Statistics Netherlands

Report

Footprint Calculations using a Dutch National Accounts Consistent Exiobase

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Executive Summary

This study has been commissioned by the Dutch Ministry of Economic Affairs in order to create a dataset which can be used in the context of the context of the National Programme for a Circular Economy (NPCE). The NPCE aims to reduce the Dutch use of primary raw materials (minerals, metals and fossil fuels) by 50% by 2030. The NPCE is also concerned with the reductions in the environmental pressures and supply chain risks associated with the linear economy. Accordingly, the aim is to prepare a Single-country National Accounts Consistent (SNAC) Multi-Regional Input-Output Table (MRIOT) and to derive footprint calculations from that SNAC-MRIOT. MRIOT is a generic term for a dataset which contains large amounts of data describing the global economy. MRIOTs are built from data provided principally by national statistical offices. A disadvantage of MRIOTs is that the data provided by national statistical offices is always altered during the process of making MRIOTs, such that MRIOTs are no longer consistent with the official national accounts statistics. Also compilers of MRIOTs do not have access to detailed trade data, which is especially important in the Dutch context. This study adapts a MRIOT so that it becomes consistent with the Dutch National Accounts, i.e. it becomes a SNAC-MRIOT, which is suitable for analysing the role of the Netherlands in the global economy from a Dutch perspective.

Specifically MRIOTs facilitate, among other analyses, the calculation of footprints. This study calculates experimental carbon footprints, GHG footprints and metal extraction footprints with a SNAC-MRIOT for the years 2010 and 2014. There are also several other analyses relevant for the NPCE which can be facilitated by the availability of a SNAC-MRIOT, although this study limits itself to the calculation of footprints.

There are several MRIOTs available, each with their own advantages and disadvantages. The first step is therefore to choose the best MRIOT to convert into a SNAC-MRIOT for The Netherlands. This report analyses six MRIOTs according to eight criteria and concludes that Exiobase version 3 is the most appropriate MRIOT for analyses concerned with the NPCE. This is because Exiobase is up to date and detailed in such a way as to facilitate analyses of the transition towards a circular economy.

The SNAC procedure is then applied to Exiobase. This involves incorporating the national accounts, trade statistics and the environmental accounts into the Exiobase dataset. The resulting data are then re-balanced such that the rules of national accounting hold. This rebalancing is a constrained minimization procedure whereby the data referring to The Netherlands remains unaltered and that whatever changes are made to the other data are as small as possible.

From the SNAC-Exiobase, footprints are derived and analysed. Footprints in this study are to be considered experimental, especially in the case of the carbon footprints for which official Statistics Netherlands statistics already exist. The carbon footprint from SNAC-Exiobase is 207 billion tonnes in 2010 and 175 billion tonnes in 2014 (a reduction of 15%). The GHG (Greenhouse Gas) footprint (which includes carbon) drops from 274 to 217 billion tonnes carbon equivalent (a reduction of 21%). The footprint for metal extraction drops from 24 million tonnes in 2010 to 19 million tonnes in 2014. Various aspects of these results are analysed including the locations of footprint emissions, the importance of specific metals, the roles of

given products, and the differences between the footprint calculations from the original Exiobase and SNAC-Exiobase.

The analysis of the results highlights several interesting conclusions, as well as issues regarding the quality of the 2014 data. Exiobase 2014 is “now-cast”, which means that the data are extrapolated based on limited available information. Quality issues relate firstly to changes in emissions between 2010 and 2014 which are an important determinant of the reduction in the GHG footprint. Secondly, the reduction in the carbon footprint according to SNAC-Exiobase is, although not implausible, appreciably larger than the reduction in the official carbon footprint. It is therefore prudent to consider the 2014 results as experimental.

Index

1. Introduction

1.1 The circular economy from the Dutch policy perspective

This report is part of Statistics Netherlands' work on the "Circular Economy". This a concept that has gained prominence over the last few years. The concept was popularized by the McArthur Foundation[1] and has been adopted internationally as a policy goal, among others by the EU in the "Closing the loop" action plan[2]. The concept of the circular economy has come to prominence in The Netherlands by way of the National Program for a Circular Economy (NPCE)[3]. The NPCE is a broad policy concerning both environmental sustainability and the economy. The central policy of the NPCE is to reduce the Dutch use of primary raw materials (minerals, metals and fossil fuels) by 50% by 2030. Also important is the substitution of critical, fossil or unsustainably produced raw materials with renewable and readily available resources (Rood en Hanemaaijer, 2016). This will increase sustainability and reduce the dependence of The Netherlands on imports of fossil fuels, as well as reducing the exposure of The Netherlands to supply chain risks associated with critical raw materials. Finally, the NPCE will also play a role in reducing the carbon dioxide emissions of The Netherlands and achieving the Paris targets (Ecofys and Circle Economy, 2016) due to the efficiency improvements resulting from circular economic systems. Further, the transition towards a circular economy is expected to provide opportunities (Bastein et al., 2013) for growth and new jobs across diverse sectors. To this end, the Raw Materials Agreement (Dutch: *Grondstoffenakkoord*) has been signed by 180 parties in January 2017. This document contains the agreements necessary to achieve the aims of the NPCE.

To understand the circular economy concept, one must first understand the "linear economy". Many authors claim that the current economy is "linear", in the sense that it can be characterised as a "take, make and dispose" process. Raw materials are taken and manufactured into products, which are then used and disposed of. The linear economy has several drawbacks, both environmental and economic. Disposal is not efficient if the products which are being disposed of could still be beneficially employed. Further, the disposal of products, especially if not done responsibly, can cause environmental degradation. An extreme example of this is the formation of plastic soup in the Pacific Ocean. Drawbacks of the linear system also exist on the input side, where raw materials are taken from the natural system. An economic system which relies on finite raw materials faces the risk that the inputs it requires will become unavailable or that price changes for given raw materials cause disruption to supply chains (UNEP, 2016). The EU has analysed 54 materials and found that 20 were critical raw materials because of the economic importance and supply risks (EC, 2014).[4] Research has also consider the specific case of The Netherlands (Bastein and Rietveld, 2015). In short, the linear economy leads to environmental pressures and economic inefficiencies and risks, while the circular economy offers many opportunities for The Netherlands, as discussed by Bastein et al. (2013).

[1] http://specials.nrc.nl/ricoh/documens/files/files/Rapport_McKinsey-Towards_A_Circular_Economy.pdf
[2] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52015DC0614
[3] In Dutch "Rijksbreed Programma Circulaire Economie" www.rijksoverheid.nl/documenten/rapporten/2016/09/14/bijlage-1-nederland-circulair-in-2050
[4] Statistics Netherlands (2010) investigates 41 critical materials for the Netherlands.

A solution which has been propagated in the environmental economic literature for a long time[5] is to redirect the linear system in on itself and to connect the ends such that the outputs of the system become its inputs and hence the system becomes circular. In the past various terms have been used for these ideas (industrial ecology, industrial metabolism, cradle-to-cradle). Other prominent concepts can also be grouped under concept of circular economy: the bio-based economy being a prominent example of this.

A truly circular economy is thus truly sustainable in that it requires no inputs from the natural system, nor does it burden it with damaging outputs. There are many ways in which practical steps can be taken to increase the circularity of an economy. Any situation where "waste" can be productively exploited increases circularity. Waste from one method of production can be used in other methods of production. China and Denmark employ "eco-industrial parks" which contain industries whose waste can serve as inputs in other industries in the park (Zhang et al., 2010, Stahel, 2016). Waste from households can also be put into productive use. For example, urban mining for valuable metals (from electronic equipment) can potentially reduce the pressure to extract more raw materials. These developments are mostly to do with recycling and form the classic view of the circular economy. However, newer ideas also exist such as re-designing products so that they can be reconstructed into components or remanufacturing. This may also lead to new business models in which the consumers no longer buy products but lease them over a period of time after which the producers takes them back for re-use. Circular economics is therefore much more than just recycling, as demonstrated by Potting et al. (2016) in their "R-ladder". The R-ladder orders various types of activities in terms of their circularity and includes novel circular economy concepts such as re-design of products to increase their circularity. The more circular activities include increasing the efficiency of production processes ("Reduce") and even stopping production altogether ("Refuse").

There are two perspectives that can be taken in the monitoring of Circular Economy.[6] The first perspective is to consider the direct use of materials (both virgin and recycled) by companies and households. The second perspective is to consider environmental pressures and economic impacts in the supply chain. This report is based on the latter approach, which is also sometimes referred to as life-cycle assessment or footprint analysis.

1.2 MRIOTs for circular economy analysis

Production processes are increasingly globalised in the sense that products have components which are produced in many different countries (Timmer et al., 2014). This defragmentation of production processes and the importance of global value chains has important economic implications (Baldwin, 2017). It also has significant environmental impacts since environmental pressures have shifted from western countries to countries like China. As developed countries have reduced their manufacturing base, their "production-based" emissions have decreased. However, the consumption-based emissions (or "carbon footprints") of developed countries have not dropped, because the embodied emissions in the final consumption of a country have remained high (Peters et al., 2011).[7]

[5] See for example, Pearce and Turner (1990).

[6] These two perspectives will be used in the CE-monitor that will be published at the end of 2017. This is a cooperation between PBL, RIVM and CBS.

[7] In fact, this shift in production is detrimental to global emissions because the production usually shift from countries with superior technologies to countries with more inefficient, and CO2 emitting production. Hoekstra et al. (2016)

Multi-Regional Input-Output Tables (MRIOTs) have become indispensable for understanding the economic and environmental pressures facing nations, both from the production and consumption perspective. The term MRIOT is a generic term for databases which contain large amounts of information describing the structure of the global economy. The production and consumption of specific goods by specific industries is made available in input-output table or supply and use tables (part of the System of National Accounts)[8].

A MRIOT therefore can show the value of products produced by example French agriculture employed in Dutch food processing.[9] In turn, this data can be used to identify supply chains and therefore to calculate footprints. Via the calculation of the “Leontief matrix” it becomes possible to identify the effect of a one unit increase on the production of the Dutch food processing industry on *all other sectors in all other countries.* This effect will often be zero or very small, but for many industries the effect will be positive because the analysis includes not only all the agricultural sectors feeding into the Dutch food processing sector, but also all the sectors which provide inputs into the agricultural sectors, and so on and so forth. In this way, supply chains can be comprehensively mapped out. Because MRIOTs allow for the comprehensive mapping of supply chains, they are a highly suitable basis with which to calculate the emissions which result from Dutch consumption, or in other words, to calculate the footprints for The Netherlands.

While MRIOTS are useful for several types of analysis relevant for the NPCE, this study focusses on footprint calculations. In the context of the NPCE, the following footprints are particularly important: the Greenhouse Gas (GHG) footprint, the carbon footprint and Raw Material Consumption (RMC) footprint. The GHG footprint is the total global emission of greenhouse gases (weighted to carbon equivalent) which are emitted in order to, both directly and indirectly satisfy the Dutch demand for final goods and services. The RMC is a measure not of greenhouse gases but of the raw material extraction, which are generally divided into the four categories of fossil energy materials, non-metallic minerals, metal ores and biomass.

1.3 Research objectives

The above section has discussed the diverse ways in which MRIOTs can be useful for analyses in the context of circular economy. However, there are two issues which need to be addressed before a MRIOT can be employed for footprint analysis or other applications. The first is the challenge of choosing the appropriate MRIOT. There are several MRIOTs available to researchers, which are suitable for analysing the circular economy[10]. Different MRIOTs are compiled using different methodologies and are built with different analyses in mind. Some MRIOTs are more up to date than others. Some MRIOTs have a strong reputation for their economic data and others have a strong reputation for their environmental/emissions data. The first research objective of this study is to choose the best MRIOT to facilitate analyses relevant

estimate that 18% of the increase in global emissions between 1995-2007 was caused by the combination of sourcing and technology differences.

[8] Specifically, supply and use tables are product-by-industry tables and input-output tables are either product-by-product or industry-by-industry.

[9] Note that the quality of this value is dependent on the underlying data. In some cases, MRIOT database have to make assumptions about certain relationships because no data exists. Care should therefore be taken to extract a single element from and MRIOT.

[10] For an overview of MRIOTs see Tukker and Dietzenbacher (2013).

for the NPCE. Chapter 2 analyses potential MRIOTs. The outcome of this analysis is that Exiobase (version 3), produced by the Institute of Environmental Science of Leiden University is the most appropriate MRIOT for analyses surrounding the circular economy.

The second objective is to prepare the MRIOT such that it is suitable for analyses from the Dutch perspective. The reasons is that the data in the MRIOT databases do not fully conform to official statistics. This is because of the manner in which MRIOTs are compiled. MRIOTs are comparable to jigsaw puzzles. The national accounts of each country are pieces of the jigsaw. Putting all the pieces together creates the MRIOT. Unfortunately, these pieces do not fit together in a way which satisfies the rules of national accounting. Therefore each piece must be altered so that all the pieces can be connected. This altering process is referred to as "balancing". This means, unfortunately, that from the perspective of each individual country, the MRIOT contains data that are inconsistent to the official national statistics of that country. In other words, the data are not "national accounts consistent"[11]. For a small open economy such as the Netherlands this problem is greatest. For example, Edens et al. (2011) find that national accounts inconsistency can be so problematic that the Netherlands, a net exporting country, can become a net importer as a result of balancing. Therefore, the second objective is to make the chosen MRIOT national accounts consistent according to the method described in Edens et al. (2015), which introduces the procedure of making a MRIOT Single-country National Accounts Consistent (SNAC) .

The third objective is to calculate footprints for metal ore (part of the RMC) and GHG for the Netherlands using the SNAC MRIOT. We do so to demonstrate the applicability of a national accounts consistent MRIOT. Statistics Netherlands has already produced a footprint for carbon for the years 2010 and 2014 using another methodology (Meijer-Cheung et al., 2016). The results of this study constitute the official Statistics Netherlands carbon footprint. Because we employ a different method to Meijer-Cheung et al. (2016), the results also differ. Accordingly an additional objective is to compare the official Statistics Netherlands carbon footprint to that derived in this study.

These research aims have been determined in conjunction with the Dutch Ministry of Economic Affairs has commissioned Statistics Netherlands to carry out this research.

[11] For a full account of the relationship between MRIOT compilation and official statistics see Hoekstra et al., 2014.

2. Choosing a MRIOT

The first step that needs to be taken in the process of preparing a *Single-country National Accounts Consistent* (SNAC) MRIOT is the selection of the most appropriate database to serve as the starting point of this procedure. A first scan of the available options has been reduced to a shortlist of six MRIOTs that will be investigated in more detail: Exiobase, WIOD, Eora, Eora26, OECD-ICIO and GTAP-MRIOT. The state of affairs at the time these MRIOs were investigated (mid-2016) are described in the following table.

Table 1: Characteristics of the selected MRIOTs as of September 2016

	Exiobase3	WIOD	Eora (full)	Eora26	OECD-ICIO	GTAP9-MRIOT
Years covered	1995-2011, now-casts for 2012-2015	1995-2011, environ-mental accounts for 1995-2009	1990-2012	1990-2013	1995, 2000, 2005, 2008, 2009, 2010, 2011.	2004, 2007 and 2011
SNA '93 or '08	1993	1993	2008	2008	1993	?
Countries /regions (#)	44 (28 EU, 16 non-EU)	40 (27 EU and 13 non-EU)	between 187 and 190 depending on the year	between 187 and 190 depending on the year	34 OECD-member + 27 non-members	140
Industries (#)	163	35	100-500	26	34	57
Table structure	SUT	SUT	SUT	IOT	IOT	IOT
Access	free	free	under license	under license	free	under license
Environ-mental data	emissions incl. GHGs (40)	emissions incl. GHGs (8)	GHGs (33)	GHGs (33)	no	emissions incl. GHGs
	materials (633)	materials (24)	materials (36)	materials (36)	no	no
	water use (172)	water use (3)	water use (5)	water use (5)	no	no
	land use (13)	land use (4)	agri-environ-mental (11)	agri-environ-mental (11)	no	no

The choice of MRIOT needs to be suitable both in the short and the long run. The short term objective is to be able to construct footprints for the Netherlands. The long term objective is to be able to have an MRIOT-system in place that enables us to tackle various issues concerning globalisation and the circular economy. This brings us to the following list of criteria on which each MRIOT is evaluated:

1. *Timeliness*. The more up-to-date the MRIOT, the more policy relevant the information it yields.
2. *Time series*. The greater the extent of time series, the greater the ability to identify trends and to create insights into these trends.

3. *Detail*. The more countries, industries and products are being distinguished in the MRIOT, the more detail the analyses will yield.
4. *SNA-system*. Whether the MRIOT follows the System of National Accounts (SNA) 1993 or SNA-2008 determines how easily the MRIOT can be connected to the national accounts of the Netherlands.
5. *Material flows*. The inclusion of material flows in terms of physical units instead of monetary units enables various additional analyses in the field of the circular economy. In particular, information about quantities of rare earth metals would be very valuable.
6. *Quality and reputation*. The more accurate and reliable the data, the better the quality of the analyses.
7. *Accessibility*. Freely available MRIOTs are preferable.
8. *Availability of supply and use tables (SUTs)*. The availability of SUTs rather than only input-output tables facilitates the SNAC-procedure.

Most criteria speak for themselves; only criteria (4) and (8) require some elaboration. The System of National Accounts (SNA) is a set of rules and definitions developed to consistently produce national accounts. The SNA-1993 are usually seen as most suitable for the calculation of footprints. The SNA-2008 is viewed as less suitable because of a modification in the way goods for processing are recorded. This results in diverging ways of measuring output and environmental effects. This issue has not yet been adequately tackled in the academic research (see Appendix 5 for a more detailed discussion of this issue and what assumptions have been made for this project).

Criterion 8 refers to the dimensions of the data. It is possible to do the SNAC procedure on an input-output table or to carry out the SNAC procedure based on the supply and use table first (and then create the Input-output tables from them). SUTs are preferable in the SNAC-process because they can be linked to high quality data. Vitally, the SNAC procedure based on SUTs can link the import and export statistics to the product dimension of the SUT. This linking process is neater than in an industry-by-industry IO table, because this would require additional assumptions or data. In summary then, it is preferable to use a SUT because this has a product dimension with which the import and export data can be linked.

Considerable variation is observable on each of the dimensions presented. The six MRIOTs have been evaluated on each of the eight criteria discussed above. The results of the evaluation are summarised in table 2.

Table 2 Evaluation of the selected MRIOTs

	Exio-base3	WIOD	Eora (full)	Eora26	OECD-ICIO	GTAP9-MRIOT
1) Timeliness	+	-	+	+	+/-	+/-
2) Time series	+	+	+	+	+/-	-
3) Detail	+	+/-	+	+	+/-	+
4) SNA-system	+	+	-	-	+	+/-
5) Environmental data	+	-	+	+	-	+/-
6) Quality	+/-	+	+/-	-	+	+/-
7) Access	+	+	-	-	+	-
8) Availability of SUTs	+	+	+	-	-	-
9) Physical accounts	+	-	-	-	-	-

Exiobase and Eora perform best on timeliness (criterion 1). The most recent year available in Eora26 is 2013. Exiobase offers data on 2015 although the data concerning the period 2012-2015 are so-called 'now-casts'. The year 2014 is important in the context of the NPCE because it is the benchmark year from which progress will be measured. Naturally, using final data instead of now-casts is preferred, but the upside of working with now-casts is that it enables us to calculate footprints for more recent years.

Most MRIOTs offers time series data (2). Only the data from OECD-ICIO and GTAP9-MRIOT show gaps. The OECD-MRIOT provides a time series from 2008-2011. The GTAP9-MRIOT is constructed only every three to four years.

The level of detail (3) of the MRIOTs varies considerably. The number of countries covered ranges from 40 (WIOD) to 190 (Eora), and the number of industries from 26 (Eora26) to up to 500 in the full Eora. Taking both the country and industry dimension into account, Exiobase, Eora and GTAP offer most detail. However, full-Eora does not offer a symmetric industry structure (Eora 26 does), which complicates application of the SNAC-method considerably.

The latest versions of Eora and WIOD follow the SNA-2008 system (4). All other MRIOTs work with SNA-1993. In addition, Exiobase, WIOD and the full Eora offer SUTs in addition to IOTs, whereas the other MRIOTs only contain IOTs.

While OECD-ICIO does include emission data, these data are not made publicly available (5). GTAP provides emission data but does not provide for the other aspects of environmental data such as materials or land and water use. In contrast, Exiobase seems geared towards analyses with an environmental component considering the level of detail in this respect (for example 633 categories of materials). Exiobase also contains diverse socio-economic variables which facilitate a wide-range of footprint calculations and other analyses. An important advantage of Exiobase are the planned extensions with physical accounts in addition to monetary accounts in the nearby future. This would further facilitate analyses of the circular economy.

The quality of the data (6) is comparable between the MRIOTs. Only Eora26 performs less on this criterion. Eora26 is a simplified version of the full Eora, which comes at the expense of detail and accuracy.[12] WIOD is generally considered to be of high quality, particularly on the economic dimensions. The OECD-ICIO is built in close cooperation with national statistics offices and is thus particularly well-institutionalized, adding to the quality of the data. EXIOBASE is however, not an institutionalised MRIOT which results in a slightly lower perception regarding quality. GTAP is originally not an MRIOT, but constructed with the purpose of investigating trade and trade policy in a multilateral framework. The data have however been used to construct a MRIOT. However, because building an MRIOT is not the first priority of GTAP, the questions remain if the quality of the MRIOT constructed from GTAP stands up to scrutiny, particularly concerning the economic dimension of the data. Also GTAP is more geared towards the trade data than the national accounts data.

Regarding access (7), Exiobase, WIOD and OECD-ICIO can be used free of charge. Eora and GTAP both charge a significant fee for non-teaching institutions to access the data.

The final row in table 2 is “physical accounts” (8). MRIOTs predominantly describe the economic system in terms of currency unit (euro or dollar). An alternative is to describe the system in terms of tonnes in a physical account.[13] At Statistics Netherlands such an account has already been made (*MaterialenMonitor*) (Delahaye et al., 2015) with funding from the Ministry of Economic Affairs. Physical MRIOTs provide additional information, which is particularly useful from a circular economy perspective. Exiobase is the only MRIOT which produces physical accounts, although they can be best considered as experimental.

Taking all these considerations into account, we consider Exiobase to be the optimal choice to take as the starting point of the SNAC-method in the context of circular economy. Previously, the SNAC procedure has been applied to the WIOD database (Edens et al., 2014). WIOD is no longer a suitable candidate due to the lack of up-to-date environmental data. Exiobase provides the most recent time series, although the years after 2011 are now-casts. Furthermore, Exiobase is free to use, offers SUTs, follows the SNA-1993 system, provides high levels of detail and the quality of the data is good, particularly concerning the environmental dimension. Finally, the availability of physical MRIOT gives Exiobase a strong advantage over the other MRIOTs from a circular economy perspective.

Exiobase has been produced by an international consortium of researchers who have provided the data Statistics Netherlands in advance of the official release. Exiobase is to be publically released only in the product by product input-output table format. Statistics Netherlands has been provided with the supply and use tables from which the input-output table has been derived.

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[12] As the constructors of Eora26 put it “*This simplified model is considerably easier to work with than the full Eora MRIOT but it is known to be slightly less accurate. Both the step of aggregating sectors from the higher sectoral detail of Eora to the lower detail of Eora26, and the step of converting Supply/Use tables to IO tables, involve both a net information loss and the introduction of some new assumptions. The full resolution Eora results are considered to be superior. The Eora26 MRIOT is provided for simplicity, but is provided as-is.*” (see http://www.worldmrio.com/simplified/)

[13] For an international overview of physical input-output tables see Hoekstra and van den Bergh (2006)

3. The SNAC Procedure

This section provides a brief description of and justification for the SNAC procedure, with technical details relegated to appendices 2 through 5. Firstly, this section considers how Dutch national accounts and trade data can be used to modify an MRIOT such that the MRIOT provides a “correct” description of the economy of the Netherlands. Secondly, we explain how the use of this data results in the need to rebalance the MRIOT such that it is in accordance with national accounting conventions. Finally, we explain the need to adapt the Exiobase in order to correctly calculate footprints for the Netherlands.

The SNAC procedure makes the data corresponding to a given country within a MRIOT consistent with the national accounts of that country. The need for this can be summarized by comparing the Gross Domestic Product of the Netherlands according to the Dutch National Accounts and according to Exiobase. In 2010, GDP was €631 billion, but according to Exiobase, it was €588 billion. Therefore Exiobase underestimates Dutch GDP by nearly 7%. These types of inconsistencies are not unique to Exiobase. More accurately, it is a problem with MRIOTs in general, which results from the need to balance the national accounts of the countries within the MRIOT (for other reasons see also Hoekstra et al., 2014). This balancing results in deviation from the official national accounts including intermediate consumption, value added and final demand, which in turn affects GDP. It is therefore necessary to take data from the Dutch national accounts and re-insert these into Exiobase and then re-balance the system. This poses several technical challenges, both in terms of preparing the Dutch National Accounts data to be linked and also in terms of linking the data to Exiobase because of different industry and product classifications between Exiobase and the national accounts. Additional technical detail on the modification of and insertion of national accounts data into Exiobase is provided in appendix 2.

3.1 Trade data

A particularly important aspect of the underlying accounts is international trade. For national accounting purposes (i.e. calculating GDP), it is not necessary to know to which country exports are sent and from which country imports are received. It is simply necessary to know the value each kind of product which is imported and exported. In order to combine national accounts into a MRIOT, it becomes necessary to employ detailed trade data to properly account for the trade relationships between countries. Specifically, in a MRIOT it is necessary to know how much product from all industries in all countries is used or consumed in all other countries and industries. The Netherlands is a particularly complicated country in terms of international trade. A significant amount of Dutch exports consists of products which were not made in The Netherlands but, in one way or another are simply passing through the Netherlands. This is known as transit trade. Some products enter the country, then are marginally altered (for example, the application of packaging) without the good in question (that having been packaged) ever actually coming into Dutch ownership. Statistics Netherlands possesses more detailed data pertaining to trade than is available to external parties. The use of Statistics Netherlands trade data is therefore an important aspect of the SNAC procedure. Additional technical detail on trade data is provided in appendix 3.

3.2 Re-balancing

The SNAC procedure takes the national accounts and trade statistics data and inserts this data[14] in the MRIOT such that the MRIOT is consistent (in terms of the economic data) with the Dutch national accounts and such that the trade relationships for The Netherlands are depicted as accurately as possible. Unfortunately, making these changes undoes the balancing that was carried out to create MRIOT in the first place. To return to the jigsaw puzzle analogy: we have inserted the correct jigsaw pieces, but they don't fit in the gaps left by removing the "incorrect" ones. The next step is therefore to re-balance the MRIOT. The innovation in the SNAC procedure is that this rebalancing does not affect parts of the MRIOT which have been corrected with the national accounts and trade statistics. The rebalancing procedure involves the application of a constrained minimisation algorithm. The constraints in the algorithm are the rules of national accounting, such as that all production must somewhere be used (supply must equal use). The procedure is a minimisation because it achieves an accordance with the rules of national accounts while making the smallest possible adjustments to the data. The result is a MRIOT which is consistent with the Dutch national accounts and which deviates as little as possible from the original Exiobase. Additional technical details on the re-balancing procedure are provided in appendix 4.

3.3 Environmental data

One of the advantages of Exiobase is the great detail in the environmental data. The SNAC procedure principally involves the economic data within a MRIOT. However, this is not sufficient given the objective of this research to produce footprint calculations which are consistent with Dutch national accounts data. To calculate, for example, a carbon (CO_2) footprint it is necessary to know that total emissions of carbon from all sectors in all regions. Exiobase contains per country and sector a series of additional data, often called "environmental extensions" or in this case "stressors" which include carbon emissions among many other, loosely speaking, non-economic effects of economic activity. Unfortunately, the environmental stressor data for The Netherlands are not consistent with Statistics Netherlands data, specifically, the Environmental Accounts, which is a satellite account of the Dutch national accounts. The Dutch Environmental Account gives total carbon emissions excluding households at 171,962 million tonnes while Exiobase gives total carbon emissions excluding households at 164,171 million tonnes. An important step in the SNAC procedure is therefore to ensure that the Exiobase stressor data are consistent with Statistics Netherlands data. To achieve this, we take the Exiobase stressor data and remove the data for the Netherlands which are inconsistent with Statistics Netherlands data. We then manipulate the Statistics Netherlands data such that they can be inserted in the Exiobase stressor data.

We modify the stressor data with respect to carbon emissions and GHGs. Exiobase contains several different categories of carbon emissions depending on their source. These different sources are aggregated in the Exiobase stressor data. The Statistics Netherlands emissions data are available per sector according to a more aggregated classification system which is different to the sector classification employed in the economic data. This means that one sector in the environmental data can refer to multiple sectors in the economic data. Therefore, the environmental data must sometimes be divided across multiple sectors. This was done

[14] The shares from the trade data are adjusted to national accounts totals for imports and exports.

according to existing linking tables which show the relationship between the two categorisations. Dividing the environmental data across multiple sectors was generally achieved using production data, but for other sectors such as those in the service sector, the number of employees was considered to be a more appropriate choice. In the case of the chemicals sector, we used data from the National Emissions Register. Previous experience within Statistics Netherlands has shown that using economic data to share emissions between sectors performs well in general, but fails to properly account for the relatively high emissions in the artificial fertilizer and petro-chemical industries compared to other industries in the chemicals sector. In this case therefore, the use the emissions registration data ensures that these sectors were properly accounted for.

In addition to carbon and GHG emissions, we will also calculate the footprints of metal extraction for the 12 metals which are included in Exiobase. As such, we calculate the amount of extraction of metals which results from Dutch final demand. For the case of metal extraction there was no need to alter the Exiobase stressor data due to the fact that extraction of metals does not occur in The Netherlands.

4. Environmental footprints

Footprints are important tools in measuring the effects of final consumption. As opposed to, for example, the total carbon emissions which occur within a given national boundary, a footprint is the total amount of emissions which occurs as a result of consumption, regardless of where the emission occurs. Thus, the Dutch carbon footprint is equal to the carbon emissions which occurs in the Netherlands to produce goods and services which are consumed in the Netherlands *plus* all emissions which occur in other countries to produce goods and services which are consumed in the Netherlands. The method therefore allows for the inclusion of the entire supply chain. Thus, the emissions from a Chinese car battery factory are also included, after accounting for the extent to which that factory supplies a German car manufacturer and the extent to which that car manufacturer manufactures cars to satisfy Dutch demand. Suppliers of the Chinese car battery factory are also included, and so on and so forth.

Footprint calculations are made according to standard formulas utilising the “Leontief matrix” derived from the SNAC-Exiobase. An accessible introduction to these techniques is provided by Kitzes (2013) or Miller and Blair (2009). The method embodies various assumptions, the implications of which need to considered when evaluating the results.

The footprints which are produced from the SNAC-Exiobase are experimental footprints. This is particularly the case for carbon footprint because Statistics Netherlands already produces an official carbon footprint for the Netherlands. The carbon footprint calculated according to the SNAC-Exiobase differs from the official footprint. Later in this section, the official footprints and the experimental footprints will be compared and discussed.

In this section footprints are presented for carbon dioxide (henceforth referred to as “carbon”), Greenhouse Gases (GHGs) and the following metal ores:

- Bauxite and aluminium ores
- Copper ores
- Gold ores
- Iron ores
- Lead ores
- Nickel ores
- Other non-ferrous metal ores
- Platinum Group Metal (PGM) ores
- Silver ores
- Tin ores
- Uranium and thorium ores

We include carbon due to its importance for climate change which is also an important component of the NPCE. The NPCE explicitly aims to achieve a reduction in carbon emissions as a consequence of the transition to a circular economy. GHGs are included in order to provide a complete picture of the emission of greenhouse gases[15] in terms of human induced global warming. Metals are included due to their importance in the NPCE and the Raw Material Agreement. Metal ore footprints are part of the RMC footprint. The complete RMC is not

[15] Greenhouse gases are weighted as follows: $C0_2$ =1, CH_4=25, N_2O=298, F gasses = 1

calculated in this study due to time constraints. Specifically, we calculate the footprints of the extraction of metals. This means that we are considering the extraction from the metal ore stocks per year resulting from Dutch consumption. Exiobase includes two categories for each metal, namely, used and unused extraction. Unused extraction in the context of mining refers to overburden and other extracted mass of no economic relevance. Accordingly, this is excluded from the analysis.

4.1 Footprint results

4.1.1 Carbon and GHG footprints

Figure 1 below provides the carbon and GHG footprints for Dutch consumption for the years 2010 and 2014. The results show a reduction in the footprints.

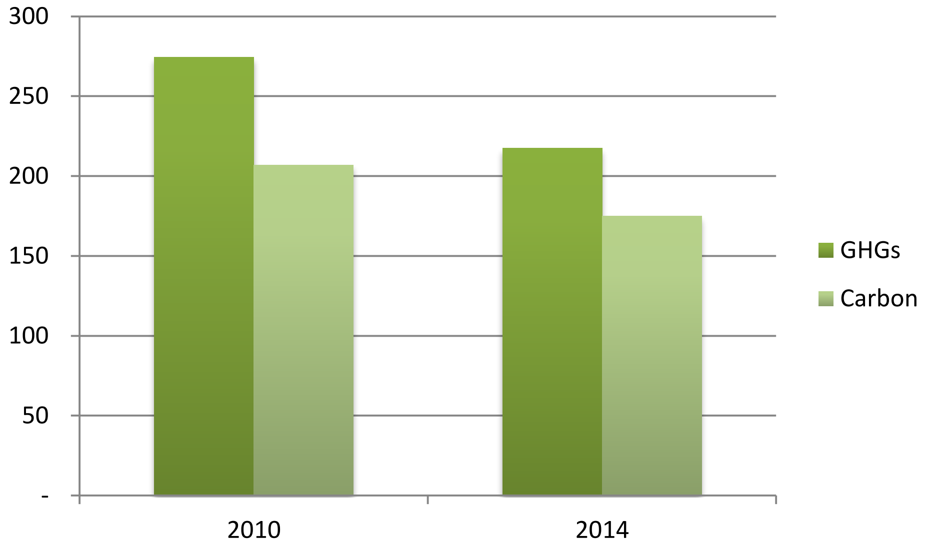

Figure 1: Experimental carbon and GHG (including carbon) footprints according to the SNAC-Exiobase of Dutch consumption in billions of tonnes.

The following table repeats provides the data behind figure 1 and also provides the official Statistics Netherlands carbon footprint. There is current no official GHG footprint available.

Table 3: SNAC-Exiobase and the official Statistics Netherlands carbon footprints in billions of tonnes.

	2010	2014
SNAC-Exiobase	207	175
Statistics Netherlands Official	204	188

There are many factors which influence the decline in the carbon footprint. First, it is important to point out that a decline in the footprints is to be expected because this is also the trend in the official Statistics Netherlands footprint. This is also a EU wide trend: Eurostat reports a 12% reduction[16] in the carbon footprint of the EU-28 between 2010 and 2014. The trend in The

[16] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:CO2_emissions_%E2%80%94_production_and_consumption_perspective,_EU-28,_2008-2014_(index_2008_%3D_100).png

Netherlands is a 15% reduction in the carbon footprint according to the SNAC-Exiobase results and 8% according to the official footprint.

The comparison of the carbon footprints for both years with the official Statistics Netherlands footprints reveals that the trend is in the same direction, but that there are some appreciable differences. Table 3 shows that the SNAC-Exiobase footprint is higher in 2010 (by 5 billion tonnes) and lower in 2014 (by 13 billion tonnes). The carbon footprint therefore declines more severely according to the SNAC-Exiobase footprints than the official footprint.

The 5 billion tonnes difference for 2010 between the official and the SNAC Exiobase footprint represents only 2.5% of the official footprint. We consider this to be a minimal deviation which does not merit deeper investigation. The difference is mostly likely to be a result of differences in the ways in which indirect foreign emissions are accounted for, as detailed in Appendix 1. This result suggests that 2010 is performing well as a base year from which to analyse trends. The larger difference between the official footprint and the SNAC-Exiobase footprint in 2014 however merits further investigation.

To understand the difference in the SNAC and official footprint it is informative to consider how the footprint is split between countries. Specifically, we can divide the Dutch carbon footprint according to the countries where the emissions (both direct or indirect) have taken place. Exiobase contains 49 regions, of which 45 are specific countries and 4 are aggregations of countries known as Rest of the World (RoW) groups. For the purposes of presentation, figure 2 presents only the countries for which are most important in terms of emissions resulting from Dutch consumption. The RoW group in figure 2 is an aggregate of the four Exiobase RoW groups plus all countries not explicitly represented.

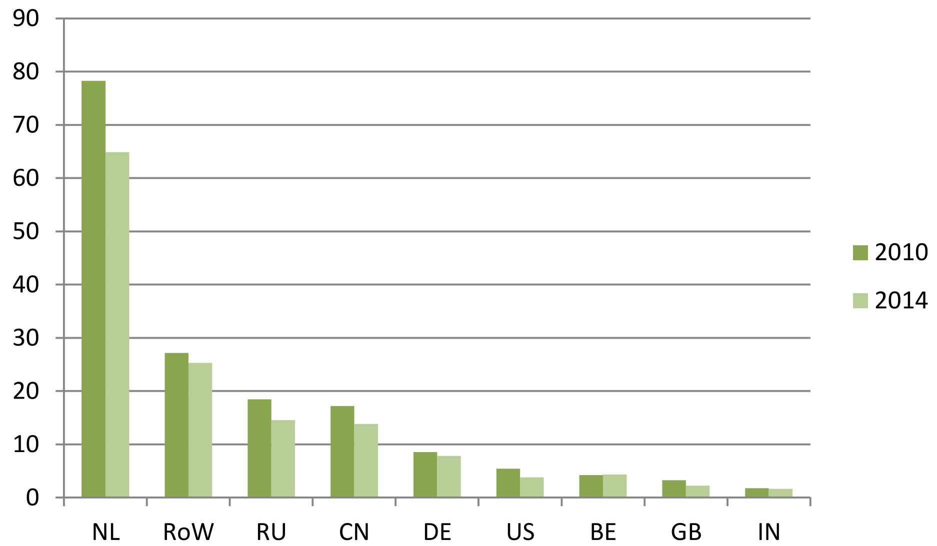

Figure 2: Experimental carbon footprints divided across countries where the emission took place in billions of tonnes (excluding Dutch household emissions).

Figure 2 shows that the most important individual countries for the emission of the Dutch carbon footprint (besides the domestic emission in the Netherlands) are Russia, China, Germany, the USA, Belgium, Great Britain and India. Due to the small increase in the share of the footprint emitted in Belgium and the decrease in the share emitted in the United States between 2010, and 2014, the ordering changes slightly between 2010 and 2014. However, the distribution of the footprint between countries remains predominantly unchanged.

Returning to the difference between the 2010 and the 2014 results, it is clear that figure 2 is a useful first step in determining what the causes the reduction between 2010 and 2014. Figure 2 shows that the reduction in the footprint between 2010 and 2014 is predominantly due to reductions in the footprint in the Netherlands and Russia. The reduction in the Dutch share of the footprint is predominantly due to a reduction in the total actual emissions which take place in The Netherlands. Between 2010 and 2014, there was an 8% reduction in carbon emissions in The Netherlands from non-household sources. Further, export has grown much quicker in The Netherlands than final demand within The Netherlands over the period 2010 to 2014. Specifically, export in goods and services (in basic constant prices) has increased 28.5% while final demand has increased only 3% (production increased by 11%).

The reduction in the share of the footprint emitted in Russia is due to an interesting combination of direct and indirect effects both relating to natural gas. The direct effect refers to a drop in the import of natural gas of 12%. Russian natural gas production is particularly environmentally damaging due to the practise of flaring, whereby waste gasses are burnt off (Tollefson, 2016). Analysis of Exiobase shows that many European countries also made a move away from Russian natural gas for electricity generation in favour of other sources of gas, other fossil fuels or renewable energy between 2010 and 2014. Italy for example, was one of Europe's largest importers of Russian natural gas in 2010. By 2014, Italy had practically ended the import of Russian natural gas, and had compensated for this predominantly by altering its energy mix towards solar energy. This is likely to relate the perceptions of Russia as being a less reliable trading partner. When products and services which are exported to The Netherlands are created with greener electricity, this indirect effect reduces the footprint emissions in the Russia natural gas sector. It is important to note that the Russia natural gas sector has however not produced less gas as a result of its changing trade patterns with Europe. Exiobase shows that Russian natural gas has simply been exported in greater quantities to Asian economies.

The reduction in the Dutch footprint between 2010 and 2014 is therefore principally driven by the reduction in total emissions which has taken place in The Netherlands over that period and the reduction in the use of Russian natural gas in the Netherlands and also in other European countries. This also helps to explain the difference in the SNAC and official footprint. The official footprint includes the Dutch component and the direct imports from Russia, but does not include the indirect effect of other European countries using less Russian gas and then exporting to the Netherlands.

We can now proceed to analyse the GHG footprint in more detail. The GHG footprint[17] is predominantly determined by the carbon footprint. Therefore, the negative trend in the GHG footprint is also to be expected. However, there are also significant reductions in the footprints of the individual GHGs (all measured in carbon equivalents). Specifically, the footprints for F-gases[18] and nitrous dioxide both drop by approximately 12% and the footprint for methane drops by approximately 45%. The reduction in methane emissions accounts for 64% of the total

[17] The Exiobase emissions data for methane and nitrous dioxide emissions in the Japanese copper mining sector were altered to produce plausible GHG footprint estimation. Specifically, these emissions were much too high in 2014. Therefore, for this specific sector, the 2014 emission data points were substituted with data from 2010.

[18] The three groups of F-gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). HFCs are by far the most relevant F-gases from a climate perspective.

reduction in GHG emissions other than carbon. We therefore consider in more detail what is causing this reduction. We find that 63% of the reductions in the footprint occurs in the USA and Russia. The reduction in the Dutch footprint which is emitted in the USA is predominantly due to a 61% reduction in the total emissions from the sector “mining of coal and lignite, extraction of peat” sector. In Russia, the reduction in the Dutch footprint which is emitted there is predominantly due to reduction in the total methane emissions in the sector “Extraction of crude petroleum and services related to crude oil extraction, excluding surveying” (a 51% reduction) and in the sector “Extraction of natural gas and services related to natural gas extraction, excluding surveying” (a 30% reduction). It is difficult to determine whether these reductions in total emissions are plausible. There is some doubt about this given that production in these industries has increased in real terms according to Exiobase. This problem is more severe in the case of the sector “mining of coal and lignite, extraction of peat”. As mentioned, total methane emissions in this sector reduces by 45% while production *increases* in real terms by 47%. Techniques exist to reduce the methane emissions from coal mining (see for example, the Coalbed Methane Outreach Programme[19]), however, it is not possible to ascertain whether such technologies have been adopted to an extent sufficient to ensure a reduction in methane emissions while production has increased.

Up to this point, we have analysed the countries which contribute to the total Dutch carbon footprint. Another analytical possibility exists, namely that we consider the emission which results from the consumption of specific products. Hence, we can split the total footprint into the parts that are emitted as a consequence of the Dutch consumption of the outputs of particular sectors in particular countries. We refer to these footprints as “product footprints”. Additionally, it is possible to consider the product footprints from domestic sectors, foreign sectors, or both together. In the following figure (figure 3), we present product footprints for sectors in foreign economies, or in other words, foreign product footprints. We choose to consider foreign product footprints because this facilitates analysis which provide insights into the extent to which globalised production results in carbon emissions. This is achieved by adding an additional vertical axis to figure 3 which allows the presentation of the import to the Netherlands of the products of sectors according to the SNAC-Exiobase[20]. Specifically, this is the import which is used for final consumption. We choose the import which is used for consumption because this is appropriate in the context of comparison to the carbon footprint resulting from consumption. A sector in the following figure is the aggregate of that sector across all foreign countries.

Figure 3 thus shows the foreign product emissions resulting from Dutch consumption per product in the context of the value of imports of those products which are used for final consumption. The importance of the product emissions of the natural gas sector conforms to the results in figure 2 which show that a large share of the Dutch carbon footprint is emitted in Russia, and specifically, the Russian natural gas sector. The other products that result in the most carbon emission are the products of diverse manufacturing industries. In general, one would expect that the more import of a given sector’s products there is to The Netherlands, the greater the product emission corresponding to that sector. The addition of the import axis to figure 3 allows us to analyse this expectation. The figure shows some evidence in support of the above mentioned expectation. However, there are clearly outliers to this trend, specifically for imports from the sector “extraction of natural gas”. In the case of natural gas the emissions

[19] https://www.epa.gov/cmop

[20] These import figures are thus not official Statistics Netherlands import statistics. Statistics Netherlands does not present import statistics according to the categories used in Exiobase.

resulting from consumption of products from this sector are relatively greater than the amount imported from this sector. Specifically, for every euro imported for final consumption there is a 4.3 tonne emission of carbon. Therefore, per euro reductions in the import of goods from this sector will result in relatively large gains in terms of carbon footprint reduction.

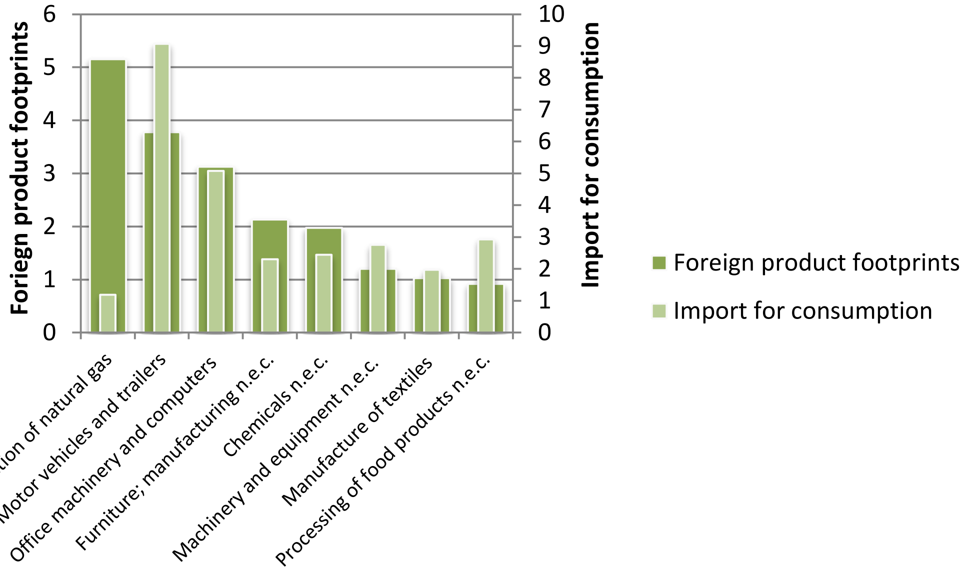

Figure 3: Experimental carbon footprints for 2014 divided across products of sectors in billions of tonnes, complemented by import per sector in billions of euros. Import includes only the import which is used for final consumption. The footprint per sector is the total emission which results from purchases of products from that sector (aggregated across countries excluding The Netherlands). The acronym n.e.c. stands for "not earlier classified". The sectors shown are those for whom the consumption of their products results in the most carbon emission.

Other sectors which have particularly large import to emission ratios are 'manufacture and distribution of gas' (3 tonnes per euro) and 'manufacture of cement, lime and plaster' (2.4 tonnes per euro). These sectors are not shown in figure 3 because their products account for only a relatively small share of the Dutch carbon footprint. However, per euro import for final consumption, these sectors produce the most carbon footprint intensive products.

4.1.2 Metal footprints

The Dutch footprint for the extraction of metal ores is approximately 24000 kilotonnes in 2010 and 19000 kilotonnes in 2014. The footprint is split out by the type of metal ore in figure 4.

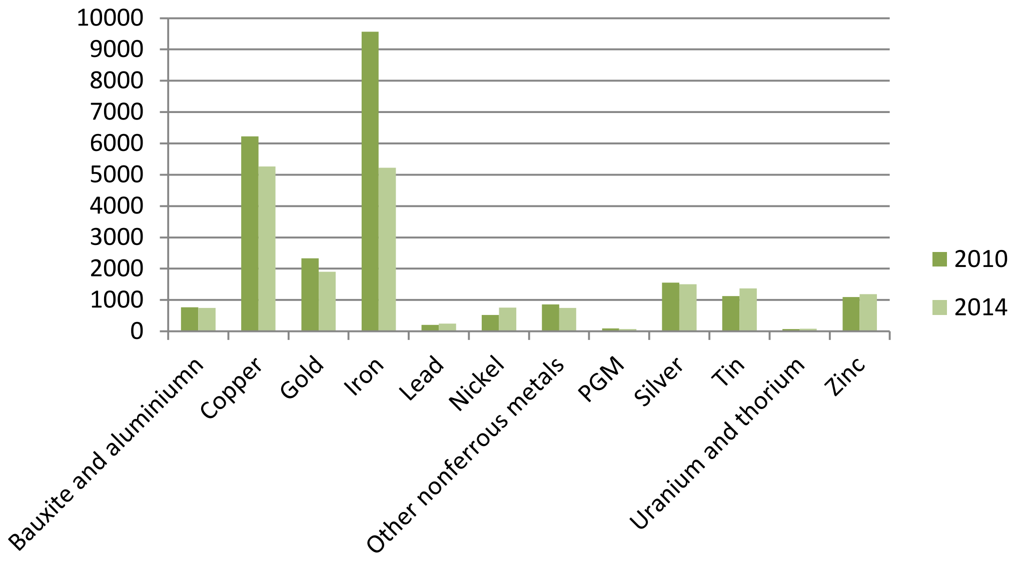

Figure 4: Footprints for metal ore extraction as a consequence of Dutch consumption in kilotons

The results in figure show that the majority of the reduction in the Dutch metal extraction footprint has occurred for iron ore. All other metals show relatively small changes between 2010 and 2014. The change in iron is due to an increase in the export of products containing iron and steel industry at the expense of the domestic market.[21] There are several industries for which exports have grown much more rapidly than domestic consumption, with many cases of domestic final consumption actually decreasing. The most extreme example is the car and trailer sector which export has increased in real terms by 41% while domestic final consumption has decreased by 27%. Other examples include the basic metals sector (11% increase in export, 39% reduction in domestic final consumption), the building materials sector (21% increase in exports, 23% decrease in domestic final consumption) and the specialised construction sector (11% increase in export, 4% decrease in domestic final consumption). For other metal intensive sectors, final consumption does not decrease but does increase considerably less than export. These are the metal products sector and machine manufacture, which both have approximately a 28% increase in exports against an 8% increase in domestic final consumption.

4.2 Comparison to Exiobase

In section 4.1 we have compared the SNAC-Exiobase footprint to the official Statistics Netherlands footprint. In this section, we compare the SNAC-Exiobase footprint to the original Exiobase footprint. Applying the SNAC procedure to Exiobase is complex and time consuming. For this reason it is useful to quickly demonstrate the importance of applying the SNAC procedure. The producers of Exiobase have released carbon footprints for all regions. These can be compared to the footprints which are produced from the SNAC-Exiobase, as is shown in figure 5.

[21] In terms of trade, the period 2010-2014 deviates from period before the crisis. There has been a significant slowing of international trade since 2012 (see Timmer et al., 2016 for references and analysis). These studies show that in 2010 there was a large surge in international trade, after the slump in 2008/2009 but that afterwards trade slowed significantly. The reasons for this “peak trade” is not yet fully understood but might affect our results.

Figure 5: Comparison of carbon footprints from the SNAC-Exiobase and the original Exiobase in billions of tonnes.

This shows that Exiobase consistently marginally overestimates the Dutch carbon footprint by about 5 billion tonnes (when compared to the SNAC-adjusted Exiobase). We illustrate the reasons for this deviation using 2010 data as an example as shown in figure 6.

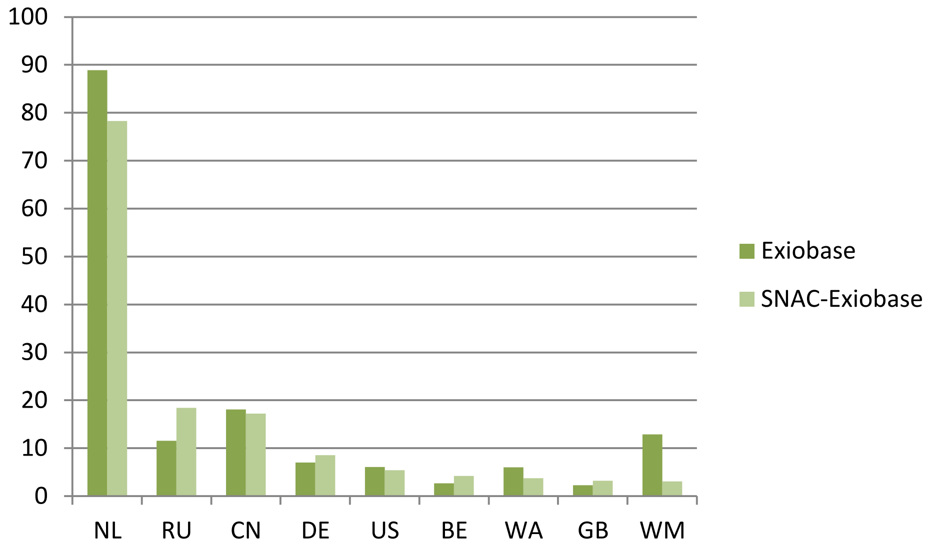

Figure 6: Comparison for 2010 between Exiobase and the SNAC-Exiobase of the countries in which the Dutch carbon footprint is emitted in billions of tonnes. WA is a RoW group for Asian countries which are present in the data as individual countries. WM is the same, but for the Middle East.

Figure 6 is interesting to contrast to figure 5. Figure 5 shows that there is a relatively small difference in the total footprints between the SNAC-Exiobase and Exiobase. However, figure 5 shows that there are quite large differences for specific countries. The most important difference relates to the emissions taking place in the Netherlands itself. The SNAC procedures eliminates this overestimation by keeping the Dutch constant during the balancing procedure. Further, we see quite large difference for Russia and the Middle East. These differences result from the more detailed trade data availably internally at Statistics Netherlands which is employed in the SNAC procedure. The trade relationships with Russia and the Middle East are dominated by industries which are in some way connected with fossil fuels, namely natural gas in Russia and oil in the Middle East. In the context of the Dutch carbon footprints therefore, the SNAC procedure provides an important improvement.

5. Conclusions

5.1 Summary

This project has three research objectives. The first has been to choose an appropriate MRIOT (multi-regional input-output table) with which to create Single Country National Accounts (SNAC) MRIOT for the Netherlands. From an analysis of six MRIOTS using eight criteria, Exiobase was chosen as the best available MRIOT. This database was chosen because it is the most up to date, has the greatest number of sectors and is most detailed in terms of the available environmental data, which in turn facilitates the calculation of a broad range of footprints. This is desirable in the context of the National Programme for a Circular Economy (NPCE) and the related Raw Material Agreement (*Grondstoffenakkoord*), which will take the necessary steps to meet the aims of the NPCE. The second and third objectives are to create the SNAC-Exiobase and to derive footprints.

The resulting footprints are to be considered as experimental footprints. This is for two principal reasons. The first is that an official Statistics Netherlands footprint already exists (this has been calculated using a different method), and because the 2014 Exiobase is a “nowcast”. This means that the data are not determined fully by available official statistics but extrapolated based on limited available data. In addition, some questions might be asked of some of the environmental data which we have been unable to verify but which have significantly effect on the results. Finally, the Dutch data that we have inserted is SNA2008 while the EXIOBASE is SNA1993 which might lead to differences.

The year 2010 serves as a suitable base-year because the Exiobase data for this year are not now-casted. We therefore have greater confidence in these figures. 2014 was chosen because it was more recent. It is also the case that 2014 has been chosen as the base-year from which to monitor the progress towards the aims of the NPCE.

The results focus in the first instance on the carbon footprint because official estimates already exist for 2010 and 2014. The experimental results produce footprints which are marginally higher than the official estimate for 2010 and appreciably lower for 2014. There are several significant methodological differences between the method that is employed in the estimation of the official carbon footprint and the method employed in this study. This is discussed in Appendix 1. The most significant difference is that Exiobase uses country specific data on the economic structure of foreign economies to estimate the indirect effects of Dutch consumption of emissions in foreign countries and fully accounts for trade between foreign countries. While these foreign indirect effects have only a small effect on the total footprint, they can still have an effect on the resulting footprint. For example, this study has found evidence to suggest that changes in the use of Russian natural gas between 2010 and 2014 in European countries have contributed indirectly to the reduction in the carbon footprint between 2010 and 2014. The most important determinant of the reduction in the Dutch carbon footprint between 2010 and 2014 are the changes in the economic activity and emissions from the Dutch economy and households.

This study also analyses the effects of carrying out the SNAC procedure by comparing footprints from the SNAC-Exiobase and the original Exiobase. This comparison shows that the SNAC procedure has a relatively small effect on the total footprint. Making Exiobase national accounts consistent results in approximately a 5% reduction in the carbon footprint. Larger differences can be seen when considering how this footprint is shared between the countries where the emission actually takes place. In particular, the use of internally available Statistics Netherlands trade data in the SNAC procedure is useful in ensuring that the emissions which take place in the Middle East (specifically petro-chemical industries) and Russia (specifically, the extraction of natural gas) are properly accounted for. In the context of the NPCE these raw material intensive industries can be properly accounted for, thanks to the SNAC procedure.

5.2 Evaluation

The use of the results in this report and future research which builds on this report needs to take several issues into account, particularly surrounding the results for 2014. Firstly, while the SNAC-Exiobase contains definitive and unaltered Dutch national accounts data, the data for other countries has been both now-casted and subject to a balancing procedure. This means that the quality of the 2014 Exiobase can be considered as somewhat lower than the 2010 Exiobase. It would be preferable to employ a MRIOT which is not now-casted in 2014 to calculate indicators for the base-year of the monitoring for the NPCE. Given the availability of MRIOTs at the beginning of this project, this was not possible. Also, we have not been able to verify all 2014 Exiobase environmental data. In some cases (methane), further analysis is needed to judge the data and perhaps manually adjust them.

Given these concerns, and the availability of alternative methodologies to produce some of the results presented in this report, we conclude this report by discussing the situations in which the use of the 2014 SNAC-Exiobase is appropriate in the context of the NPCE. Firstly, in terms of carbon footprints, the official 2014 CBS footprint should be adopted over the experimental 2014 SNAC-Exiobase footprint. SNAC-Exiobase can potentially be used to provide more information with which to better understand the trend. The results of the SNAC-Exiobase can also be used to evaluate the appropriateness of the method employed in the calculation of the official Statistics Netherlands carbon footprint. For example, if the domestic technology assumption (see Appendix 1) can be shown to be particularly problematic for a given country, alternative approaches can be explored, such as potentially, employing an input-output table for that specific country in the analysis.

There is currently no official Statistics Netherlands footprint for GHG emissions (as opposed to carbon emission). The SNAC-Exiobase GHG footprint can therefore be employed in this regard. In order to be consistent with the official carbon footprint, the SNAC-Exiobase footprint can be easily adjusted such that it only refers to GHGs other than carbon, and this result can then be added to the official footprint. In this way the GHG footprint remains consistent with the official carbon footprint. The GHG footprint can best be considered as provisional given the now-casted nature of Exiobase. Additional footprints for the extraction of metal ores could also be provisionally included in the monitoring for the NPCE. It is however important to note that the calculation of metal footprints in the future is highly dependent on the availability of reliable external data.

This brings us to a useful conclusion, which relates to updates to Exiobase. It is not known whether Exiobase will be updated in the future. This is due to the nature of the funding for Exiobase which is predominantly through EU Horizon 2020 programmes. Exiobase is not an “institutionalised” MRIOT such as the OECD-ICIO MRIOT which is regularly updated. There is therefore a need to continually evaluate the choice of MRIOT for this analysis. Evaluation of this choice should take into account new MRIOTs which become available. The ideal MRIOT is as up to date and detailed as Exiobase, but as institutionalised as the OECD-ICIO MRIOT. Such a MRIOT would facilitate the production of indicators to monitor the NPCE throughout the lifetime of the programme.

5.3 Future Research

The NPCE has chosen 2014 to be the base-year from which progress towards its goals will be measured. The 2014 SNAC-Exiobase can function as a source of data for setting the 2014 baseline. This is the case for the consumption-based analysis (i.e. footprints) as well as for the indicators relating to the production activities (which will also be derived by Statistics Netherlands). Given that the NCPE base-year is 2014, it would be preferable to employ "real" data for this year rather than a now-cast. It would also be good to look, in greater detail at some of the environmental data from countries that are important for the Dutch footprint. For example, the GHG-footprints were heavily influenced by sharp decreases in the methane data of Exiobase. If possible, it would be useful to recalculate the 2014 footprints if and when actual 2014 data become available and these data are further verified.

Following on from this, it will be necessary to periodically repeat the calculation of footprints for future years in order to monitor the macro-economic effects of the NPCE. In this regard, it is firstly important to note that MRIOT data for a given year often only become available rather late in comparison to other sources of data. For example, the latest version of Exiobase (to 2015), will likely only become publicly available in late 2017, which constitutes almost a two year lag time. Whether such a time-lag is acceptable for the monitoring of the NPCE is an important question when considering future monitoring. A fundamental issue regarding this, is the uncertainty regarding future developments of MRIOTs. Whether Exiobase will be updated in the future is not currently known. The most recent version of Exiobase was financed through the EU FP7 programme and is thus reliant on future grants for updates. WIOD is also financed in this manner. This is one reason to prefer a MRIOT which is produced regularly by an institution, such as that produced by the OECD (although that MRIOT has been discounted because of the lack of public environmental data, see chapter 2). Future research must therefore continue to evaluate which MRIOT is most suitable to produce indicators to monitor the NPCE. In the coming years, a new MRIOT will become available called FIGARO ('Full International and Global Accounts for Research in Input-Output Analysis[22]), which is being produced by Eurostat and which will cover all European countries. FIGARO should be included in the list of potential MRIOTs.

Future research needs to take into account the broader possibilities for research facilitated by SNAC-MRIOTs, the time and cost involved with producing SNAC MRIOTs and the results that can be derived from a SNAC-MRIOT. This is important due to two main reasons: firstly the SNAC procedure is complicated and time-intensive, and therefore costly, and secondly, there are other methods to calculate footprints which are not as advanced but more cost-effective. Specifically, the official Statistics Netherlands carbon footprint is calculated using the method of Haan (2004), which uses an input-output table only for the country in question, complemented by trade-data and emission data. Therefore the creation of the SNAC-MRIOT can

[22] See http://ec.europa.eu/eurostat/web/economic-globalisation-and-macroeconomic-statistics/multi-country-supply/figaro for more information

only be justified if it adds value in terms of quality and applicability. Some additional applications are discussed below.

This project has created SNAC input-output tables in industry by industry format. It is also possible to create such tables in a product by product format in order to maximise the benefit of a SNAC-MRIOT. This provides more information because there are 200 products in Exiobase as opposed to 163 industries. Footprints can thus be provided for the Dutch consumption of specific products produced in specific countries. Product by product input-output tables can be produced from the SNAC supply and use tables which were made as part of this project.

MRIOTs can also give vital insights into networks and complexity in global supply chains. It can also be used for economic analysis of globalisation. Specifically, supply chains can be analysed to determine if for example Dutch supply chains exhibit flexibility such that they can deal with supply side shocks, or whether supply chains frequently run through hubs or bottlenecks which could pose risks in the supply to the Dutch economy.

The SNAC-Exiobase can also be complemented with additional data such as data on the ownership of enterprises, as has been done by, for example[23] by several Nordic countries in cooperation with the OECD. The possibility for such analyses in the context of Exiobase has also been explored by Statistics Netherlands (Roekel et al., 2016) . Given that the economic activities of nations are no longer confined to their own borders, adding ownership data to Exiobase would provide an extra dimension with which to analyse the environmental and resource effects of Dutch consumption.

[23] http://www.dst.dk/Site/Dst/Udgivelser/GetPubFile.aspx?id=28140&sid=nordglobchains

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Appendix 1: Methodology of the Official Statistics Netherlands carbon footprint compared to the SNAC-Exiobase footprint methodology

The official methodology employed by Statistics Netherlands to calculate carbon footprints is discussed in this appendix. The official RMC footprint is calculated according to a separate methodology, namely, the country raw material equivalents tool[24] from Eurostat. The methodology for compiling the RMC is not discussed here.

In order to understand the differences between the official carbon footprint results derived from the SNAC-Exiobase, it is necessary to understand the differences in the methods employed. Accordingly this section describes the method employed to calculated the official carbon footprint. The key difference between the methods is that the method use for the official footprint does not make use of a MRIOT, but only the Dutch input-output table, complemented with additional data on trade and emission intensities (emission per unit of output for a given sector in a given country).

There is overlap between the two methods. The majority of the emissions that result from Dutch consumption take place in the Netherlands. These are emitted by households themselves and by the activities taking place within the Dutch economy which occur directly or indirectly due to Dutch consumption. Both methodologies include these emissions and use what is essentially the same method to calculate this part of the footprint. The difference is that the official method uses a more aggregated description of the economy (fewer sectors).

There are differences in how the methods deal with foreign emissions as a direct consequence of Dutch consumption. Consider the example of German car production. To account for the emissions which result from German car production as a direct result of Dutch consumption, the official method takes the value of cars imported to the Netherlands which are sold to households assumes that these cars are produced in the Netherlands (i.e. with a Dutch economic structure). However, the emission intensities of the German auto production plant are used instead of the Dutch emission intensities. These emission intensities are acquired from Eurostat if possible, and if not possible Exiobase. Conceptually, and in terms of data employed, the foreign emissions directly resulting from Dutch consumption are calculated in very similar ways. Small differences are likely to occur due to differences in methods of aggregation to different levels and linking between different data sources. Further, the balancing procedure employed to make the SNAC-Exiobase means that the emission intensities of the SNAC-Exiobase (which are used in the SNAC-Exiobase footprint) will not be precisely the same as the intensities used in those employed in the official method. However, these differences are small and should have only a minimal effect on the results.

The major difference between the methods relates to how foreign emissions resulting indirectly from Dutch consumption are included. The official method does not employ a MRIOT and therefore has to make some assumptions about the structure of foreign economies. The official method assumes that foreign imports are made according Dutch production technologies, however with foreign emission coefficients. This is called the “domestic technology assumption”

[24] http://ec.europa.eu/eurostat/web/environment/methodology

For many industries, this is a reasonable assumption. The relationships between German car production and other German industries are, in terms of proportions, unlikely to deviate much from those in the Netherlands. For other sectors however, the assumption is more vulnerable. Some economic activities do not take place at all in the Netherlands (for example iron ore mining). Further, some economic activities take place with very different production processes, which can have implications for the carbon footprint. For example, the mix of technologies used to create electricity varies between countries.

While the approach to indirect foreign emissions in the official method relies on a few assumptions it is vitally important to note that footprints are predominantly determined firstly by domestic emissions and secondly by direct foreign emissions. The proportion of indirect foreign emissions in the total footprint is relatively small and therefore has a small effect on the final result. The differences between the SNAC-Exiobase method and the official method are smallest for the types of the emissions which matter the most for the results. For example, the domestic household emissions are precisely the same and domestic direct and indirect emissions are calculated using essentially the same method.

Appendix 2: SNAC: Combining national accounts data with Exiobase

This section details how the Dutch national accounts data has been manipulated such that it can be combined with Exiobase. The starting point are the Supply and Use Tables (SUTs). As a basis we employ the SUTs which are more detailed than those which are publically available. The intermediate block consists of around 215 goods (small variations can occur between years) and 133 sectors. Value added is split into 11 categories and there are 24 categories for taxes and subsidies. Additional, there are a number of additional categories in the "fourth quadrant" of the input-output table which include corrections for cif/fob prices, consumption of non-residents and consumption of residents in foreign countries. The SUTs also include several categories for "margins". These contain the profit made from trading in goods without modifying the good. For example, wholesale companies buy goods from suppliers and sell them to retailers. Including the entire value of the goods in question is inappropriate because the wholesalers have not produced the goods in question. Therefore, only the economic activity resulting from the trade in the goods (i.e. the margin) is recorded. The task at hand is to structure the SUTs tables in such a way that they are compatible with Exiobase without altering the SUT data such that it is no longer consistent with the Dutch national accounts.

In order to achieve the above task, there are many modifications which need to be made to SUTs. Many of these modifications are technically trivial, but two are important to explain in more detail. These are the modifications regarding the wholesale margins and the modifications regarding through-traded goods in the export processing sector. Let us first discuss through-trade goods in the export processing sector and then the modifications of the margins.

The export processing sector purchases goods and then exports them as-is, possibly after small modifications such as packaging. As such, the export processing sector is mainly a sector which just trades in goods and engages only sometimes and marginally in "adding value" to the good in question. The export processing sector can process either goods produced in the Netherlands or goods produced abroad. The question of whether the correct values are included in the export processing sector depends on the question of what is actually being exported. If the good is not produced in The Netherlands, it is the service of processing the good that is exported. Therefore, the value of the import of the goods for export processing must be excluded from the value of its export. In this way, the economic activity in the export processing sector is properly included in the analysis.

We can now proceed to consider the modifications of the wholesale margins. Margins result from the fact that wholesalers charge incrementally more for products than they paid for them. This increment is in fact what wholesalers produce and it is thus this which needs to be recorded in the national accounts. The use table contains data on both the export and domestic use of wholesale margins. The modification which needs to be made results from the fact that the supply table does not split wholesale margins into exports and domestic use. This is important information in the case that the supply table will be used in the context of a MRIOT. It is therefore necessary to divide the supply of wholesale margins between the domestic export market. Because there is no data available with which to split the supply of wholesale margins between the domestic and export market, we employ a minimisation algorithm available within the Microsoft excel solver package. This allocates the wholesale margin, per sector, between the domestic and export market such that sum of the squared differences between the supply and the use of wholesale margins for the domestic and export market is minimalized. The algorithm consistently succeeds to allocating the wholesale margin such that the difference between supply and use is consistently less than 1 euro and therefore is performing sufficiently well.

Appendix 3: SNAC: Trade data

In the national accounts data, the export and import data is known per product but not by country of origin (in the case of imports) or destination country (in the case of exports). In order to properly account for the trade relationship between the Netherlands and the rest of the world in SNAC-Exiobase, it is necessary to use trade data. Specifically, the trade data is used to distribute the imports and exports from the national accounts to specific countries. As such, the trade data is not employed directly, but it used to inform how national accounts imports and exports are shared between countries.

The trade data is divided between two separate sources: the Trade in Goods Statistics (TGS) and the Trade in Services Statistics (TSS). A consistent time series of data is available to the TGS (2010, 2014) but not for the TSS. This is due to the new Balance of Payments Methodology (BPM6). This means that the time series is not consistent between 2010 and 2014. There are two options for dealing with this inconsistency. The first is to ignore the methodological change and to apply the 2014 data as-is to inform the import export shares. The alternative is to employ 2013 data, which is methodologically consistent with the 2010 data. In order to make this decision, we analysed the effect of the change in the methodology on the time series. If it transpired that the change in the methodology only has an effect on the absolute amounts of trade in given goods to given countries while the shares appear to be unaffected by the methodological change, then it would be better to use the 2014 because it refers to the correct year. If however, the methodological changes affect the shares of the trade in a given good between countries then it might be better to use the 2013 because the 2013 data is a better representation of what the data would look like under the old methodology than the 2014 data (under the new methodology). We found that the methodological change leads to large increases in the volume of trade as well as the distribution of trade across sectors and countries. We therefore decided to use the 2013 TSS.

Appendix 4: SNAC: Rebalancing

This section formally explains the SNAC procedure, which reconciles a national use and supply table (SUT) with an international use and supply table (IntSUT). This reconciliation process basically implies that we replace part of an IntSUT with its corresponding SUT and re-adjust the IntSUT such that the new IntSUT complies again to the standard economic conditions. This discussion contains three elements. First the structure and properties of the IntSUT, second the structure and properties of the SUT, third the SNAC procedure.

Structure of IntSUT

An IntSUT contains an international use (U^{int}), supply (S^{int}), final demand (FD^{int}) and value added (VA^{int}) table. We should note that there is no imports and exports like in a standard SUT, because an IntSUT considers the whole world to be one country, so the existence of exports and imports would require trade with other planets. The IntSUT distinguishes a set of C countries and for each country it distinguishes a set G^{int} of goods & services, as set I^{int} of industry & service sectors and a set F^{int} of final demand categories. Furthermore, VA^{int} contains a set V^{int} of value added categories. This implies there is the set C x I^{int} of different country/industry & service sectors combinations, the set C x G^{int} of different country/goods & services combinations and the set C x F^{int} country/final demand combinations. Then we can write that an IntSUT complies to the following (standard economic) conditions:

$$\sum_{\mathrm{CxG}^{int}} \sum_{\mathrm{CxF}^{int}} FD^{int} = \sum_{\mathrm{CxI}^{int}} \sum_{\mathrm{Cx}V^{int}} VA^{int} \tag{1a}$$

$$\sum_{\mathrm{CxI}^{int}} U^{int}_{\mathrm{CxG}^{int}} + \sum_{\mathrm{CxI}^{int}} FD^{int}_{\mathrm{CxG}^{int}} = \sum_{\mathrm{CxI}^{int}} S^{int}_{\mathrm{CxG}^{int}} \qquad \forall \mathrm{CxG}^{int} \tag{2a}$$

$$\sum_{\mathrm{CxG}^{int}} U^{int}_{\mathrm{CxI}^{int}} + \sum_{\mathrm{CxG}^{int}} VA^{int}_{\mathrm{CxI}^{int}} = \sum_{\mathrm{CxG}^{int}} S^{int}_{\mathrm{CxI}^{int}} \qquad \forall \mathrm{CxI}^{int} \tag{3a}$$

Where (1a) implies 'total final demand equals total value added', (2a) implies 'intermediate use plus final demand of a product equals total supply of a product' and (3a) implies 'intermediate use plus value added of a sector equals total supply of a sector'.

Structure of a SUT

A SUT contains, just like the IntSUT, a national use (U^{nat}), supply (S^{nat}), final demand (FD^{nat}) and value added (VA^{nat}) table. However, additionally it contains imports (*IM*) and exports (*EX*) data. It distinguishes a set G^{nat} of goods & services, a set I^{nat} of industry & service sectors, and a set F^{nat} of final demand categories and a set V^{nat} of value added categories. Furthermore, *IM* and *EX* is available for each good & service in SUT and we assume it is available for each country/region in C. Then we can write that a SUT complies to the following (standard economic) conditions:

$$\sum_{\mathrm{G}^{nat}} \sum_{\mathrm{F}^{nat}} FD^{nat} + \sum_{\mathrm{C}} \sum_{G^{nat}} EX = \sum_{\mathrm{I}^{nat}} \sum_{\mathrm{V}^{nat}} VA^{nat} + \sum_{\mathrm{C}} \sum_{\mathrm{G}^{nat}} IM \tag{1b}$$

$$\sum_{\mathrm{I}^{nat}} U^{nat}_{\mathrm{G}^{nat}} + \sum_{\mathrm{F}^{nat}} FD^{nat}_{\mathrm{G}^{nat}} + \sum_{\mathrm{C}} EX_{\mathrm{G}^{nat}} = \sum_{\mathrm{I}^{nat}} S^{nat}_{\mathrm{G}^{nat}} + \sum_{\mathrm{C}} IM_{\mathrm{G}^{nat}} \qquad \forall \mathrm{G}^{nat} \tag{2b}$$

$$\sum_{G^{nat}} U^{nat}_{I^{nat}} + \sum_{\mathrm{V}^{nat}} VA^{nat}_{I^{nat}} = \sum_{\mathrm{G}^{nat}} S^{nat}_{\mathrm{I}^{nat}} \qquad \forall \mathrm{I}^{nat} \tag{3b}$$

Where (1b) implies 'total final demand plus exports minus imports equals total value added', (2b) implies 'intermediate use plus final demand plus exports of a product equals total supply plus imports of a product' and (3b) implies 'intermediate use plus value added of a sector equals total supply of a sector'.

The SNAC procedure

Now imagine we have *N* countries, such that $\mathrm{C} = c_1, \dots, c_n$ we can than write $\mathrm{C} = (c_i, \mathrm{C}_j)$ where c_i is our country of interest and $\mathrm{C}_j = c_1, \dots, c_{i-1,}c_{i+1}, \dots, c_n$(i.e. all other countries) and we have linking schemes that allow us to project G^{nat}on G^{int}, I^{nat}on I^{int}, F^{nat}on F^{int} and V^{nat}on V^{int}. These linking schemes allow us to write each table in SUT in both *int* and *nat* dimensions. Then, when we replace country c_i in the IntSUT by its SUT, we can write:

$$U_{c_i,c_i}^{int} \rightarrow U^{nat} \tag{4}$$

$$S_{c_i,c_i}^{int} \rightarrow S^{nat} \tag{5}$$

$$FD_{c_i,c_i}^{int} \rightarrow FD^{nat} \tag{6}$$

$$VA_{\mathrm{V}^{int},c_i}^{int} \rightarrow VA_{\mathrm{V}^{int}}^{nat} \tag{7}$$

$$U_{\mathrm{C}_j,c_i}^{int} \rightarrow IM_{\mathrm{G}^{int},\mathrm{I}^{nat}} \tag{8}$$

$$U_{\mathrm{c}_i,\mathrm{C}_j}^{int} \rightarrow \Psi EX_{\mathrm{G}^{nat},\mathrm{I}^{int}} \tag{9}$$

$$FD_{\mathrm{c}_i,\mathrm{C}_j}^{int} \rightarrow (Y - \Psi)EX_{\mathrm{G}^{nat},\mathrm{F}^{int}} \tag{10}$$

$$FD_{c_i,\mathrm{C}_j}^{int} \rightarrow IM_{\mathrm{G}^{int},\mathrm{F}^{nat}} \tag{11}$$

where Ψ is a matrix of dimension $\mathrm{G}^{nat}$by C_j, that contains for each good or service in G^{nat} and for each country in C_j the share of exports that serve as foreign intermediate use. Y is a matrix with only ones of the same dimension as Ψ and so $(Y - \Psi)$ contains the shares of exports for each good or service and country that serve as foreign final demand. Without additional information on country's c_i exports, Ψ can be determined by using the original shares in the IntSUT.

Under (4),..., (11), condition (1a), (2a) and (3a) become:

$$\sum_{\mathrm{C}_j\mathrm{xG}^{int}} \sum_{\mathrm{C}_j\mathrm{xF}^{int}} FD_{\mathrm{C}_j,\mathrm{C}_j}^{int} + \sum_{\mathrm{c}_i\mathrm{xG}^{nat}} \sum_{\mathrm{c}_i\mathrm{xF}^{nat}} FD_{\mathrm{c}_i,\mathrm{c}_i}^{nat} + \sum_{\mathrm{c}_i\mathrm{xG}^{nat}} \sum_{\mathrm{C}_j\mathrm{xF}^{int}} (Y - \Psi)EX_{\mathrm{c}_i,\mathrm{C}_j} + \sum_{\mathrm{C}_j\mathrm{xG}^{int}} \sum_{\mathrm{c}_i\mathrm{xF}^{nat}} IM_{\mathrm{C}_j,\mathrm{c}_i} = \sum_{\mathrm{C}_j\mathrm{xI}^{int}} \sum_{\mathrm{V}^{int}} VA^{int} + \sum_{\mathrm{c}_i\mathrm{xI}^{nat}} \sum_{\mathrm{V}^{int}} VA^{nat} \tag{1c}$$

$$\sum_{\mathrm{C}_j\mathrm{xI}^{int}} U_{\mathrm{C}_j\mathrm{xG}^{int}}^{int} + \sum_{\mathrm{C}_j\mathrm{xF}^{int}} FD_{\mathrm{C}_j\mathrm{xG}^{int}}^{int} + \sum_{\mathrm{c}_i\mathrm{xI}^{nat}} IM_{c_i\mathrm{xI}^{nat}} + \sum_{\mathrm{c}_i\mathrm{x}F^{nat}} IM_{c_i\mathrm{x}F^{nat}} = \sum_{\mathrm{C}_j\mathrm{xI}^{int}} S_{\mathrm{C}_j\mathrm{xG}^{int}}^{int} \qquad \forall \mathrm{C}_j\mathrm{xG}^{int} \qquad (2c - \mathrm{C}_j)$$

$$\sum_{c_i\mathrm{xI}^{nat}} U_{c_i\mathrm{xG}^{nat}}^{nat} + \sum_{c_i\mathrm{xF}^{nat}} FD_{\mathrm{c}_i\mathrm{xG}^{nat}}^{nat} + \sum_{\mathrm{c}_i\mathrm{xI}^{int}} \Psi EX_{\mathrm{G}^{nat},\mathrm{I}^{int}} + \sum_{\mathrm{c}_i\mathrm{xF}^{nat}} (Y - \Psi)EX_{\mathrm{G}^{nat},\mathrm{F}^{int}} = \sum_{c_i\mathrm{xI}^{nat}} S_{c_i\mathrm{xG}^{nat}}^{nat} \qquad \forall c_i\mathrm{xG}^{nat} \qquad (2c - c_j)$$

$$\sum_{C_j xG^{int}} U^{int}_{C_j xI^{int}} + \sum_{V^{int}} VA^{int}_{C_j xI^{int}} + \sum_{c_i xG^{nat}} \Psi EX_{c_i xI^{nat}} = \sum_{C_j xI^{int}} S^{int}_{C_j xG^{int}} \quad \forall C_j xI^{int} \quad (3c - C_j)$$

$$\sum_{c_i xG^{nat}} U^{nat}_{c_i xI^{nat}} + \sum_{V^{int}} VA^{nat}_{c_i xI^{nat}} + \sum_{C_j xG^{int}} IM_{G^{int},I^{nat}} = \sum_{c_i xG^{nat}} S^{nat}_{c_i xI^{nat}} \quad \forall c_i xI^{nat} \quad (3c - c_j)$$

When the SUT complies to (1b), (2b) and (3b), the constraints $(2c - c_j)$ and $(3c - c_j)$ automatically hold, however, they do not assure that equation (1c), $(2c - C_j)$and $(3c - C_j)$ also hold. Therefore, the SNAC procedure needs to assure they do, without violating the constraints $(2c - c_j)$and $(3c - c_j)$, which implies that the SNAC procedure is not allowed to alter any of SUT data. Finally we should note that constraint that $(2c - C_j)$ and $(3c - C_j)$ do not only guarantee that use is equal to supply for each industry and good, but also that the totals of use and supply of goods and industries are unaltered for C_j with respect to the IntSUT. In a graphical representation the replacement of country $c_i$with its SUT (excluding the supply table), together with the appropriate constraints looks like:

	$c_i xI^{nat}$	$C_j xI^{int}$	$c_i xFD^{nat}$	$C_j xF^{int}$	
$c_i xG^{nat}$	U^{nat}	$\Psi EX_{G^{nat},I^{int}}$	FD^{nat} (1c)	$(Y - \Psi)EX_{G^{nat},F^{int}}$ (1c)	$(2c - c_i)$
$C_j xG^{int}$	$IM_{G^{int},I^{nat}}$	$U^{int}_{C_j,C_j}$	$IM_{G^{int},F^{nat}}$ (1c)	$FD^{int}_{C_j,C_j}$ (1c)	$(2c - C_j)$
V^{int}	$VA^{nat}_{V^{int}}$(1c)	$VA^{int}_{V^{int}}$ (1c)			
	$(3c - c_i)$	$(3c - C_j)$			

Where $c_i = c_1$and the constraints inside the figure are in the squares that are affected by this constraint and the constraints outside the figure apply to the respective rows and columns.

So far we have considered the SUT and IntSUT constraints that evolve from the standard economic SUT conditions. However, we could also consider other constraints, such as an unchangeable world GDP (GDP^{int}). When we replace country $c_i$with its SUT, GDP^{int} that evolves from the IntSUT has probably changed (i.e. the sum of *VA* has changed). Because GDP^{int} is a well-established statistic, it is probably desirable to keep it constant in a SNAC procedure. Therefore we add an additional constraint that can be written as:

$$\sum_{V^{int}} VA^{nat}_{c_i xI^{nat}} + \sum_{V^{int}} VA^{int}_{C_j xI^{nat}} = \mathrm{GDP}^{int} \quad (12)$$

SNAC reconciliation procedure

The SNAC reconciliation procedure assures that the constraints (1c), (2c), (3c) and (12) are met, keeping all cells (beside stocks) positive and without altering the SUT data of country c_i. This is done by changing the original data as little as possible, i.e. by minimising the sum of squared changes. Furthermore, the SNAC procedure takes into account that some data is more reliable than other, by altering more reliable data less in the reconciliation process. This procedure is performed in R with the package ‘rspa’ (for details see: https://cran.r-project.org/web/packages/rspa/rspa.pdf).

Appendix 5: SNA2008 and footprint calculations

The system of national accounts (SNA1993) has recently been updated (EC et al., 1993 and 2009). The new SNA 2008 poses a significant problem for global value chain analysis and environmental analysis. Timmer et al. (2016) describe the issue as such:

It is important to note that in the new SNA there are some major changes in the recording of trade statistics. There is a major conceptual change under item "Goods sent abroad for processing" which – in a nutshell – means that the value of goods sent abroad for processing does no longer impact on gross exports and imports because SNA2008/ESA2010 uses a change in ownership approach and is no longer based on physical movements, but on ownership principle. SNA2008/ESA2010 therefore just records the value added of the export processing service. A similar conceptual change is made in the Balance-of-Payments accounts (with their corresponding change from BPM5 to BPM6).

These changes affect the output, trade figures and therefore environmental intensities. One of the main issues is the changes to the trade statistics. In fact the System of Environmental-Economic Accounts therefore does not follow this approach for physical supply and use tables (EC et al., 2013):

Although this treatment accords with that of the SNA and provides the most appropriate recording of the monetary flows, it does not correspond to the physical flows of goods. Consequently, a different treatment of goods for processing is recommended for physical supply and use tables.

The SEEA solution is therefore to re-adjust the SNA2008 supply and use data to the SNA1993 definitions. This would also make the Dutch economy and the rest of the world consistent (both in SNA1993). However, the Dutch national accounts make the adjustments only in the import export figures and not in the supply and use framework. We were therefore unable to make these adjustments (they could be done in the input-output setting but our SNAC approach is based on SUTs).

This is major problem for all MRIOT studies but no solution currently exists. Timmer et al. (2016) uses the same assumption that we do in which they link the SNA1993 trade shares to the SNA2008 national account tables.

As the construction of WIOTs requires bilateral trade information it is assumed that bilateral trade shares (calculated from the trade in goods and services data) are also valid for the processed exports. This proportionality is to be doubted (e.g. Germany is likely to have a higher share of processing trade with Czech Republic than with say France), but a solution must await further data information.

Statistics Netherlands does not yet have a fully functional solution to this issue (which would also require information from all other countries). One solution might also be to change the trade data to the SNA2008 definition but this has not yet been proven. The only research done so far at Statistics Netherlands is by van Rossum (2014) who find that it has little impact on the total footprint but can affect industry footprints significantly.