have been developed that allow users to obtain data according to their research interest (calculate your own carbon footprint).

3. Overview of MRIO databases

The last decade has seen the development of many multi-regional input-output (MRIO) databases, many of which include environmental data. A few excellent overviews have already been published or will be published this year (Wiedmann et al (2011), Special issue of *Economic Systems Research* (2013) including the editorial by Tukker and Dietzenbacher (2013) and Murray and Lenzen (2013)). In this overview the focus lies on the question: which databases would be most useful for the purposes of creating “official footprints”?

Table 2 lists some of the characteristics of the MRIO datasets that are currently available (or will be published this year). The existing datasets are very much different in terms of detail or country coverage; industry breakdown and time series. All data sets seem to suffer from a time lag.

Assume that an NSI wants to use one of the above MRIO databases for its future work on footprints. Which would they choose? This is not a simple question, and it does depend on the exact aims of the NSI.

The GTAP database (or adaptations thereof) is probably the most widely adopted in academic publications. However, in many cases the economic and environmental data differ quite significantly from official sources, making it less of a candidate for work on official statistics. Furthermore, the GTAP consortium warns the users of the data for the risks of using the data in IO modelling; the database is not a repository of IO tables, but a consistent representation of the world economy in a specific base year for use in CGE modelling (GTAP website).

The GTAP database has existed for a very long time and is widely used. However, a new generation of MRIO databases has been launched in the period 2011-2013: EXIOPOL/CREEEA, WIOD, EORA and the renewed OECD database. A common characteristic of these MRIOs is that they attempt to stay close to official statistics.

The EXIOPOL database which was released in 2011 and its successor the CREEA database (currently still under construction) are EU funded databases (FP6 and FP7 respectively). These databases provide a detailed sector structure and a lot of detail in environmental externalities. These databases are very much suited to environmental applications. Nevertheless, the fact that it does not have a time series (or a very recent year) is a drawback. EXIOPOL has data for the year 2000, while CREEA will produce data for 2007.

The WIOD database is also an EU-funded (FP7) database which was released in April 2012 and also based almost entirely on official data sources (Timmer et al, 2012). The fact that the database includes time series in current and constant prices makes WIOD useful for detailed analysis of changes in footprints over time. The database also has information on air emissions, materials, water and land so that it is possible to calculate a variety of footprints (Arto et al, 2013a,b). However, the sector structure is only 35 industries. This seems sufficient for a CO_2 footprint (although more detail would be preferred) but it is not really good enough for water or land footprints, which require a more detailed data of the agricultural sector. A disadvantage is that there are no plans to update WIOD.

Table 1: 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 and 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).

Table 2. Overview of databases-Summary

	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	-	-	1995-2006	-	-	-
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

The EORA database has been developed at the University of Sydney and was released in 2012 (Lenzen *et al.*, 2012). It has the largest country coverage (187) and the longest time series (from 1990). Given the large amount of countries covered by EORA, the source data varies significantly. For some countries there are supply and use tables, while for other there are only macro-economic aggregates or input-output tables once every 5 years. As a result the EORA database has created a flexible system in which countries may have varying source data and classifications.

The OECD has a long tradition in creating MRIOs and calculating footprints from them (Ahmad and Wyckoff, 2003; Nakano et al., 2009). In the past the OECD would produce 5-yearly input-output tables for 41 counties. Recently however, the work on the production of MRIOs has intensified at the OECD (together with the WTO) because of the academic interest in trade in value added. There is not a lot of information about the methodology but they seem to have extended the WIOD approach. They have only very recently published the first results for trade in value added for 3 years for 40 countries (OECD, 2013). The database does not however have environmental data, has very aggregated industry classification and the MRIO database is also not freely available (only the indicators or trade in value added are published). However, the database is still under construction.

Which database is best to calculate "official" footprints?
The above overview has shown that there is currently no "perfect" MRIO database. Each database has its strengths and weaknesses. Depending on the goals of the calculations, a variety of options are available. It is also likely that MRIO database will start to be combined instead of choosing a single source (see section 6 for the choices made by Statistics Netherlands).

4. MRIO versus NSI data: A case study for the Netherlands

The most recent MRIO databases (EXIOPOL/CREEA, WIOD, EORA and OECD) discussed in section 3 attempt to stay close to official statistics. Nevertheless, the methodology for producing MRIOs leads to results that are inconsistent to the "official" national accounts, trade 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.[13]

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 from 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). However, if they are not available other sources such as input-output tables or macro-economic aggregates are used. The SUTs are augmented with information from trade statistics and environmental data.

Linking WIOD to the data from Statistics Netherlands.
In this section the difference between MRIO databases and official statistics is illustrated using the Netherland as a case study. As an example the WIOD database is taken because it is a promising database for future work. The differences between WIOD and the data from Statistics Netherlands are compared. The Netherlands is a good example for a case study because of the "Rotterdam-effect": this port acts as a gateway to Europe and the trade therefore consist of a sizeable amount of

[13] Note that when the footprint calculations are done using the domestic technology assumption, only official statistics are used. However, the scientific literature shows that this assumption does not provide a very good estimate of the actual emission abroad (Battjes et al., 1998; Lenzen et al., 2004; Andrew et al., 2009; Tukker et al, 2011).

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 is created using a trade database (such as Eurostat's COMEXT database) which includes transit trade, it will overestimate the Dutch footprint in China. This may lead to very different results for the Dutch footprint, depending on the database used (discussed in Section 1-Figure 1).

Figure 2 shows the relationship between the data of Statistics Netherlands, international statistical databases and WIOD.[14] 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). Let us now have a closer look at the data from Statistics Netherlands (the international database which have these statistics are shown in italics):

1. SUT/IOT: Statistics Netherlands produces detailed supply and use tables which distinguish approximately 600 different products and about 130 industries at its most detailed level. These SUTs are the basis for the production of the industry-by-industry input-output tables which are available at 133 industries for analytical purposes. To produce the input-output tables, a manual procedure is used in which the source and destination is specified for each product group. This is different to the WIOD procedure which uses a simple mathematical procedure.
   The SUT/IOT tables are sent to Eurostat every year, in the format and frequency requested.[15] *There is however a conceptual difference in the treatment of trade margins (see box 1).*
2. Environmental accounts: Environmental accounting has a long history at Statistics Netherlands. A large range of different accounts are produced, including the emission of greenhouse gases from 1990 to the present. The industry breakdown is about 70 sectors.
   These environmental accounts data are provided to Eurostat as part of the compulsory EU-transmission of environmental accounts data.
3. International trade statistics: Statistics Netherlands produces monthly data for trade of goods as part of the INTRASTAT and EXTRASTAT deliveries for respectively trade with EU-countries and countries that are not members of the European Union. International trade in services data are compiled by Statistics Netherlands (from 2003 onwards-before it was collected by the Dutch Central Bank).
   The data on trade in goods is published in the Eurostat databases (COMEXT, includes transit trade) and the United Nations database (COMTRADE, does not include transit trade).

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 are derived from Eurostat[16,17]. Trade in goods is derived from COMTRADE.

In the process of producing the WIOD database the SUTs are combined with the international trade data. The latter provide information about the bilateral trade flows, and are used to create trade shares which are used to split imports/exports in the SUTs. This yields asymmetries which need to be resolved. Finally the input-output tables are produced from the SUTs by using the "fixed product sales structure" (model D of the Eurostat (2008) manual).

---

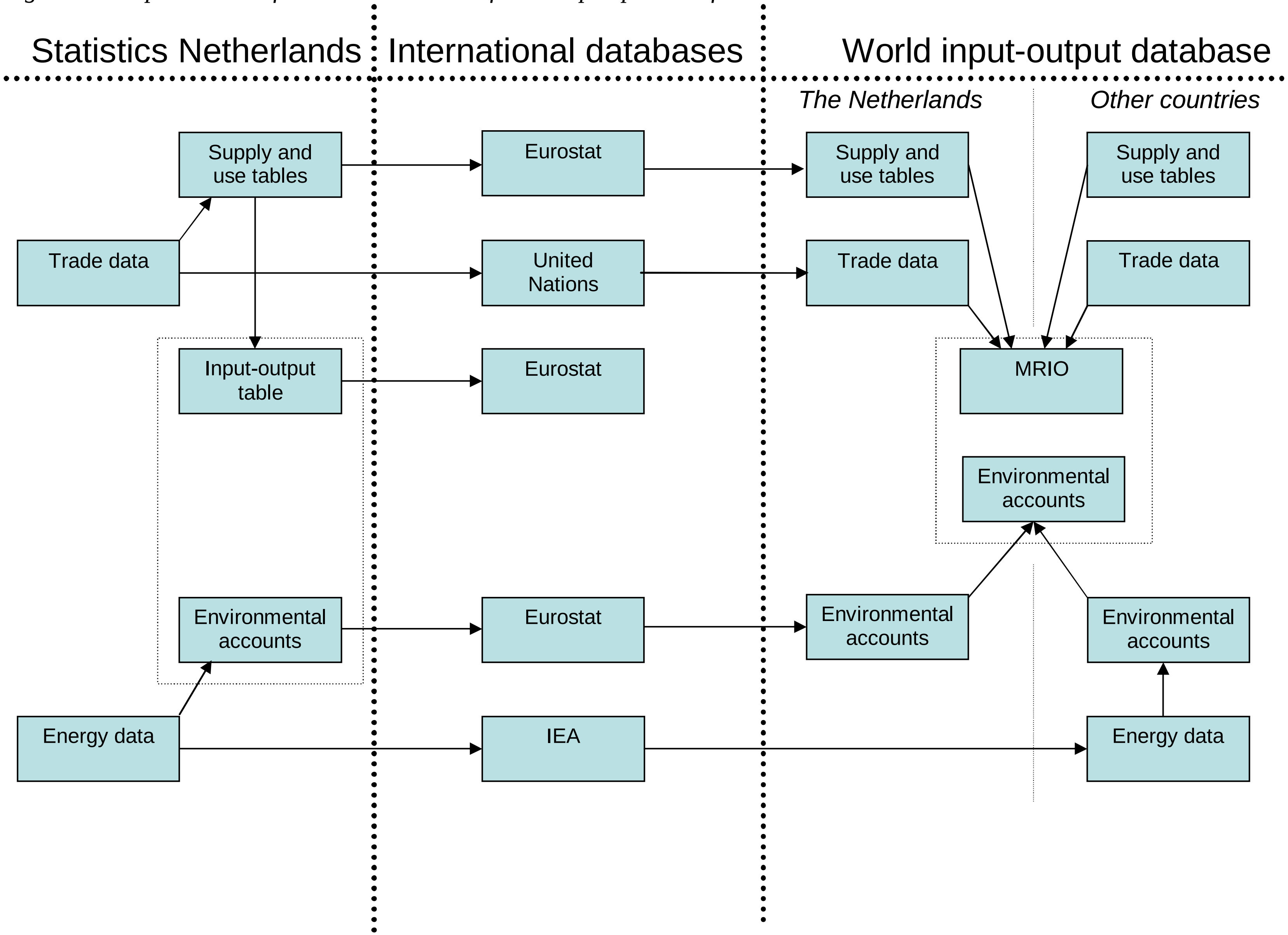
[14] For the moment on the carbon footprint modeling as opposed to other footprints such as water or land.

[15] ESA95 Questionnaire 1500 - Supply table at basic prices; ESA95 Questionnaire 1600 - Use table at purchasers' prices; ESA95 Questionnaire 1700 - Symmetric input-output table at basic prices; ESA95 Questionnaire 1850 - Symmetric input-output table for domestic production; ESA95 Questionnaire 1950 - Symmetric input-output table for imports.

[16] Note that the input-output data that is delivered to Eurostat is not used.

[17] For countries which do not have environmental accounts, the WIOD consortium uses an indirect method using the energy data from the International Energy Agency (IEA) database.

Figure 2. The production of the WIOD database from the perspective of Statistics Netherlands



Box 1. Treatment of margins in the Dutch input-output table

The Dutch IO tables are derived from the individual input-output tables that are compiled for each product that we distinguish in the National Accounts. Essentially, the database that underlies the compilation of the aggregate Input-Output table contains information of the form (supply * product * use, for a range of valuation layers, basic prices, margins, taxes and subsidies).
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.

Potential differences in data from WIOD and Statistics Netherlands

The WIOD database contains different information for the Netherlands than that provided by Statistics Netherlands. This means that footprint analysis, based on the WIOD database will not be based on official statistics. The main sources of differences are the following:

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. 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 the balancing procedures of the national accounts, some of the source data is adjusted.
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. Box 1 has discussed the conceptual differences between the SUT and IOT used by Statistics Netherlands and those sent to Eurostat. The Dutch input-output analysis would therefore take place using a different conceptual basis.
    - Aggregation level. The SUT and IOT data delivered 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 (72 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 is used to produce input-output tables. In the case of producing an input-output table at the 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)). This conversion is not present in the source data from 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).

Empirical differences in data from WIOD and Statistics Netherlands

The remainder of this section takes a closer look at the empirical differences between WIOD data[18] and the official data from Statistics Netherlands. Table 3 provides an overview of a selection the macro-economic aggregates based on WIOD and the official figures. The column showing value added is precisely equal in both databases except for 2008 and 2009. The difference in the latter two years can be explained because the figures might have been revised since the time that the WIOD database was created. Output is only marginally different. This very large correspondence of value added and output can be explained by the aims of the WIOD database which is to analysis global value chains (GVC) and other economic aspects of globalization. For this type of analysis, it is essential to have variables that are as close as possible to the official data.

The other variables do exhibit differences. What is important for the calculations of the footprint is the difference in the imports. The results show that the total imports are higher in WIOD (in basic prices) than the official figures. Given that the carbon intensities are also likely to be different for domestic and foreign product, the footprint will be affected.

A second important aspect of the footprint calculations (and also for the differentiation of where the carbon emissions take place) are the trade shares. Table 4 shows the import shares for the top 10 countries from which the Netherlands imports (for CPA codes 1-36). Note that this data was specially prepared by the Dutch trade statistics department. Re-exports and transit trade were excluded to get the best possible estimate of the trade shares from each country.

Overall, the difference between the shares from the trade data and WIOD (both excluding re-exports) are not very large. China and the Rest of the World stand out, but the percentage difference is not very high (1,7%). One would expect that this difference will not affect the footprint calculations detrimentally.

Table 5 shows that at a macro-level, the differences in the environmental accounting data of WIOD and official data published by Statistics Netherlands, are not very large. However, at the industry level the differences are greater. Two reasons can been identified: 1) the environmental accounts are revised every year because the emissions inventories are updated annually 2) the environmental accounts have already adopted the new NACE classification (see next section). The latter change is likely to have created the largest differences. As a result the CO_2 intensities (CO_2 emission divided by output) for the Netherlands which are currently in the WIOD database will not be equivalent to the official CO_2 intensities currently being published.

[18] WIOD is actually produced in 3 steps: 1) International SUT stage 2) World input-output table 3) World input-output table adjusted for the Rest of the World. The latter is seen as the relevant database for analytical studies, and this is therefore taken as the basis for the comparisons in tables 3,4 and 5.

Table 3. Macro-economic aggregates: WIOD minus Statistics Netherlands data (1995-2009) (1000 million Euros and %)

Year	Output		Intermediate demand (Basic prices)		Value added		Imports (excluding re-exports)	
	Difference	%	Difference	%	Difference	%	Difference	%
1995	-1131	-0,2%	10350	3,8%	0	0,0%	14081	11,8%
1996	-1166	-0,2%	11076	3,8%	0	0,0%	14029	11,1%
1997	-1192	-0,2%	11652	3,8%	0	0,0%	15105	10,8%
1998	-1214	-0,2%	13193	4,1%	0	0,0%	13972	9,5%
1999	-1225	-0,2%	15507	4,5%	0	0,0%	18050	11,6%
2000	-1255	-0,2%	15190	3,9%	0	0,0%	21072	11,9%
2001	-1269	-0,1%	18425	4,5%	0	0,0%	19941	11,1%
2002	-1276	-0,1%	18964	4,7%	0	0,0%	16864	9,5%
2003	-1244	-0,1%	20170	5,0%	0	0,0%	19424	11,0%
2004	-1225	-0,1%	21018	5,0%	0	0,0%	23704	12,9%
2005	-1214	-0,1%	21355	4,8%	0	0,0%	27474	14,1%
2006	-1205	-0,1%	22841	4,7%	0	0,0%	31111	14,5%
2007	-1252	-0,1%	24027	4,7%	0	0,0%	33667	14,8%
2008	1010	0,1%	22374	4,0%	1080	0,2%	52738	21,6%
2009	-5236	-0,5%	16337	3,1%	-1233	-0,2%	44819	21,1%

Table 4. Import shares in goods (CPA1-36) in 2009: Statistics Netherlands (trade statistics) versus WIOD

		Imports (1000 million Euros)	Country shares (%)		
Rank	Country	Trade data	WIOD	Trade data	Difference
1	Germany	30.420	20,3%	20,2%	0,1%
2	Rest of World	26.217	19,0%	17,4%	1,7%
3	Belgium	17.873	11,7%	11,8%	-0,1%
4	United Kingdom	10.157	6,2%	6,7%	-0,5%
5	USA	9.133	5,1%	6,1%	-1,0%
6	China	8.280	7,2%	5,5%	1,7%
7	Russia	7.994	4,6%	5,3%	-0,7%
8	France	7.944	5,1%	5,3%	-0,2%
9	Italy	3.893	2,2%	2,6%	-0,4%
10	Spain	2.872	2,2%	1,9%	0,3%

Table 5. CO_2-emissions: WIOD minus Statistics Netherlands data (1995-2009) (kton and %)

	1995		2000		2009	
	Difference	%	Difference	%	Difference	%
Agriculture, Hunting, Forestry and Fishing	782	7,5%	711	7,4%	-361	-3,3%
Mining and Quarrying	-15	-0,7%	-12	-0,5%	341	16,1%
Food, Beverages and Tobacco	-50	-1,1%	-49	-1,0%	-163	-4,3%
Textiles and Textile Products	-3	-0,8%	-5	-1,2%	-1	-0,3%
Wood and Products of Wood and Cork	-1	-0,7%	-5	-1,8%	49	27,7%
Pulp, Paper, Paper , Printing and Publishing	-44	-2,9%	-40	-2,4%	-54	-4,4%
Coke, Refined Petroleum and Nuclear Fuel	224	1,9%	300	2,5%	-478	-4,4%
Chemicals and Chemical Products	32	0,2%	171	1,1%	-4758	-31,3%
Rubber and Plastics	-6	-2,1%	-6	-2,2%	-68	-30,6%
Other Non-Metallic Mineral	-7	-0,3%	-4	-0,2%	-80	-3,7%
Basic Metals and Fabricated Metal	56	0,7%	32	0,5%	-224	-3,4%
Machinery, Nec	-7	-2,3%	-32	-8,7%	1	0,3%
Electrical and Optical Equipment	68	15,6%	89	25,3%	26	7,5%
Transport Equipment	69	31,4%	20	10,0%	49	29,1%
Manufacturing, Nec; Recycling	9	2,6%	10	2,9%	98	45,2%
Electricity, Gas and Water Supply	-3	0,0%	-2	0,0%	2141	4,0%
Construction	-679	-28,5%	-669	-25,0%	256	11,5%
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	486	388,8%	558	468,9%	666	616,5%
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	-692	-30,3%	-828	-37,5%	-1089	-42,5%
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	-25	-2,5%	-78	-9,6%	-170	-17,2%
Hotels and Restaurants	-29	-2,1%	-41	-3,2%	-109	-7,0%
Inland Transport	-1153	-14,2%	-1315	-16,3%	-1081	-13,6%
Water Transport	92	1,5%	130	1,7%	-179	-2,7%
Air Transport	490	5,7%	656	5,6%	8375	70,6%
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	-9	-3,2%	-28	-8,9%	-86	-20,7%
Post and Telecommunications	-17	-8,6%	-30	-12,3%	-48	-20,0%
Financial Intermediation	-27	-4,6%	-97	-13,4%	-160	-17,4%
Real Estate Activities	-3	-1,0%	-15	-5,6%	69	29,5%
Renting of Machines and equipment and Other Business Activities	-150	-6,2%	-311	-8,6%	-556	-13,7%

Public Admin and Defence; Compulsory Social Security	-544	-22,2%	-620	-23,5%	-99	-3,6%
Education	-51	-5,1%	-64	-7,2%	-175	-16,0%
Health and Social Work	6	0,3%	-33	-2,0%	-269	-13,4%
Other Community, Social and Personal Services	1871	33,6%	1422	18,3%	220	2,0%
Total	**671**	**0,4%**	**-183**	**-0,1%**	**2083**	**1,3%**

5. MRIO versus NSI data: The issue of revisions in the national accounts

The WIOD database was created before a number of revisions were adopted in the realm of national accounts. As a result there were quite long time series of SUTs which could be used as inputs. For example the Eurostat database contained time series of SUTs starting from 1995 for many countries.

However national accounts are currently in a period where they are working on three revisions: the ISIC/NACE (industry classification), CPC/CPA (goods classification) and the revision of the *System of National Accounts* (SNA2008). These revisions pose quite a conundrum for MRIO producers, because it will take some time to revise all the necessary source data (and create time series).

SNA revision

The System of National Accounts revision in 2008 has chosen to strictly follow the change of ownership criterion when recording transactions between units. This has major ramifications for input-output analysis as it drives a wedge between monetary supply and use tables and the physical supply and use tables. These 2008 SNA recommendations were felt necessary to ensure quality of economic statistics as it is much more aligned with business statistics.

Let us consider the following realistic example for the Netherlands (Van Rossum et al 2010):
An oil refinery plant (the processor) –resident in the Dutch economic territory - converts 75 million € worth of crude oil into 100 million € worth of petrol. The crude oil is owned by a foreign parent company and shipped in from abroad. The foreign parent sells the petrol abroad. The oil refinery plant is receiving processing fees from the parent company to compensate for operational costs.

The differences between the 1993 SNA and 2008 SNA recording of this economic activity are illustrated in the table below. 1993 SNA demands the imputation of a transfer of ownership. In this way the output of petrol and intermediate consumption of crude oil is explicitly covered in the production account of the oil refinery plant. The new national accounting guidelines do no longer allow this imputation and as a result imports of crude oil and exports of petrol are no longer recorded. Instead exports consist only of industrial services delivered to the owner of all products (crude oil and petrol).

Although value added remains the same, the recording of imports and exports and production changes significantly (see Table 6).

In short: the new recording requirements drive a wedge between a physical and monetary description of the economy. For instance, as the chimney of our refinery will continue to smoke, large changes in emission coefficients will occur that reflect not only technical efficiencies but also legal / economic circumstances. Processors will have high emission coefficients (same emissions, much lower production). Emission coefficients between countries can no longer be easily compared. Moreover, using trade statistics (which is based on the cross-border principle and does not follow the SNA ownership criterion) to compile international SUTs (as in WIOD) becomes problematic as estimated ratio's (across countries) calculated for gross trade (e.g. product) will be a mismatch to actual trade flows which (partly) cover trade in services.

Table 6. Global manufacturing: inward industrial processing

According to SNA 1993		
Output of petrol	100	
Intermediate use of crude oil		75
Value added		25
Import of crude oil	75	
Exports of petrol		100
According to SNA 2008		
Output of industrial services	25	
Value added		25
Export of industrial services		25

This issue was addressed during the revision process of System of Environmental and Economic Accounting (SEEA). Essentially, two options were discussed:

- 2008 SNA SUT/IO tables are modified by adding monetary imports and exports information regarding processors: in other words, we continue to compile 1993 SNA based IO tables.
- Processors and regular manufacturers are separately identified in the IO table which would therefore obtain additional row(s) and column(s); each with their own emission coefficients.

The SEEA Central Framework recommends:
"in situations of goods send to other countries for processing or repair, or in cases of merchanting, the SEEA Central Framework recommends recording the actual physical flows of goods in those cases where the ownership of those goods does not change but remains with a resident of the originating country. No change to the monetary recording of these flows is recommended. This variation is particularly applicable in recording physical flows associated with the processing of raw materials (e.g. oil refining) where the physical flows may be largely invariant to the nature of the contractual relationships which are the focus of the recording of monetary flows in the SNA and the Balance of Payments." (UN 2012 1.43)

When doing environmental input-output analysis, monetary SUTs (or IO tables) would need to be adjusted, preferably according to the first option. Statistics Netherlands is conducting a project this year were such adjustments will be made. To give a rough idea, during the SNA revision process the recording of about 80 (large) companies in the Netherlands is being changed (in case of inward processing). This implies changes of the order of billions of euros in Trade Statistics according to the principles of National Accounts. It is not inconceivable that this issue is more problematic in the Netherlands than in other countries, due to the large (international) trade sector. Nevertheless, this issue clearly warrants more research.

ISIC/NACE and CPC/CPA revisions
In addition to the conceptual revision (from 1993 SNA towards 2008 SNA), two technical revisions are being implemented by National accounts programs: the transition from ISIC rev 3.1 towards ISIC rev 4, and CPC Ver. 1.1 towards CPC Ver. 2. The ISIC revision has already been

implemented in the Dutch National accounts for 2010 (Statistics Netherlands 2011) but the CPC revision will only be implemented together with the conceptual revision (2014).

As Table 7 illustrates, the ISIC transition is a difficult one in the sense that it is often not 1-1 and requires splitting up many industries. Major changes are that more detail in introduced in the services sectors (e.g. financial; real estate and business services are now disaggregated); but for instance also repair services has become a separate activity; important for E-IO is that there have been changes regarding the treatment of waste, wastewater treatment and recycling. (see Statistics Netherlands 2011 for more detail).

In the Netherlands the transition matrix was compiled based on employment data available in our business register. Time series of IO and SUTs have been made starting in 1969.

Changes in ISIC classification will be important for the possibilities to do E-IO analysis based upon MRIO models for recent years, given that source data has been changed already. For example in the UK (DEFRA 2012), data according to the new classification has been re-allocated towards the old classification in order to do the 2009 calculations.

It needs to be assessed whether MRIO time series such as WIOD should be upgraded taking both technical and conceptual revisions into account all at once (but then there is a need to wait for 2014 at least) or whether ISIC revision should be dealt with as soon as possible. Dealing with the ISIC revision itself seems to require input country specific allocation matrices as presented in Table 7.

Table 7. Transition matrix from ISIC rev 3.1 towards ISIC rev 4. (from Statistics Netherlands 2011b)

SBI 2008 \ SBI '93	1 Landbouw, bosbouw en visserij	2 Delfstoffenwinning	3 Industrie	4 Energie- en waterleidingbedrijven	5 Bouwnijverheid	6 Handel, horeca en reparatie	7 Vervoer, opslag en communicatie	8 Financiële en zakelijke dienstverlening	9 Overheid	10 Zorg en overige dienstverlening	Totaal
1 Landbouw, bosbouw en visserij	25 868	–	–	–	–	–	–	–	–	–	25 868
2 Delfstoffenwinning	–	20 716	–	–	–	–	–	–	–	–	20 716
3 Industrie	–	28	268 624	–	–	–	–	14	–	–	268 666
4 Energiebedrijven	–	–	–	33 271	–	–	–	–	–	–	33 271
5 Waterbedrijven en afvalbeheer	–	–	1 151	1 604	–	–	–	–	–	8 187	10 942
6 Bouwnijverheid	–	–		–	78 211	–	–	2 243	–	–	80 454
7 Handel, vervoer en horeca	–	–		–	–	135 955	52 458	–	–	–	188 413
8 Informatie en communicatie	–	–	7 976	–	–	–	20 249	19 070	–	5 867	53 162
9 Financiële dienstverlening	–	–	–	–	–	–	–	61 648	–	–	61 648
10 Exploitatie van en handel in onroerend goed	–	–	–	–	–	–	–	57 249	–	–	57 249
11 Zakelijke dienstverlening	1 710	–	–	–	–	–	5 288	102 301	–	1 252	110 551
12 Overheid en zorg	–	–	–	–	–	–	–	–	89 559	61 550	151 109
13 Cultuur, recreatie, overige diensten	–	–	336	–	–	312	–	194	–	28 130	28 972
Totaal	27 078	20 744	278 087	34 875	78 211	136 267	77 995	242 719	89 559	99 986	1 085 521

Timing of the revisions and the delivery to international databases

The European statistical institutes are currently going through these revisions or have just completed one of them. However it is expected to take a couple of years for all statistical institutes to complete all these adaptations. One of the aspects which is not clear, and which will be of significance in the production of MRIOs, is whether time series of SUTs will be made available. For the moment the new European transmission programme requires annual SUTs starting from 2010. This means that the data situation for MRIO projects that wish to create time series using the latest concepts and classifications will no longer have the source data which WIOD had when that project started.

6. Towards a method for "official" footprint calculations

The previous sections have focussed on the differences between MRIO and official data. This section discusses a method to reconcile the two approaches to produce an "official" carbon footprint. The project is currently being carried out at Statistics Netherlands. Section 7, on future work, discusses how this may be expanded towards more types of footprints.

The method which is currently being developed at Statistics Netherlands is to follow the WIOD methodology but to adapt it in three ways:

- The data for the Netherlands is exactly equal to the data from Statistics Netherlands. Supply and use tables, international trade in goods and services and environmental accounts data for the Netherlands are used.
- The maximum aggregation (of industries and goods) of the Dutch data is taken rather than the 35 industries and 60 goods in the WIOD database.
- In the WIOD reconciliation procedures, the Dutch data is kept intact. All adjustments will therefore end up in the figures for other countries.

A time series of carbon footprints (1995-2009) is expected to be ready by the end of 2013. The method can also be used by other countries, because the script is easily adjusted as long as the source data is available.

7. Conclusions

This paper provides input to bridge the gap between academic MRIO-work and statistical work on footprints. A method to reconcile the two areas and thereby to create "official" footprints is also provided. The following areas have been discussed:

Overview of footprint work by NSIs and affiliated institutes
An inventory of publications (by NSIs, government and international institutes) that have produced footprints is provided. Most work is focused on carbon footprints, but the methods adopted vary significantly. Many of the institutes see these calculations as highly relevant, but do not yet see them as "official statistics".

Overview of MRIO databases
An overview of MRIO databases is provided. Some have existed quite some time (GTAP, OECD) while other have emerged over the last 2-3 years (EXIOPOL/CREEA, WIOD, EORA and the new OECD database on trade in value added). The most recent MRIO are increasingly close to official statistics, but there are still inevitable differences. There is no "perfect" MRIO for all purposes so depending on the aims of a project one or the other may be used. Also it is conceivable that, in future, MRIOs will start to be combined.

Differences between MRIO databases and official statistics
The methodological and empirical differences between MRIO and official statistics are explored by comparing the WIOD database with the data from Statistics Netherlands. There are quite large differences in the levels and development in imports, which are likely to affect the level and trend

of footprint calculations. Also the SUT and environmental accounts data are already in the latest NACE revision (see next point).

The issue of revisions of the national accounts
Problems that are related to the revision of the national accounts are also discussed in this paper: the revision of industries (ISIC/NACE), goods (CPC/CPA) and national accounting concepts (SNA2008). These revisions will pose problems for the next generation of MRIO databases: the new guidelines in the SNA2008 on goods for processing provide conceptual problems, but also the transmission of time series of SUTs and IOTs to international database is not currently organised.

Towards an "official" footprint
To start adopting MRIO-based footprint at NSIs, official data will have to be combined with MRIO data from one or more MRIO databases. Statistics Netherlands and the PBL Netherlands Environmental Assessment Agency are currently exploring a method which combines Dutch data to the WIOD database to produce a carbon footprint. However, the industry classification is not disaggregated enough for other footprints such as water or land footprints. In future, the method will require more additional data, perhaps from other MRIOs (such as GTAP, CREEA or EORA), to calculate these footprints.

8. Future work

The insights provided by this paper are not only relevant to the production of "official" environmental footprints. It is also possible to produce other indicators such as "trade in value added" or "embodied" labour or knowledge in imports and exports. This methodology will therefore be capable of producing all sorts of "official" measures that are relevant to globalization issues.

References

Ahmad and Wyckoff, 2003. Carbon Dioxide Emissions Embodied in International Trade of Goods. OECD STI Working Paper 2003/15

Andrew, R., Peters, G.P., Lennox, J., 2009. Approximation and Regional Aggregation in Multi-Regional Input-Output Analysis for National Carbon Footprint Accounting. *Economic Systems Research* 21 (3), pp. 311-335.

Arto, I, A. Genty, J. Rueda-Cantuche, A. Velanueva and V. Andreoni, 2013[a]. Global resources use and pollution, Volume 1/ Production Consumption and trade. JRC Scientific and Policy reports.

Arto, I, A. Genty, J. Rueda-Cantuche, A. Velanueva and V. Andreoni, 2013[a]. Global resources use and pollution, Volume 2/ Country Factsheets. JRC Scientific and Policy reports.

Babiker, M.H., 2005. Climate change policy, market structure, and carbon leakage. *Journal of International Economics* 65 (2), pp. 421-445

Battjes, J.J., Noorman, K.J., Biesiot, W., 1998. Assessing the Energy Intensities of Imports. *Energy Economics*. 20, pp. 67-83.

Bergh, J.C.J.M. van den, and H. Verbruggen, 1999. Spatial sustainability, trade and indicators: an evaluation of the 'ecological footprint'. *Ecological Economics.* 29 (1), pp.63–74.

B. Boitier, CO_2 emissions production-based accounting vs consumption: Insights from the WIOD databases. Paper for Final WIOD Conference: Causes and Consequences of Globalization, Groningen, The Netherlands, April 24-26, 2012

Cole, M.A., 2004. Trade, the pollution haven hypothesis and the environmental Kuznets curve: Examining the linkages. *Ecological Economics* 48 (1), pp. 71-81.

DEFRA, 2012. UK's Carbon Footprint 1990 – 2009, 8 March 2012

Destatis, 2010. CO_2-content of German imports and exports, Helmut Mayer, Statistisches Bundesamt, Wiesbaden, December 2010.

Edens, B., Delahaye, R., Schenau, S., 2011. Analysis of changes in Dutch emission trade balance(s) between 1996 and 2007, *Ecological Economics*. 70 (12), pp. 2334 – 2340.

Erumbana, A. et al, 2010 World Input-Output Database (WIOD): Construction, Challenges and Applications. Paper presented at the IARIW Conference St. Gallen.

Eskeland, G.S., Harrison, A.E., 2003. Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of Development Economics*. 70 (1) , pp. 1-23.

ESR (Economic Systems Research), 2009. Special Issue: Carbon Footprint and Input–Output Analysis. Volume 21, Issue 3.

ESR (Economic Systems Research), 2013. Special Issue: Global Multiregional input-models. Forthcoming.

Eurostat, 2012. Table: “Emissions of greenhouse gases and air pollutants induced by final use of products, by place of origin - results from environmental input-output analysis” (accessed Feb 2012) http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ac_io&lang=en based upon http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/documents/eeSUIOT%20TechDoc%20final%20060411.pdf

Fiala, N., 2008. Measuring sustainability: Why the ecological footprint is bad economics and bad environmental science. *Ecological Economics*. 67 (4), pp. 519–525.
Galli, A., T. Wiedmann, E. Ercin, D. Knoblauch, B. Ewing and S. Giljum, 2011. Integrated ecological, carbon and water footprint: Defining the “footprint family” and its application in tracking human pressure on the planet. Technical document. OPEN-EU. January 28th 2011.

Gaston, C. Environment Accounts and Statistics Division http://www.statcan.gc.ca/pub/16-002-x/2011004/part-partie4-eng.htm accessed Feb 2012.

Grazi, F., J.C.J.M. van den Bergh and P. Rietveld, 2007. Welfare economics versus ecological footprint: modeling agglomeration, externalities and trade. *Environmental and Resource Economics*. 38 (1), pp. 135–153.

Haan, M. de, 2004, *Accounting for goods and for bads. Measuring environmental pressure in a national accounts framework*, PhD thesis, Statistics Netherlands (CBS), Voorburg, The Netherlands.

Hao, S.M., G. Legoff, K. Mahadeva, N. Chia and A. Cadogan-Cowper, 2012. Australian Greenhouse gas emission: experimental consumption-based estimates via input-output analysis. Australian Bureau of Statistics, May 2012.

Hoekstra, A.Y. (ed.), 2003. Virtual water trade: Proceedings of the international expert meeting on virtual water trade, Value of Water Research Series No. 12, UNESCO-IHE

Hoekstra, A.Y. and A. K. Chapagain, 2008. Globalization of water: Sharing the planet's freshwater resources, Blackwell Publishing, Oxford, UK.

Hoekstra, R., 2010. (Towards) a complete database of peer-reviewed articles on environmental extended input-output analysis. Paper for the 18th international input-output conference, Sydney, Australia.

Hoekstra, R., B. Edens and H. Wilting, 2012. Footprint Calculations from the Perspective of National Statistical Institutes. Paper for the Final WIOD Conference: Causes and Consequences of Globalization, Groningen, The Netherlands, April 24-26, 2012

Lenglart, F. Lesieur, C., Pasquier, J., 2010. CO_2 emissions from the economic circuit in France, Paper presented at the IARIW conference St Gallen, Switzerland.

Lenzen, M., Pade, L.-L., Munksgaard, J., 2004. CO2 multipliers in Multi-region Input-Output Models. Economic Systems Research 16, pp. 391-412.

Lenzen M, Kanemoto K, Moran D, and Geschke A (2012) Mapping the structure of the world economy, Environmental Science & Technology 46(15) pp 8374–8381.

Lenzen, M., Moran, D., Kanemoto, K., Foran, B., Lobefaro, L., Geschke, A. International trade drives biodiversity threats in developing nations Nature 486 7401. DOI:10.1038/nature11145

Murray, J. and M. Lenzen (2013) The Practitioner's Guide to Multi-Regional Input-Output Analysis. Champaign, USA, Common Ground.

Nakano et al., 2009. The Measurement of CO2 Embodiments in International Trade: Evidence from the Harmonised Input-Output and Bilateral Trade Database. OECD STI Working Paper 2009/3

Nijdam, D.S., H.C. Wilting, M.J. Goedkoop, J. Madsen, 2005. Environmental Load from Dutch Private Consumption: How Much Damage Takes Place Abroad? Journal of Industrial Ecology. 9 (1-2), pp. 147-168.

OECD, 2013. Measuring Trade in Value Added: An OECD-WTO joint initiative. http://www.oecd.org/industry/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm

Peters, G.P., 2008. From production-based to consumption-based national emission inventories. *Ecological Economics*. 65 (1), pp. 13-23.

Peters, G.P., Hertwich, E.G., 2006. Pollution embodied in trade: The Norwegian case. *Global Environmental Change* 16 (4), pp. 379-387.

Peters, G.P., Hertwich, E.G., 2008. Post-Kyoto greenhouse gas inventories: Production versus consumption. *Climatic Change* 86 (1-2), pp. 51-66.

Peters, G. J. Minx, C. L. Weber and O. Edenhofer, 2011. Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences, 108 (21): pp. 8903-8908.

Peters, G. P., S. J. Davis and R. Andrew, 2012. A synthesis of carbon in international trade. *Biogeosciences*, 9, 3247-3276, 2012

Rees, W. E., 1992. Ecological footprints and appropriated carrying capacity: what urban economics leaves out. *Environment and Urbanisation* 4 (2), pp. 121.

Rørmose, P., Olsen, T., Hansen, D., 2009. GHG emissions embodied in trade. Statistics Denmark 2009.

Rossum, M. van, Delahaye, R., Edens, B.,2010. SNA 2008 concepts related to goods sent for processing and merchanting and its implications for environmental accounts. Paper presented at the 16th meeting of the London Group.

Schoer, K. J. Giegrich, J. Kovanda, C. Lauwigi, A. Liebich, S. Buyny, J. Matthias, 2012. Conversion of Euorepan Product flows into raw material equivalents. ifeu - Institut für Energie- und Umweltforschung, Heidelberg in cooperation with: Sustainable Solutions Germany – Consultants, Wiesbaden (SSG) Charles University in Prague, Environment Centre CUEC, Heidelberg, May 2012

Statistics Canada, 2011.Consumption-related greenhouse gas emissions in Canada, the United States and China. EnviroStats; Winter 2011 Vol. 5, no. 4.

Statistics Netherlands, 2011a. Persoonlijke carbon voetafdruk. http://www.cbs.nl/nl-NL/menu/themas/natuur-milieu/cijfers/extra/footprint.htm

Statistics Netherlands 2011b. Nationale Rekeningen 2010. Den Haag.
Statistics Netherlands 2010. Environmental accounts of the Netherlands 2009. CBS, Den Haag/Heerlen.

Statistics Sweden, 2003. Table: "Environmental impact from households" http://www.scb.se/Pages/ProductTables____38186.aspx accessed Feb 2012.;

Statistics Sweden, analysis tool. http://www.mirdata.scb.se/MDInfo.aspx

Statistics Sweden, 2003. Households in the environmental accounts , Prepared for DG Environment and Eurostat by: Anders Wadeskog; Maja Larsson

Timmer, M. (ed), A.A. Erumban, R. Gouma, B. Los, U. Temurshoev and G.J. de Vries (University of Groningen), I. Arto, V. Andreoni, A. Genty, F. Neuwahl, J.M. Rueda-Cantuche and A. Villanueva (IPTS), J. Francois, O. Pindyuk, J. Pöschl and R. Stehrer (WIIW), G. Streicher (WIFO). *The World Input-Output Database (WIOD): Contents, Sources and Methods*. April 2012, Version 0.9

Tukker, A. and E. Dietzenbacher, 2013. Global multiregional input-output frameworks: an introduction and outlook. Economic Systems Research (forthcoming).

Tukker, A., M. Bouwmeester, J. Oosterhaven (RUG), A. de Koning and R. Heijungs, 2011. TECHNICAL REPORT: Policy impact assessment – resources, products and imports and exports. Deliverable: IV.2.b of the Exiopol project.

Wackernagel, M. and W. Rees. 1996. *Our Ecological Footprint: Reducing Human Impact on the Earth*. Gabriola Island, BC: New Society Publishers.
Weber, C.L., Peters, G.P., Guan, D., Hubacek, K., 2008. The contribution of Chinese exports to climate change. Energy Policy 36 (9) , pp. 3572-3577

Weinzettel, J.K. Steen-Olsen, A. Galli, G. Crantson, E. Ercin, T. Hawkins, T. Wiedmann, E. Hertwich, 2011. Footprint family technical report: Integration into MRIO model. Technical document. OPEN-EU. February 7th 2011.

Weinzettel, J., E.G. Hertwich, G. P. Peters, K. Steen-Olsen, A. Galli, 2013. Affluence drives the global displacement of land use. *Global Environmental Change* (forthcoming).

Wiebe, K.S., C. Lutz, M. Bruckner and S. Giljum, 2012. Calculating energy-related CO_2 emissions embodied in international trade using a global input-output model. *Economic Systems Research*, Vol. 24(2), pp. 113-139.

Wiedmann, T., Wood, R., Lenzen, M., Minx, J., Guan, D. and Barrett, J., 2008. *Development of an Embedded Carbon Emissions Indicator – Producing a Time Series of Input-Output Tables and Embedded Carbon Dioxide Emissions for the UK by Using a MRIO Data Optimisation System.* Report to the UK Department for Environment, Food and Rural Affairs by Stockholm Environment Institute at the University of York and Centre for Integrated Sustainability Analysis at the University of Sydney, June 2008. Defra, London, UK

Wiedmann, T., H.C. Wilting, M. Lenzen, S. Lutter, V. Palm, 2011. Quo Vadis MRIO? Methodological, data and institutional requirements for multi-region input–output analysis. *Ecological Economics*, 70(11), pp. 1937-1945.

Wilting, H.C. and K. Vringer, 2009. Carbon and land use accounting from a producers and consumers perspective – an empirical examination covering the world *Economic Systems Research.* 21 (3), pp. 291-310.

Wilting, H.C. 2012. Sensitivity and uncertainty analysis in MRIO modelling; some empirical results with regard to the Dutch Carbon footprint. *Economic Systems Research.* Vol. 24, pp. 141-171.

WWF, 2010. *Living planet report. Biodiversity, biocapacity and development.*

Annex 1. Technical details of footprint calculations

This section is based on the chapter on applications of environmental accounts in Part 3 of the System of Environmental-Economic Accounts (SEEA) (forthcoming).

Table A.1 shows a simplified multi-regional input-output table for two countries A and B. The rows signify the output (both to the domestic and foreign market) and the columns represent the inputs (also domestic and foreign). In this way imports and exports are fully accounted for. The superscripts indicate the country of the variable. If there are two superscripts the first indicates the source and the second the destination. E.g. c_{AB} is the final consumption in country B of the output of country A.

Table A.1. A multiregional input-output table (2 country) with environmental data

		Country A	Country B	Country A	Country B	Output
		Industries	Industries	Domestic final demand	Domestic final demand	
Country A	Industries	Z_{AA}	Z_{AB}	c_{AA}	c_{AB}	q_A
Country B	Industries	Z_{BA}	Z_{BB}	c_{BA}	c_{BB}	q_B
	Value added	v_A	V_B			
	Total input	q_A	q_B			
	GHG emissions	r_A	r_B			

The GHG emissions per industry are shown as a row below the MRIO. The carbon footprint of country A can be calculated using the following formula:

$$\Phi_A = \begin{pmatrix} n_A & n_B \end{pmatrix} \cdot \left(\begin{pmatrix} I & 0 \\ 0 & I \end{pmatrix} - \begin{pmatrix} A_{AA} & A_{AB} \\ A_{BA} & A_{BB} \end{pmatrix} \right)^{-1} \cdot \begin{pmatrix} c_{AA} \\ c_{BA} \end{pmatrix}$$

Where

$$n_A = r_A \cdot \hat{q}_A^{-1}$$
$$n_B = r_B \cdot \hat{q}_B^{-1}$$
$$A_{AA} = Z_{AA} \cdot \hat{q}_A^{-1}$$
$$A_{BA} = Z_{BA} \cdot \hat{q}_A^{-1}$$
$$A_{AB} = Z_{AB} \cdot \hat{q}_B^{-1}$$
$$A_{BB} = Z_{BB} \cdot \hat{q}_B^{-1}$$

Where the variables which have are not in table A.1:

Φ_A Carbon footprint of country A

n_A	GHG intensity of country A
n_B	GHG intensity of country B
$\begin{pmatrix} A_{AA} & A_{AB} \\ A_{BA} & A_{BB} \end{pmatrix}$	MRIO technical coefficient matrix
I	Identity matrix