Environmental Input-Output Analyses for the Netherlands

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Remark: The views expressed in this paper are those of the authors and do not necessarily reflect the policies of Statistics Netherlands.

Explanation of symbols

:	Not applicable
.	Data not available
x	Publication prohibited (confidential figure)
-	Nil
0 (0.0)	Less than half of unit concerned
*	Provisional figure
**	Revised provisional figure (but not definite)

Abbreviations

CBS	Statistics Netherlands (Centraal Bureau voor de Statistiek)
CH_4	Methane
CIF	Cost, Insurance, Freight
CO_2	Carbon dioxide
CN	Combined Nomenclature
DTA	Domestic Technology Assumption
FOB	Free on Board
GHG	Greenhouse gas
ICIO	Inter-Country Input-Output table
IO	Input-output
IDA	Index decomposition analysis
MLN	Million
MRIO	Multi Regional Input Output
NACE	Standard Industrial Classification
NSI	National Statistical Institute
N_2O	Nitrous oxide
ProdCom	Production Communautaire (statistics on production of manufactured goods)
SDA	Structural decomposition analysis
SIOT	Supply Input Output Table
SMEs	Small and medium-sized enterprises
SNA	System of National Accounts
VAT	Value Added Tax

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The results presented in this report should be considered preliminary.

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Introduction

Environmental Accounts present both economic and environmental data in an internationally accepted framework that is consistent both in terms of concepts and classifications. This makes the accounts especially suitable for input-output (IO) analyses. Input-output analyses reveal economic-environmental relationships that cannot be achieved from other statistics. Examples are greenhouse gas footprints and structural decomposition analyses (SDA). In the former, the amount of greenhouse gas emissions as a result of a country's consumption can be estimated. In the latter, driving forces behind the development of greenhouse gases can be estimated. In order to disseminate the usability of the Environmental Accounts it is important to explore the possibilities of input-output analyses further.

Currently there is much work being done at Statistics Netherlands with regard to input-output analyses with a multiregional input-output framework (MRIO). The big advantage of this framework is that IO data of different countries in the world are linked together. However there are also some disadvantages with MRIOs: 1) the country's IO data imputed in the MRIO deviates from the official country's data, 2) MRIOs are not up to date (timeliness of results), 3) they are complex to use and it is not certain to what extent they will be available in the future. This makes it difficult for National Statistical Institutes (NSIs) to incorporate footprints and SDAs based on MRIOs into their regular production program.

At the Environmental Accounts of Statistics Netherlands we have made a start with setting up IO footprint analyses in a more simple and transparent way. Our input consists mainly of Dutch IO tables and foreign emission coefficients (partly based on Eurostat and Exiobase data). Our approach is future proof and provides up to date results (t-1). Furthermore, decomposition analyses can be performed that provide useful insights in for instance the long-run developments or the drivers behind certain changes in emissions. In the Netherlands demand for up to date footprint data and its underlying drivers is high by policy makers regarding the transition towards a circular economy. CBS and partners are setting up a monitor for the circular economy in which IO-analyses of indirect resource use and greenhouse gas emissions play an important part.

This report describes work in progress with respect to environmental input-output analyses. Firstly, a stocktaking exercise was executed to investigate the quality of and issues with respect to Dutch IO-tables and –analyses. This was done as a first step to assess the validity of the performed IO-analyses. The main findings and points for improvement that originate from this stocktaking exercise are presented in chapter 1. Chapter 2 is divided into four parts, it includes data sources used and three types of analyses, namely production and consumption based (footprint) IO-analyses and decomposition analyses. For all analyses the methodology, data sources used and results will be presented. Chapter 3 focuses on Eurostat's consumption-based accounting tool which can be used to derive greenhouse gas footprints. The methodology used and results will be compared to the approach applied by Statistics Netherlands. The report finalizes with a brief discussion and recommendations.

1. Improving the quality of IO-tables and -analyses

Statistics Netherlands' IO-experts pointed out certain issues with regard to the quality of the current IO-tables and how these issues may affect the usability of the IO-tables for certain types of IO-analyses. It was decided that, as a starting point, these issues had to be investigated before continuing work on IO-analyses, because they may negatively affect the quality of the performed IO-analyses.
In order to assess the quality of IO-analyses, a stocktaking exercise was executed to investigate the issues with respect to IO-tables and –analyses. This was done by interviewing several IO-experts from the National Accounts department on the shortcomings of the current IO-tables, the effect of these shortcomings on IO-analyses and possible ways to overcome them.
Chapter 1.1 summarizes the issues that require special attention and describes how these issues might affect IO-analyses. Subsequently, chapter 1.2 presents possible action points aiming to, at least partly, overcome the issues and to improve the quality of IO-analyses. This section will also include the current status of these action points to show to what extent they have been implemented so far, or will be implemented in the future. Chapter 1.3 presents conclusions and recommendations that can be of benefit to users of IO tables.

1.1 Main issues of current IO-tables and -analyses

Most countries compile commodity by commodity IO-tables, the Netherlands however compiles industry by industry IO-tables. IO-tables are derived from supply and use tables, which present suppliers and users for all (type of) products[1] at an aggregate level. The added value of IO-tables, as compared to supply and use tables, is that they display the relationships between suppliers and users of products (i.e. who supplies to whom?). Unfortunately, the lack of information on these relationships, both domestically and with foreign countries, between suppliers and users is one of the main issues with respect to compiling IO-tables. In particular two types of relationships turn out to be troublesome, which are the relationships between domestic companies (i.e. intermediate consumption) and the relationships between SMEs (small and medium-sized enterprises) and foreign countries (i.e. imports and exports of SMEs).

1) Relationships between domestic companies (i.e. intermediate consumption)

2) Relationships between SMEs (small and medium-sized enterprises) *and foreign countries (i.e. imports and exports of SMEs*)

These relationships are important for performing IO-analyses, as will be explained by the following example. A carbon footprint for the Netherlands includes all carbon emissions that are emitted for the purpose of Dutch final consumption. Imagine, for instance, that more CO_2 is emitted by the production of Russian gas than by the production of gas in the Netherlands[2]. The Netherlands uses both domestic and imported Russian gas for heating homes and as energy input in the chemical industry. Carbon emissions caused by gas used for heating Dutch homes are part of the Dutch footprint. The largest part of chemical products produced in the Netherlands is exported, which means that emissions caused by the production of chemical products are, for a large part, not part of the Dutch footprint. Only carbon emissions caused by gas used for the production of chemical products destined for Dutch final consumption are included in the Dutch footprint. Thus, if Russian gas is used for heating homes it ends up in the Dutch footprint, on the other hand, if it is used as energy input in the chemical industry it will (for a large part) not. Therefore, the allocation of Dutch and Russian gas to the

[1] Goods and services; goods include resources, semi-finished products and end-products.
[2] Different production technologies used by both countries affect the amount of greenhouse gases emitted.

right users (e.g. to industries, households, the government or even to exports) affects the outcome of IO-analyses. So, accurate information on relationships between suppliers and users is important for IO-analyses. Due to the lack of information on the relationships between domestic companies and between SMEs and foreign countries, it is difficult to fill the inner work of the IO-table (which shows who supplies to whom). Data on total supply and use by industry is of high quality. However, the inner work (the intermediate part) of the IO-table is mainly based on assumptions and common sense about who supplies to whom. Due to lack of data this economic structure remains roughly the same over time, it is not structurally and continuously being improved. The economic structure is only updated in case of remarkable changes in the economy. Therefore, the economic structure of the Dutch economy as presented in the IO-table is not optimal, especially the development of this economic structure over time does not seem to be well captured in the IO-tables.

Another issue with regard to the compilation of IO-tables are trade and transport margins.

3) Trade and transport margins (and product-related taxes and subsidies)

The production of trade and transport margins belongs to the production at basic prices[3], as presented in the supply table. They are mainly produced by the wholesale, retail and transport sector, but are also produced as by-product in other industries. On the other hand, the use table is displayed in purchase prices (excl. VAT), which include trade and transport margins. Every industry will use trade and transport margins implicitly. However, when considering the use table in basis prices trade and transport margins (and product-related taxes and subsidies) would be excluded. IO-tables are displayed in basic prices, hence the use of margins (and product-related taxes and subsidies) as part of the primary costs is excluded from IO-tables. Displaying the IO-tables in basic prices is necessary to make the intermediate part of the IO-table square and invertible. Therefore, trade and transport margins (and product-related taxes and subsidies) are displayed outside the intermediate part of the IO-table. In order to be able to perform IO-analyses trade and transport margins should be displayed inside the intermediate part of the IO-table, because (carbon) emissions related to transport activities are significant and should be included in the analyses. Although this issue requires some additional work, a minor adjustment of displaying margins (and product-related taxes) inside the intermediate part of the IO-table could also be executed afterwards, once the IO-table has been finished.
Furthermore, trade and transport margins differ by product group. The customers of each group of products and the amount of these products that are being used, are determined in the IO-table. Consequently, trade and transport margins (and product-related taxes and subsidies) are divided proportionally over these consumers, which include industries and final users such as households and the government. This proportional division is applied due to a lack of data, but it is an estimate and affects the outcomes of IO-analyses.

The next issue related to international trade.

4) International transport (CIF and FOB)

If a Dutch company transports goods on Dutch territory it is included in the Dutch IO-table as a so called transport margin. However, when transport crosses the border it becomes the export of a service. When goods are exported from the Netherlands they are valued as FOB (Free on Board). It includes the incidental costs (freight and insurance) which relate to the journey within the territory of the country from which the goods are exported. If the goods are imported by another country, they will be valued as CIF (Cost, Insurance

[3] The basis price is the price that a producer actually receives. It is the selling price of a good or service excluding the trade and transport margins and excluding product-related taxes and subsidies.

and Freight). It includes the incidental costs which relate to the journey outside the territory of the country which imported the goods.
This seems to result in a mismatch when performing environmental IO-analyses such as a greenhouse gas footprint. If the Netherlands imports cars at CIF-prices, the value of the cars and the transport margins are summed together and considered as the total price for the cars. When determining the corresponding amount of greenhouse gases emitted for the production and transportation of the cars, the total value of the car is multiplied by the emission coefficient of the car industry (see paragraph 2.3 for a more detailed explanation about the method). There is no distinction between the car industry that manufactured the cars and the transport sector that exported the cars. There seems to be a mismatch here between what we would like to measure and what we actually measure. It is not exactly clear what the effect of this is on the outcomes of the performed analyses, but it seems to be limited.

The final issue to be discussed is processing abroad.

5) Processing abroad

Based on SNA 1993 (System of National Accounts) international trade in goods occurs when goods pass the border physically, known as the territorial principle. However, in SNA 2008 a different approach is adopted. According to SNA 2008, trade occurs when there is an economic transfer of ownership between a Dutch resident and a non-resident, known as the residence principle. So, in international trade a distinction can be made between financial and physical flows. The new SNA 2008 follows financial flows wherein transfer of ownership is leading to determine international trade.
This difference in definition between SNA 1993 and SNA 2008 is reflected in two different IO-tables, depending on the definition applied (Van Rossum et al. 2010, p.3). For instance, in case of performing a carbon footprint analysis it affects emission intensities and thereby also the outcomes of IO-analyses as is illustrated by van Rossum et al. (2010, p.7-8).
In some cases, 'Dutch' goods are sent abroad just for processing after which they return to the Netherlands, or the other way around, foreign goods are processed in the Netherlands after which they return to the owner abroad. These goods pass the border but there is no change in ownership, so according to SNA 2008 there is no international trade in goods involved. However, instead of trade in goods trade in services takes place. An example of such an international transaction is the processing of crude oil into petroleum products by a Dutch refinery commissioned by a non-resident. The contractor supplies the crude oil, but remains the owner of the crude oil and petroleum products during the production process. There is no change of ownership thus no international trade in goods. However, the Netherlands provides a service abroad. With regard to IO analysis the best results are obtained when a single industrial branch either produces goods or services.

1.2 Possible improvements

This chapter presents possible action points aiming to, at least partly, overcome the issues presented in chapter 1.1.

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1) *Relationships between domestic companies (i.e. intermediate consumption)*

In 2017 a project was initiated at the methodology department of Statistics Netherlands in which a network dataset will be developed at micro level for the Dutch economy. The aim of this project is to enable certain analyses, such as network analyses of the Dutch economy. This dataset will contain information on the relationships between domestic companies. Ideally, this information will be used to improve the Dutch IO-tables. The results of the project and its value added to the compilation of IO-tables are yet unknown, as the project is currently in progress. So far, the network dataset has primarily been built on rough assumptions

rather than on hard input data. The lack of available information and data to map the relationships between domestic companies remains problematic, also for this project. Therefore, it remains uncertain whether the outcomes of this project could eventually contribute to improve the quality of the Dutch IO-tables.
So, the main issue regarding the relationships between domestic companies is that it is unclear who supplies to whom. Besides, the network dataset project identified some other possibilities which may help to improve on this. The first possibility is to take a closer look at affiliated companies. For instance, if a company produces a semi-finished good to sell on the market and an affiliated company requires that same good as input for its production process, then it is most likely that this good will be sold to the affiliated company instead of a random company. This simple assumption may be useful to determine who supplies to whom. Data at Statistics Netherlands on the supply and use of products (e.g. production statistics of businesses and ProdCom data) can be used to identify these relationships between affiliated companies.
The second possibility is by looking at the relationships between industries with common sense. The first step here would be to select a set of product groups which significantly affect the outcomes of environmental IO-analyses. Criteria used for the selection of product groups could include:

- The degree of complexity (i.e. many relationships between industries);
- The degree of by-products (i.e. many producing industries);
- The level of total output (is the impact significant?);
- CO_2-intensity of the products (regarding environmental-economic analyses)[4].

Step two would then be to look at the identified relationships with common sense. For instance, it makes no sense if all imported gas is consumed in the Netherlands while all domestically extracted gas is exported. Such rarities could be identified by looking at these product groups with common sense, and possibly improvements could be made. These possible steps for improvement are not yet put into practise due to a lack of capacity.

2) *Relationships between small and medium-sized enterprises (SMEs) and foreign countries (i.e. imports and exports of SMEs*)

In 2016 a project has been executed at Statistics Netherlands which gave better insights into import and export flows of small and medium-sized enterprises. This was done by using the link between VAT-units (Value Added Tax) which are used by both the international trade in goods statistic and the Dutch Business Register units. This connection enabled the possibility to link international trade data to receiving (importing) and delivering (exporting) industries. Direct import and export, which is import and export that takes place without intermediary, such as a wholesaler, could be determined because traded goods can now be linked to a specific industry. On the other hand imports and exports that took place by means of an intermediary could not be linked directly to a specific industry. This part of the estimation is based on the shares of direct import and export. This seemed to be the best assumption to allocate trade that took place by means of an intermediary to the right industries. The results of this project also have a positive impact of other parts of the IO-table, such as the use of trade and transport margins.
The results obtained in this project cover the year 2012, but the insights gained have been used to improve the underlying structure of the IO-tables for the complete time series. The results of this project have been implemented during the revision that took place in 2017.

3) *Trade and transport margins (and product-related taxes and subsidies)*

No possibilities have been identified yet to improve the allocation of the trade and transport margins (and product-related taxes and subsidies) to the actual consumers, which is currently done by a proportional

[4] This last criteria could be adjusted depending on the type of analysis performed.

division based on the type of production and the level of consumption. To improve on this would require further investigation by the National Accounts department, the makers of the IO-table.
Eurostat presents trade and transport margins inside the intermediate part of the IO-table, as a service. Statistics Netherlands considers this option as a possibility for implementation during the 2017 revision. However, this does not solve the way in which transport and trade margins are allocated to the industries.

4) *International transport (CIF and FOB)*

The issue regarding international trade seem to have a negative but very limited impact on IO-analyses, because it only concerns a small fraction of international trade (the difference between CIF and FOB value). No possibilities were identified to improve on this. However, it is still good to be aware of limitations of current IO-analyses that are based on national IO-tables. A future solution could be the use of Multi Regional Input Output (MRIO) tables, in which these international trade issues might be a lesser problem.

5) *Processing abroad*

Environmental-economic IO-analyses require IO-tables based on the territorial principle, in which physical flows of goods are leading instead of financial flows. Physical flows are more closely related to the environmental impacts caused by production processes, than financial flows. Therefore, IO-tables based on SNA 2008 (residence principle) are converted into IO-tables based on SNA 1993 (territorial principle) by the Dutch Environmental Accounts department. Figures from National Accounts about processing abroad are used to make the required corrections. Another solution would be to split single industrial branches into one that produces services (processing aboard) and one that produces goods. For each different emission coefficients would apply. Due to limited data and high capacity demand this option is not pursued.

1.3 Conclusions and recommendations

Some of the outcomes of possible improvements mentioned above were implemented in order to improve the quality of IO-tables. First, a conversion of IO-tables based on SNA 2008 guidelines into IO-tables based on SNA 1993 guidelines was executed by the Environmental Accounts department. Second, improvements on relationships between domestic companies with each other and improvements on relationships between foreign countries and SMEs are executed by the National Accounts department. However, the latter improvement will not be done annually. IO-experts suggested to revise the IO-tables thoroughly once every five years during the revision (starting with the revision in 2017), for which additional capacity is required. In between revisions the IO-tables will be updated but with limited resources. Both improvements could significantly improve the IO-tables and (environmental-) economic analyses performed with them. The remainder of the potential improvements mentioned are not put into practise. Their impact on IO-analyses remains unclear.
Although this specific IO-table quality assessment might not be directly useful to other EU-countries as they might face different issues regarding the quality of their IO-tables, it does show that quality assessment of IO-tables should be the first step considered when performing IO-analyses. It provides insight into the strengths and weaknesses of the IO-tables, which will eventually also affect the outcomes of the IO-analyses. For instance, in case of the Netherlands the change in economic structure (who supplies to whom) over time was not well captured in the IO-tables, therefore it was decided not to include this economic structure effect in the decomposition analyses (see chapter 2.4). Instead of a structural decomposition analyses an index decomposition analyses was performed, which does not take into account the economic structure as presented in the IO-table. However, due to this decision the decomposition analysis loses some useful information.

2. Environmental Input-Output Analyses

This chapter presents a theoretical rational for input-output analyses that results in production and consumption based footprints. These footprints can be compared to direct emissions by both producers and consumers (table 2.0.1 gives an overview).

Table 2.0.1 Overview of production and consumption based footprints

	Direct emissions	Indirect emissions
Production	Producers	Footprint producers
Consumption	Consumers (final demand)	Footprint consumption country

Due to time constrains or practical reasons only some of the footprints will be estimated. For these estimates the required data sources and the used methodology will be discussed. Furthermore, drivers behind the development of greenhouse gas emissions over time will be investigated.

2.1 Data sources

The environmental analyses in this chapter require roughly the same input data. Most of the data is directly obtained from Statistics Netherlands. However, most data could also have been obtained directly from Eurostat's database, which could be useful for other countries willing to perform similar analyses. For instance, data from the National Accounts (e.g. IO-tables including economic output by industry), Environmental Accounts (e.g. greenhouse gas emissions by industry) and Energy Accounts (e.g. energy use by industry) could be used . Only data on greenhouse gas emissions and economic output of foreign countries was obtained from international data sources: Eurostat and Exiobase.

Data for the production based IO-analyses (paragraph 2.2) and the consumption based IO-analyses (paragraph 2.3) is required biannually from 2008 up to 2016. Further, the industrial level (43 x 43) used to perform these IO-analyses is presented in Annex A. The data obtained from Statistics Netherlands include:

- Economic output by industry;
- Greenhouse gas emissions (CO_2, CH_4 and N_2O, excluding F-gases[5]), both by industry and for the economy as a whole;
- International trade data, import to and export from the Netherlands at CN 8-digit level;
- IO tables, converted according to the SNA93, thus following the physical flows;
- Dutch supply and use tables.

Next to Dutch data, foreign emission coefficients (greenhouse gas emissions per unit output) are required to determine emissions related to imports. Emission coefficients are needed for foreign countries or regions by industrial branch. For European countries this data was obtained from Eurostat's database. For the rest of the world, data was obtained from the MRIO database Exiobase[6] (Wood et al. 2015 & Tukker et al. 2013). Annex B provides an overview of which data source is used for each country and/or region. The data obtained from Eurostat's database and Exiobase include:

- Economic output by industry;
- Greenhouse gas emissions (CO_2, CH_4 and N_2O) by industry.

[5] The data on greenhouse gas emissions used in the IO-analyses are excluding F-gases, due to a lack of data availability at the international level. The data on greenhouse gas emissions used in the index decomposition analyses includes F-gases, because these analyses only require national data.

[6] The choice for the MRIO Exiobase was made because it includes both economic and environmental (greenhouse gas emissions) data, and it comprises the most recent time series up to 2014.

Finally, the index decomposition analyses (paragraph 2.4) only require data for the Netherlands. However, this type of analysis requires a longer time series, in this case ranging from 1995 to 2016. Data required for the index decomposition analyses includes:

- Economic output, total and by industry (1995-2016);
- Energy use by industry (1995-2016);
- Greenhouse gas emissions by industry (1995-2016).

2.2 Production footprint based IO-analyses

2.2.1 Introduction

Air Emission Accounts show figures on net emissions by Dutch residents such as emissions by Dutch industries, households and government. In the production approach the producing sectors in the economy (industries) are considered. The amount of direct emissions by industry is straightforward. With regard to indirect emission (emissions that occurred in the production chain) different approaches can be adopted:.

1) emissions are allocated to the production of products for final demand by industry (final demand includes products destined for export),

2) emissions are allocated to the production of products for global final demand by industry (export is not an issue here)

3) emissions are allocated to a sector's total output (this includes output for intermediate consumption).

All options provide a different perspective of who could be held responsible for the emissions. In option 1, emission have allocated to industries that produce for final demand (including export). This means that even if exported products are used for foreign intermediate consumption, the corresponding emissions are still allocated to the domestic producer. An advantage of this method is that the amount of direct emissions of a country equals the amount of emissions allocated to the production of final products. Another advantage is that this analyses can be done using a relative "simple" IO-analyses. A disadvantage is that in a small country, like the Netherlands, with a lot of export, relative much of the produced products will be allocated to final products even when they are used for intermediate consumption abroad.

In option 2, emissions have been allocated to industries that produce for final consumption both domestic or in foreign countries (export is not applicable). This approach gives a more accurate allocation of emissions to producers of final products. A disadvantage is that this analyses can not be done easily when using the CBS approach. For this option is would be easier to use a MRIO database.

Emissions allocated to a sector's total output, as put forward in option 3, gives a lot of double counting because production chains of different sectors overlap. However, industries themselves favour this kind of approach (it is similar to an Life Cycle Assesment (LCA) approach) because they are interested in amount of emissions that have occurred in their production chain.

Only option 1 has been worked out below. Due to time constrains it was not possible to work out option 2 and 3 at this time.

2.2.2 Domestic emission allocated to final demand (option 1)

In this paragraph option 1 is being worked for domestic emissions in the Netherlands. Direct CO_2 emissions of economic sectors are allocated to final demand categories (export, household and government consumption, stocks and investment). This analysis shows the purpose for which emissions have taken place for different economic activities. It shifts the responsibility of domestic direct emissions to producers of final products.

In order to allocate domestic emissions to final demand category for each industrial sector v_{nl}^{FD} the following formula is used.

$$v_{nl}^{FD} = E_1'(I - AD_1)^{-1}Y_{nl}$$

Where AD_1 represent a matrix with technical coefficients of domestic intermediate use. I is the identity matrix. Y_{nl} is a matrix of Dutch final demand categories.

Figure 2.2.1 shows direct CO_2 emission by industrial sector and CO_2 emissions allocated to the producers of products destined for final demand. The highest direct emissions are produced by electricity producers followed by respectively industry and transport. Emissions allocated to final demand are largest for industry. This is because industry produces many final products and uses, among others, electricity and transport services as intermediate input. A similar development can be seen for the service sector.

Figure 2.2.1: CO_2 emissions direct and allocated to producers of final products.

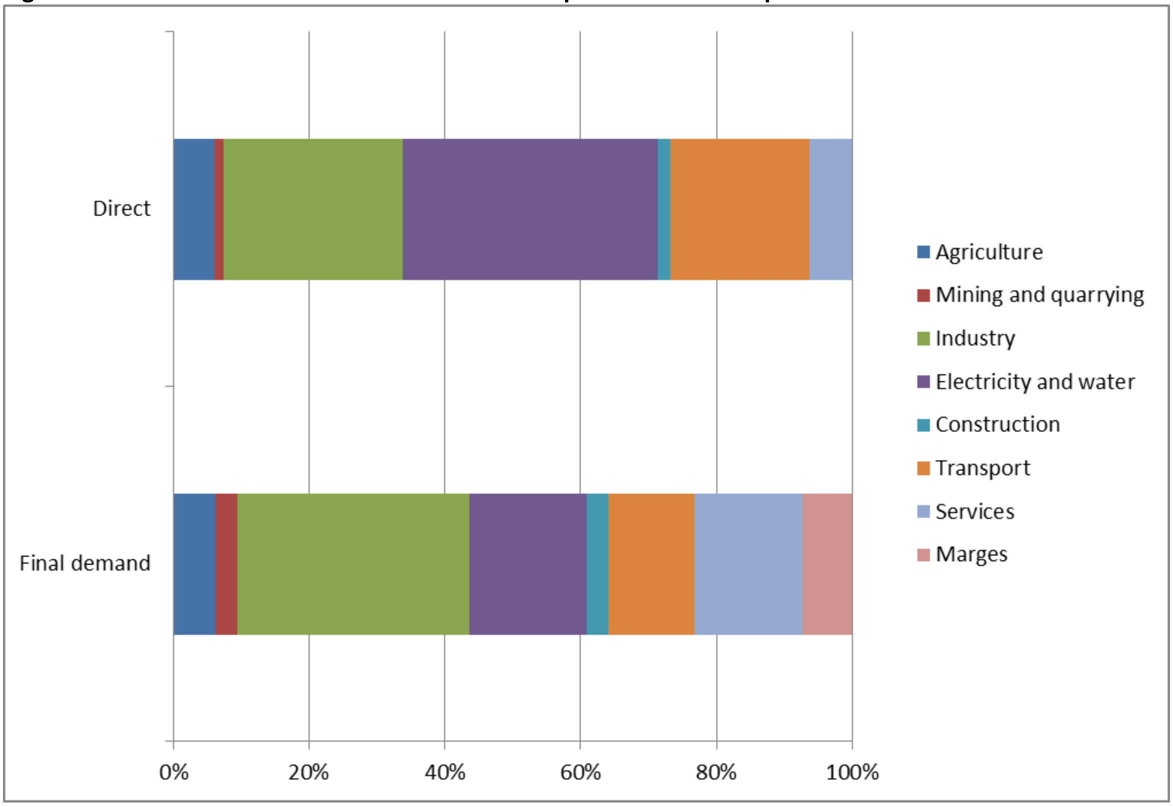
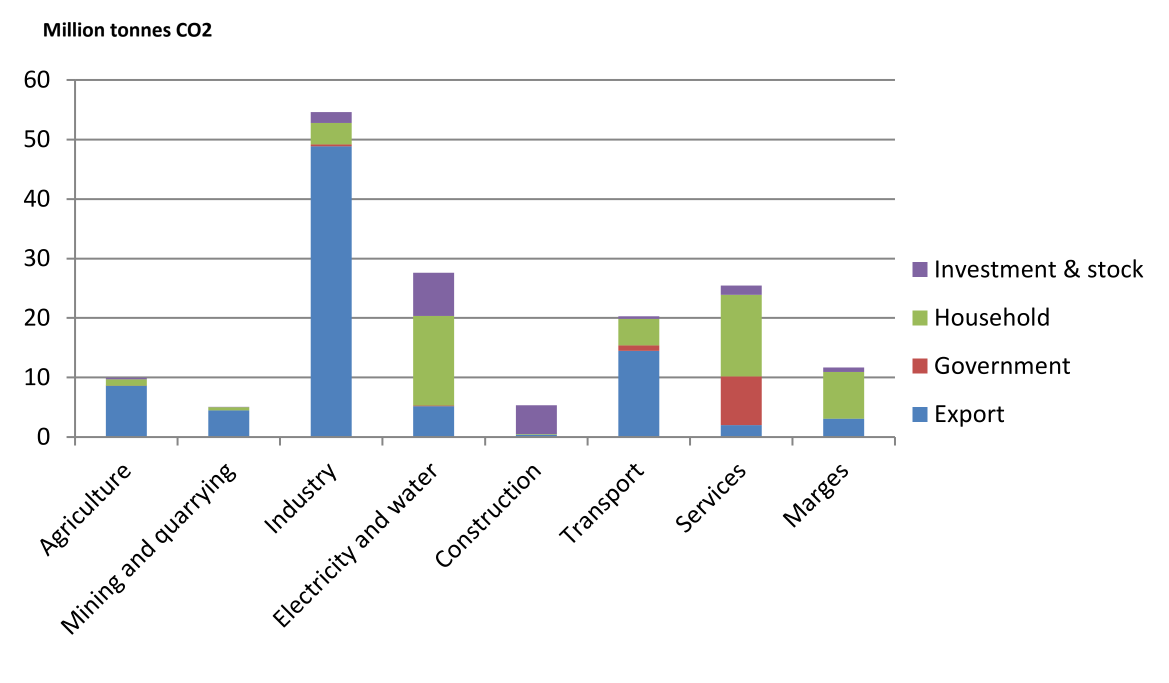


Figure 2.2.2 shows different final demand categories for which production took place. Final products produced by agriculture, mining and industry are mostly destined for export. Electricity and services are mostly produced for domestic consumption by household and government. Final products produced by the construction sector end up in stocks and investments.

Figure 2.2.2: CO_2 emissions allocated to final demand categories by sector.



2.2.3 All emission allocated to final consumption globally (option 2)

In the previous approach "exports" are one of the final demand categories. However, if a product is exported it can be used abroad for either intermediate or final use. It would be interesting to see to what extent an economic sector produces products that are used abroad for intermediate consumption or final demand. The Netherlands are a small country with a large of amount of exports. Therefore, a large amount of our domestic emissions are allocated to export (in a large country with a large domestic market this might be less). However, it would be interesting to see how emissions would be allocated if there were no borders. Due to time constraints this option was not worked out. Using our IO methodology it could be worked out by making a distinction in exports for intermediate or final consumption. In a MRIO model it would be easier to estimate these figures.

2.2.4 All emission allocated to total output (option 3)

The advantage of the approaches above (allocating emissions to final demand) is that figures of all economic activities add up to total emissions without any double counting. However, it turns out that industrial branches are especially interested in the total amount (direct and indirect) of emissions that occur as a result of their output. Thus, regardless if their output is determined for intermediate of final consumption. This is another way of looking at the responsibility of the environmental impact as a result of the production process. The big disadvantage of this approach is that double counting will occur. The CO_2 emissions allocated to the output of the agricultural sector will for a large part also be allocated to the emissions allocated to the output of the food industry.

2.3 Consumption based IO-analyses: Greenhouse gas and carbon footprint

2.3.1 Introduction

Chapter 2.3 will focus on a consumption based IO-analysis, namely a greenhouse gas and carbon footprint. The greenhouse gas and carbon footprint present emissions of greenhouse gases and carbon dioxide that are emitted in order to meet Dutch consumption needs, also known as the consumption perspective. This means that the footprint includes emissions that are caused by production of goods abroad that are finally consumed in the Netherlands. The other way around, emissions caused by goods produced domestically, that are consumed abroad, are excluded from the footprint.

2.3.2 Methodology

Greenhouse gas and carbon footprints are calculated by subtracting the environmental balance of trade from net emissions by residents. The environmental balance of trade equals emissions attributed to export minus emissions attributed to import. Data on direct emissions by residents are available the emission accounts. The environmental balance of trade has to be estimated. This is done by attributing emissions to import and to export flows by means of IO-analysis.

The first step is to determine emission intensities for different countries and regions that the Netherland import from. Emission intensities are defined as the amount of emissions divided by gross output in basic prices (kg greenhouse gases per euro output). Emission intensities largely depend on the type of economic activity and on the type of technology used, this causes emission intensities to differ greatly among countries and among industries. To take these differences into account, a subdivision was made of 43 industries (different economic activities) and 20 countries or regions. The subdivision of industries can be found in Annex A, and the subdivision of countries or regions can be found in Annex B. The more extensive the subdivision of countries and industries the more accurate the footprint can be calculated. The main constrained however is data availability, as data must be comparable among all countries included.

In the second step, all imported products are allocated to a specific industry within a specific country or region in which they have been produced. The industry to which each product is allocated depends on the type of product, each product is allocated to a specific industry depending on its principal producer. The principal producer is determined by means of Dutch supply and use tables, which contain information on which type of product is produced by each industry.

Third, emissions are attributed by multiplying the value of Dutch imports with corresponding emission intensities, i.e. the emission intensity of the country and industry that produced the specific product. Indirect emissions, emissions that are emitted during earlier stages in the supply chain, are then attributed by means of the Dutch input-output structure (i.e. Dutch input-output table). This input-output structure provides information on inputs used (and output produced) by each industry and by whom these inputs were produced (and by whom their output is used). This structure can be applied to calculate all indirect emissions of imported and exported products. The Dutch input-output structure is used for all countries in order to keep the model relatively simple.

The following formula is used to calculate emissions caused by production of exported goods and services produced in the Netherlands (v_{nl}^{exp}) and emissions caused by the production abroad of imported goods and services (v_{nl}^{imp}). Abroad is divided in nineteen areas (see Annex B). For each region (j, in which region 1 represents the Netherlands), the respective emissions coefficients are applied (E_j'). See also de Haan (2004) for a more generalised form of the analysis.

$$v_{nl}^{exp} = E_1'(I - AD_1 - AI_1)^{-1}s_1$$
$$v_{nl}^{imp} = E_j'(I - AD_1 - AI_1)^{-1}t_1$$

Where AD_1, AI_1 represent matrices with respectively technical coefficients of domestic intermediate use and imported intermediate use of the Netherlands (i.e. the input-output structure of the Netherlands). I is the identity matrix. Export and import vectors are denoted by s and t respectively.

The carbon footprint only includes carbon dioxide (CO_2) emissions, whereas the greenhouse gas footprint also includes nitrous oxide (N_2O) and methane (CH_4). F-gases are excluded from the greenhouse gas footprint due to limited data availability internationally. For both the greenhouse gas and carbon footprint a biannual time series is developed for the period 2008-2016. Figures for 2016 are preliminary, because both Exiobase and Eurostat's data is only available until 2014. So, emission intensities of 2016 for foreign regions and countries are equal to those of 2014.

The methodology applied is somewhat between a full MRIO model and a model based on the Domestic Technology Assumption (DTA). The big advantage over the DTA-model is that foreign emission coefficients are taken into account for imported products. The big advantage over a full MRIO analyses is the independence on an update of the MRIO database[7]. This makes our approach relatively easy to execute with up to date figures.

2.3.3 Results[8]

Table 2.3.1 and table 2.3.2 present respectively the carbon and greenhouse gas footprint, both total and per capita, and show how footprints are calculated. The difference between emissions attributed to imports and emissions attributed to exports is the environmental balance of trade. Subtracting this environmental balance of trade from net emissions by residents gives the total footprint.

Table 2.3.1. Carbon (CO_2) footprint, biannual 2008-2016

	Unit	2008	2010	2012	2014	2016
Emissions attributed to import (-)	Million tonnes	161	139	140	135	135
Emissions attributed to export	Million tonnes	145	131	134	138	147
The environmental balance of trade	Million tonnes	-17	-9	-6	2	11
Net emissions by residents	Million tonnes	210	217	202	196	205
Footprint	Million tonnes	227	226	208	193	194
Footprint per capita	Thousand kg	13,8	13,6	12,4	11,5	11,4

Table 2.3.2. Greenhouse gas footprint (excluding F-gases) in CO_2-equivalents, biannual 2008-2016

	Unit	2008	2010	2012	2014	2016
Emissions attributed to import (-)	Million tonnes	238	202	200	186	182
Emissions attributed to export	Million tonnes	173	157	161	165	176
The environmental balance of trade	Million tonnes	-65	-45	-39	-21	-7
Net emissions by residents	Million tonnes	240	245	229	223	232
Footprint	Million tonnes	305	290	268	244	239
Footprint per capita	Thousand kg	18,6	17,5	16,0	14,5	14,1

In general, the value of Dutch exports is higher than the value of imports (>10% taken into account all years). However, for many years emissions attributed to imports exceeded those attributed to exports (this counts

[7] Although we do not need the whole MRIO database, we do need estimations for emission-intensities. However, emission intensities are not very volatile in general, so for provisional figures emission intensities from previous years can be used.

[8] The results differ significantly from an earlier publication by Statistics Netherlands (CBS, 2016). The method used is the same, however the input data has been updated. The difference in both results is caused by changes in data on greenhouse gas emissions, to a large extent due to an update of Exiobase data (Tukker et al., 2013), but also due to data updates of some EU-countries (mainly Germany and Sweden) in Eurostat's database and to a smaller extent due to a revision on Dutch air emissions.

for greenhouse gases for all years and for carbon dioxide for the years 2008, 2010 and 2012). This is because emission intensities (kg emissions per euro traded value) of imported products are higher than of exported products, which means that imported products are in general more emission-intensive[9].

Both footprints have declined significantly between 2008 and 2016, the carbon footprint decreased by almost 15 percent and the greenhouse gas footprint decreased by almost 22 percent during this period. In per capita terms this decrease has even been greater as a result of population growth (3,5 percent) during the same period. Two underlying factors can be identified to explain the decrease in footprints. First, net emissions by residents have fallen slightly. Carbon emissions fell from 210 to 205 million tonnes of CO_2 and greenhouse gas emissions fell from 240 to 232 million tonnes of CO_2-equivalents. Second, the decrease in emissions by residents is strengthened by an increasing environmental balance of trade. A positive environmental balance of trade means that more emissions are attributed to export than to import. So, an increasing environmental balance of trade has a decreasing effect on the footprint. Despite a relative large increase, the environmental balance of trade of greenhouse gases is still negative in 2016, while for carbon emissions the balance of trade has flipped over from negative to positive for 2014 and 2016. Emissions of methane and nitrous oxide resulting from Dutch consumption purposes have fallen more rapidly than carbon dioxide emissions.

The environmental balance of trade changes in time due to several reasons. Emissions attributed to import fell significantly despite an increase in import in monetary terms (see Annex D for monetary figures on import and export). This means that the decrease in emissions attributed to import is caused by a decrease in foreign emission intensities or by a change in composition of imported products (i.e. a shift towards less emission-intensive goods). The monetary value of exports increased more than the value of imports but emission intensities fell less. This is why emissions attributed to exports have been relatively stable between 2010 and 2016. The different developments in attributed import and export emissions causes the change in the environmental balance of trade.

2.4 Index decomposition analyses

2.4.1 Introduction

Decomposition analysis is a tool that can be useful to gain insight in underlying drivers of change in the amount of greenhouse gases emitted by the Dutch economy. The amount of greenhouse gases emitted by the Dutch economy fluctuates and develops over time. These changes over time in the level of greenhouse gas emissions may have multiple causes, such as economic growth, changes in composition of the economy, more energy-efficient production processes or a change in energy mix. Decomposition analyses can be used to quantify these effects separately. Depending on the type of effects that are considered different decomposition analyses can be performed. The main idea behind the decomposition analysis is that for each separate effect considered it is calculated what would have happened to total emissions if only this particular effect is taken into account, so the other effects are excluded from the analysis (ceteris paribus).

This report presents index decomposition analyses (IDA) rather than structural decomposition analyses (SDA). SDAs uses information from input-output tables while IDAs uses aggregate data at the sector-level. The reason not to use an SDA is that current IO-tables do not represent changes in the economic structure over time well. This issue is addressed in chapter 2. Therefore an IDA was preferred over and SDA.

2.4.2 Methodology

[9] This applies in general, based on the Dutch trading package and trading partners. But emission intensities may differ between industries and countries.

Index decomposition analysis of carbon dioxide emissions:

When taking a look at carbon dioxide emissions there are multiple effects that would be interesting to analyse. In this analysis a closer look is taken at the effect of changes in economic activity, changes in energy-intensity (energy use by unit of economic output), and changes in energy mix (CO_2-emissions by unit energy use[10]). The following formula can be used to decompose the amount of carbon dioxide emissions into the separate effects considered above.

$$\Delta C = \sum(\Delta \frac{Ci}{Ei} * \Delta \frac{Ei}{Pi} * \Delta P_i)$$

In which C presents the carbon dioxide emissions, E the energy use and P the level of economic output. All data on emissions, energy use, economic output is available at the industry (i) level as presented in Annex C. The sum of all effects by all industry equals the total change in emissions. These effects are calculated for all years (1995-2016) with respect to base year 1995.

The amount of CO_2-emissions in the economy is now decomposed into three separate effects, which together add up to the total amount of CO_2 emitted by Dutch residents. The first effect, ΔC/E, presents the change in amount of CO_2 emitted per unit of energy used. It is called the energy mix because it largely depends on the type of energy used, e.g. coal versus renewable energy. However, it may also include efficiency gains in energy production (lower conversion losses) or carbon capture and storage (CCS). The second effect, ΔE/P, presents the change in CO_2-emissions as a result of changes in energy-intensity of industries, i.e. the amount of energy required to produce one unit (euro) of output. This could for instance be achieved by more energy efficient production processes as a result of energy saving measures. The final effect, ΔP, presents the change in CO_2-emissions as a result of changes in economic activity, i.e. both volume (economic growth) and structural changes. For instance, although economic growth in general could have been positive it is possible that economic activity in certain industries (e.g. construction) dropped while economic activity in other industries (chemical industry) increased.

Index decomposition analysis of greenhouse gases, effect of servicisation:

Another possibility is to take a closer look at the effect of structural changes of the economy on air emissions, for instance by looking at the effect of shifting towards a more service-based economy, called servicisation[11]. In this case all greenhouse gas emissions are considered. When servicisation takes place the share of the service sector in the economy would increase at the expense of other sectors. The following formula can be used to decompose the total amount of greenhouse gases into separate effects, including the effect of servicisation.

$$\Delta GHG = (\Delta \frac{GHGg}{Pg} / \Delta \frac{Pg}{P} * \Delta P) + (\Delta \frac{GHGs}{Ps} / \Delta \frac{Ps}{P} * \Delta P)$$

In which GHG presents greenhouse gases, and the small g and s stand for goods and services respectively. The total change in greenhouse gas emissions is the sum of the change in greenhouse gases emitted by the production of services and of goods. The production of goods and services is distinguished at industry level, see Annex C. The first effects, ΔGHGg/Pg and ΔGHGs/Ps, present the change in greenhouse gas emissions as a result of the change in emission intensity of goods and services respectively (i.e. greenhouse gases emitted per unit of output (euro) produced). Emission intensity can for instance be improved by energy saving measures or by using renewable energy instead of fossil fuels. The second effects, ΔPg/P and ΔPs/P, represent

[10] In this case the focus is on CO_2 instead of greenhouse gases, because energy use is stronger related to CO_2-emissions than for instance to methane (CH_4).

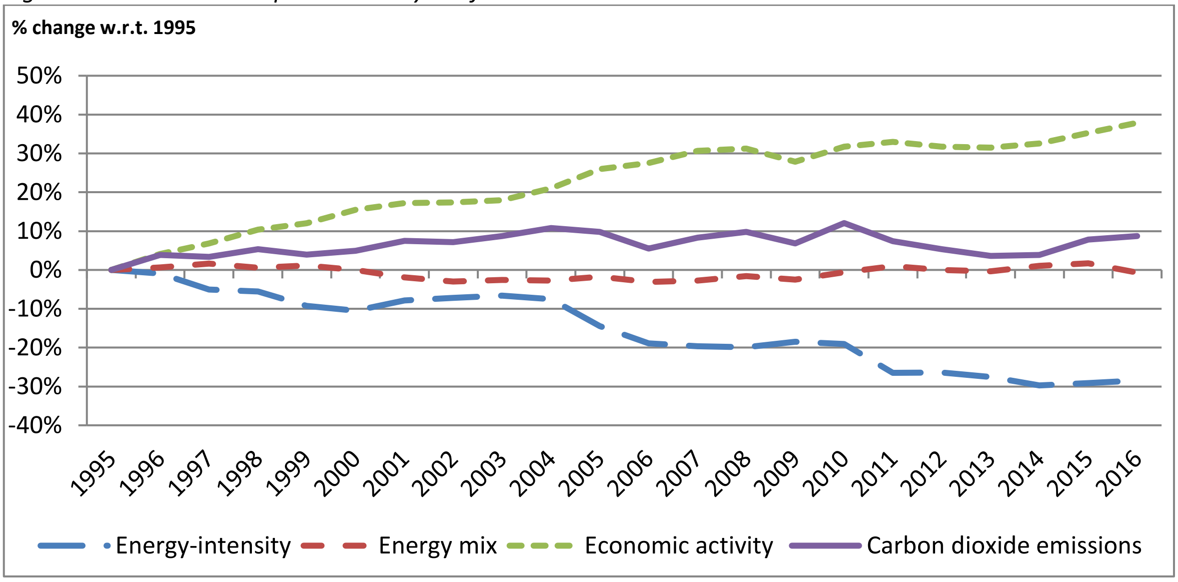
[11] The shift from an industry-based economy to a service-based economy.

the change in greenhouse gas emissions as a result of changes in the share of respectively goods and services in the economy. The final effect, ΔP, presents the change in greenhouse gas emissions as a result of a change in economic activity, i.e. both volume and structural changes but excluding the effect of a shift between the production of goods and services.

2.4.3 Results

Carbon dioxide emissions have increased by almost 9 percent between 1995 and 2016[12], as presented in figure 2.4.1 Change in economic activity, predominantly economic growth, has been the main driver behind this increase in emissions. Without changes in the energy mix and energy-intensity, emissions of carbon dioxide would have increased by 38 percent as a result of changes in economic activity. However, if solely economic growth was considered emissions would have increased even more, by 56 percent[13]. So apparently there has been a shift of economic activities from more polluting to less polluting industries, which had an inhibitory effect on carbon dioxide emissions.
In particular improvements in energy-intensity had a reducing effect on carbon dioxide emissions. Without improvements in energy-intensity emissions would have increased by another 29 percent with respect to 1995 (ceteris paribus). The energy mix has been relatively stable between 1995 and 2016. During this period renewable energy production has increased steadily. However, the amount of coal used to produce electricity has increased significantly since 2011 at the expense of the use of natural gas. Altogether, the net effect of the change in energy mix since 1995 is limited.

Figure 2.4.1 Index decomposition analysis of carbon dioxide emissions



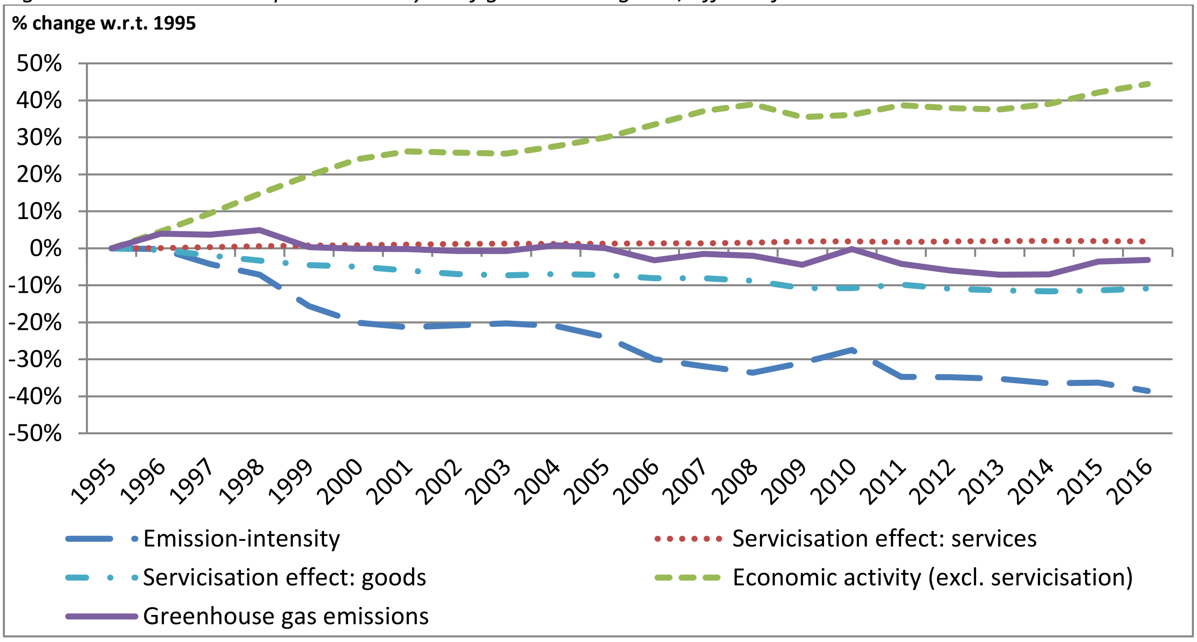
Greenhouse gas emissions have decreased by 3 percent between 1995 and 2016, as presented in figure 2.4.2. Similar as to carbon dioxide emissions, changes in economic activity have been the main driver of increasing greenhouse gas emissions. Improvements in emission-intensity (emissions per unit of output) have had a reducing effect on greenhouse gas emissions, without these improvements (e.g. energy saving measures, CCS, more efficient production technologies, etcetera) greenhouse gas emissions would have increased by an additional 39 percent with respect to 1995.However, in this figure economic activity does not include the

[12] Only emissions by industries as presented in Annex C have been included in this analysis, it for instance excludes emissions by households.
[13] Total economic output (2010 price level) has increased by 56 percent between 1995 and 2016.

effect of servicisation, which is now separated for analytical purposes. Servicisation is the shift from an industrial economy towards a more service-based economy.

For many developed economies servicisation has been one of the most important structural changes in the last decades. This also applies to the Netherlands, in which the share of the services sector in total output increased from 59 percent in 1995 to 65 percent in 2016 at the expense of producers of goods. This shift towards a more service-based economy affects direct emissions of greenhouse gases. Because production of services is less emission-intensive than production of goods, the economy as a whole becomes less emission-intensive. On one hand, the shift from goods to services causes emissions of the services sector to increase. As a result of this, total greenhouse gas emissions of the Dutch economy increased by 1,9 percent since 1995. On the other hand, this same shift caused emissions of the goods sector to decrease more strongly, because production of goods is more emission-intensive than production of services. As a result of this shift away from the production of goods, total greenhouse gas emissions of the Dutch economy decreased by 11 percent since 1995. Altogether, servicisation had a net decreasing effect on total Dutch greenhouse gas emissions of 9 percent between 1995 and 2016. So, without this effect of servicisation greenhouse gases would have increased by almost 6 percent instead of fallen by 3 percent.

Figure 2.4.2 Index decomposition analysis of greenhouse gases, effect of servicisation



3. Eurostat's Consumption-based accounting tool

3.1.1 Introduction

The methodology currently used by Statistics Netherlands to compile the carbon and greenhouse gas footprint for the Netherlands (paragraph 2.3) has been developed by *de Haan (2004)*, and has later on been extended and improved. Although the compilation method is relatively simple, gathering all required input data is still time consuming. In the past, Eurostat has developed a more general method (*Eurostat, 2011)* that can be applied by all EU-member states. In June 2017[14] they published the so called 'Consumption-based accounting tool' which allows users to estimate air emission footprints, or other type of footprints for which the required data is available. It is a relatively simple and convenient method to apply. However, the method differs from the Dutch approach and so do the results. In this chapter the methodology used for 'Eurostat's Consumption-based accounting tool' will be discussed briefly focusing on the main differences with respect to the Dutch approach. Furthermore the results of both methods will be compared and differences will be discussed.

3.1.2 Methodology

The required inputs of the Eurostat model are a supply table, a domestic use table, an import use table and a table of environmental extensions, in this case carbon and greenhouse gas emissions. This data can be obtained directly from Eurostat's online database[15], and can easily be converted into the format used by the tool. The supply and use tables are transformed into a symmetric product-by-product input-output table (SIOT), by using the 'industry technology assumption' (Eurostat 2008, p.349). A detailed description of Eurostat's consumption-based accounting tool can be found on Eurostat's methodology webpage[16].
Basically, both Eurostat and Dutch compilation methods are quite similar. Both approaches use Leontief input-output modelling to determine the carbon and greenhouse gas footprints. The main difference between both methods lies in the assumption on how emissions are attributed to import. Eurostat's Consumption-based Accounting tool applies the so called 'domestic technology assumption'. This assumption implies that international trading partners use the same production technology as is used domestically. This assumption greatly reduces the amount of input data required, only domestic data is required, and simplifies the model. However, assuming equal production technologies may significantly bias the results, especially in open economies like the Netherlands (Pinero et al., 2015).
On the other hand, the Dutch approach aims to take into account these inter-country differences in production technologies, by calculating emission intensities for 19 different countries or regions (see Annex B). Ideally, emission intensities would be determined for all trading partners separately, however due to data availability, the number of regions distinguished was limited. However, the most important trading partners of the Netherlands, e.g. Germany, Belgium, United Kingdom are all included separately, and less important countries are included by region.

3.1.3 Comparison of the results

In paragraph 2.3 carbon and greenhouse gas footprints based on the Dutch approach were presented. In this paragraph a comparison is made between the results of the Dutch approach and Eurostat's Consumption-based accounting tool.
In the Dutch approach re-exports are excluded because they distort the outcome of the IO analysis. When using Eurostat's tool re-exportation should not significantly affect the results of the carbon footprint because

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[14] This tool can be found on the methodology page on the Eurostat website, under the sub-heading 'air emissions accounts'. http://ec.europa.eu/eurostat/web/environment/methodology
[15] This data is provided by EU-member states in a fixed format.
[16] http://ec.europa.eu/eurostat/web/environment/methodology
Input-output modelling tools; Air Emissions; Consumption-based accounting tool – June 2017. Methodology tab.

it applies the 'domestic technology assumption', i.e. both imports and exports (thus including re-exports) are calculated based on the same Dutch production technology. Nevertheless, in order to compare emissions attributed to imports and exports, re-exports were also excluded from the Eurostat's Consumption based accounting tool for the year 2014. The carbon footprint, both including and excluding re-exports for 2014, are presented in table 3.1.1. Annex E presents the same table with respect to the greenhouse gas footprint.

Table 3.1.1. Carbon footprint, comparing CBS and Eurostat's methods excluding re-exportation, 2014

		Eurostat		CBS
	Unit	Incl. re-exports	Excl. re-exports	Excl. re-exports
Emissions by residents	Mln kg CO2	195659	195659	195827
Emissions attributed to imports	Mln kg CO2	195627	101778	135442
Emissions attributed to exports	Mln kg CO2	239451	144871	137919
Footprint	**Mln kg CO2**	**151835**	**152565**	**193349**

A small difference can be observed in emissions by residents between Eurostat's and CBS' method. The emissions by residents are directly obtained from the input data, so there should not be a difference at all. However, recently Dutch emission figures have been revised. The Dutch approach takes into account the revised data while Eurostat's tool is based on pre-revision data, which causes a slight difference (<0.4%) between both methods.

As expected, after excluding re-exportation from international trade, emissions attributed to import and export decrease significantly by around 94.000 mln kg CO_2. With regard to the Eurostat tool it is unclear why there is a difference in emissions attributed to re-exportation of imports and exports, however the difference is very small. Due to this difference, also the carbon footprint estimated by the Eurostat tool differs slightly (<0.5%).

Emissions attributed to imports and exports of both methods can only be compared in case re-exportation is excluded[17]. When re-exportation is excluded there is only a small difference (<5%) between emissions attributed to export in both approaches. Despite a small difference, export figures of both methods correspond roughly[18]. However, emissions attributed to import are underestimated by more than 30 percent as compared to the Dutch approach. Emissions attributed to exports and to imports in the Dutch approach are almost equal. As a result, the carbon footprint based on Eurostat's method is significantly lower than the carbon footprint based on the Dutch approach This difference can be explained by the methodological differences of both methods.

Apparently, for the Netherlands, emissions attributed to import are higher when additional information about the production technology of foreign economies is included in the analyses. In general, foreign emission coefficients are higher than Dutch emission coefficients[19]. This implies that, in general, Dutch production technologies are relatively clean: emissions attributed to imports are relatively (per euro) more polluting than emissions attributed to exports. So, the domestic production technology assumption made by Eurostat underestimates the emissions attributed to imports in case of the Netherlands. Therefore it is important for a country with large import flows, like the Netherlands, to take foreign emission coefficients into account.

Table 3.1.2 presents a time series of the carbon footprint for both methods[20]. Annex E presents the same results for the greenhouse gas footprint. For 2010 and 2012, Eurostat's method results in a relative large balance of trade due to higher emissions attributed to exports than to imports while this is exactly the opposite for the Dutch approach (a negative environmental balance of trade). This means that for 2010 and 2014, the environmental balance of trade is the opposite. Despite differences between methods, both carbon

[17] Re-exportation is excluded in the Dutch approach.

[18] Also bear in mind the small difference in input data which may affect the outcomes slightly.

[19] At least for those products imported by the Netherlands, and from those countries the Netherlands imports from.

[20] When simply filling Eurostat's tool with data from Eurostat's online database, re-exportation is included in the data.

footprints (and also the greenhouse gas footprint, see Annex E) show the same downward trend over time. However, the overall level of the carbon footprint is about 30 percent higher when applying the Dutch approach (in case of the greenhouse gas footprint this difference is about 40 to 50 percent).

Table 3.1.2. Carbon footprint, comparing CBS and Eurostat's methods[21]

		Unit	2010	2012	2014
Eurostat	Emissions by residents	Mln kg CO2	217653	203155	195659
	Environmental balance of trade	Mln kg CO2	42919	44432	43824
	Footprint	**Mln kg CO2**	**174734**	**158723**	**151835**
CBS	Emissions by residents	Mln kg CO2	216948	202385	195827
	Environmental balance of trade	Mln kg CO2	-8596	-5557	2478
	Footprint	**Mln kg CO2**	**225544**	**207942**	**193349**
Differences	**Footprint**	%	29,1%	31,0%	27,3%

[21] CBS method excludes re-exportation, this adjustment is not required for Eurostat's tool which includes re-exportation..

4. Discussion and recommendations

In this report, IO analyses as part of the environmental accounts are explored. Three main issues are discussed: the quality of the IO table, Dutch methodology and data used to compile footprints and a comparison of the Dutch footprints estimates with the outcome of the Eurostat footprint tool.

The quality of IO-tables

The quality of the Dutch IO table was assessed. Such an assessment provides insight into the strengths and weaknesses of the IO-tables, which will eventually also affect the outcome of the IO-analyses. One of the main flaws of the Dutch IO table is a lack of information on relationships between suppliers and users (i.e. who supplies to whom), both domestically and with foreign countries. With regard to import and export of small countries this information is improved by applying a new data source. Some other potential improvements were mentioned but not explored due to a lack solid information and time. A second flaw was a result of the SNA2008 guidelines which recommend to record goods sent for processing and production abroad as a service and not a physical flow. As a result single industrial branches could both produce goods and services, while having the same economic activity, depending on the ownership of the company. Because this affects IO analyses in a bad way, IO-tables based on SNA 2008 (residence principle) were converted into IO-tables based on SNA 1993 (territorial principle). Other flaws in the IO tables were also described but no action was taken because of a lack of time, data or clear sign for urgency. However, it was decided not to compile a structural decomposition analysis, which focuses on the changes in economic structure over time, because the development of this economic structure is not well captured in Dutch IO-tables. We would recommend countries to perform a quality assessment on its IO tables before performing an IO analyses.

Production and consumption based IO-analyses

The data sources use for the production and consumption based IO analyses are mostly available from Eurostat's database: a domestic IO table, domestic greenhouse gas emissions, international trade data and emission coefficients of European countries. Only for emission coefficients of non-European countries an external data source is used. This latter data sources is not very up to date. In order to compile up to date footprint figures for the Netherlands we use old emission coefficients for the most recent years. We assume that domestic emissions and import and export volumes have a much larger effect on the outcome than a change in emission coefficients. The methodology that is applied for IO analyses is somewhat between a full MRIO model and a model based on the Domestic Technology Assumption (DTA). The big advantage over the DTA-model is that foreign emission coefficients are taken into account for imported products. The big advantage over a full MRIO analyses is the independence on an update of the MRIO database . This makes our approach relatively easy to execute with up to date figures. A disadvantage with regard to a MRIO model is that analytical possibilities are somewhat limited. We would recommend to make a decision on what type of model to use based what is important in the balance between quality and timeliness of the outcome and effort needed to compile the figures.

With regard to the production approach three different approaches, with each a different perspective of who could be held responsible for the emissions, are discussed: 1) emissions allocated to domestic final demand, 2) emissions allocated to global final demand and 3) emissions allocated to total production. Before estimating a production based footprint it is important to get it clear what questions you want to answer.

With regard to the consumption approach we found decreasing footprints for both CO_2 and GHG emissions between 2008 and 2016. This decline can be explained by two underlying factors: fallen net emissions by residents and an increase in the balance of trade. For CO_2emissions the balance of trade even flipped over from negative to positive. The environmental balance of trade changed due a decrease in emissions attributed to import which, in turn, is caused by a decrease in foreign emission intensities.

With regard to the decomposition analyses the main issue was the choice for an index decomposition analyses (IDA) instead of a structural decomposition analyses (SDA). Due to lack of quality of the IO-tables the development of the Dutch economic structure over time was not well captured in the IO-tables. Therefore the structural decomposition analysis was replaced by an index decomposition analysis, which does not take into account the economic structure as presented in the IO-table. Change in economic activity, predominantly economic growth, has been the main driver behind this increase in emissions. Improvements in energy-intensity counteracted this effect resulting in only small changes in emissions over time. Servicisation had a small decreasing effect on greenhouse gas emissions.

Eurostat's Consumption-based accounting tool

Two different approaches to calculate greenhouse gas footprints are reviewed, the Dutch approach and Eurostat's Consumption-based accounting tool. Both approaches are quite similar except in the way they attribute emissions to imports. Eurostat's tool applies the Domestic Technology Assumption (DTA), in which emissions are attributed to imports based on domestic emission intensities, whereas the Dutch approach uses country-specific data on emission-intensities of industries of countries that export products to the Netherlands. This difference in methodology significantly affects the balance of trade and, as a result, the carbon footprint based on Eurostat's method is significantly lower than the carbon footprint based on the Dutch approach. In the case of the Netherlands, emissions attributed to imports seem to be underestimated by Eurostat's tool. It turns out that for the Netherlands imported products are in general more emission-intensive. The effect of these different methodologies is more prominent for countries with an open-economy than for those with a more closed economy, because in these open-economies import and export flows have a relatively large impact on the total footprint. Despite these differences between methods, both carbon footprints show the same downward trend over time.

We would recommend that countries that want to use the Eurostat tool investigate to what extend the DTA affect the results. It also to depends if absolute figures are developments in time are presented. Maybe Eurostat could, in the future, consider a similar accounting tool that also takes into account these country-specific emission-intensities of industries. However, the model would become more comprehensive and would require additional input data, such as international trade data broken down by countries, which makes it less convenient to use for EU-member states.

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Annex A

Classification of industries applied to consumption based IO-analyses (i.e. footprints)

1	A011 Agriculture
2	A012 Horticulture
3	A013 Livestock
4	A02 other agriculture and forestry
5	A03 Fishing and aquaculture
6	B Mining and quarrying
7	C10-C12 Manufacture of food products; beverages and tobacco products
8	C13-C15 Manufacture of textiles, wearing apparel, leather and related products
9	C16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
10	C17 Manufacture of paper and paper products
11	C18 Printing and reproduction of recorded media
12	C19 Manufacture of coke and refined petroleum products
13	C20 Manufacture of chemicals and chemical products
14	C21 Manufacture of basic pharmaceutical products and pharmaceutical preparations
15	C22 Manufacture of rubber and plastic products
16	C23 Manufacture of other non-metallic mineral products
17	C24 Manufacture of basic metals
18	C25 Manufacture of fabricated metal products, except machinery and equipment
19	C26 Manufacture of computer, electronic and optical products
20	C27 Manufacture of electrical equipment
21	C28 Manufacture of machinery and equipment n.e.c.
22	C29 Manufacture of motor vehicles, trailers and semi-trailers
23	C30 Manufacture of other transport equipment
24	C31_C32 Manufacture of furniture; other manufacturing
25	C33 Repair and installation of machinery and equipment
26	D Electricity, gas, steam and air conditioning supply
27	E36 Water collection, treatment and supply
28	E37-E39 Sewerage, waste management, remediation activities
29	F Construction
30	G Wholesale and retail trade; repair of motor vehicles and motorcycles
31	H Transportation and storage
32	I Accommodation and food service activities
33	J Information and communication
34	K Financial and insurance activities
35	L Real estate activities
36	M Professional, scientific and technical activities
37	N Administrative and support service activities
38	O Public administration and defence; compulsory social security
39	P Education
40	Q Human health and social work activities
41	R Arts, entertainment and recreation
42	S Other service activities
43	T Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use

Annex B

Classification by country or region (used for consumption based IO-analyses, i.e. footprints)

	Countries/regions	Source	In case of a region, data is obtained from
1	Netherlands	Statistics Netherlands	
2	Germany	Eurostat	
3	Belgium	Eurostat	
4	United Kingdom	Eurostat	
5	France	Eurostat	
6	Russia	Exiobase	
7	Italy	Eurostat	
8	Spain	Eurostat	
9	Sweden	Eurostat	
10	USA	Exiobase	
11	China	Exiobase	
12	Japan	Exiobase	
13	Other Western-Europe	Eurostat	Denmark, Greece, Cyprus, Austria, Portugal and Finland
14	Other Western	Exiobase	Taiwan, South Korea
15	Africa	Exiobase	RoW Africa
16	Other Asia	Exiobase	India, Indonesia
17	South and Central America	Exiobase	Brazil
18	Middle East	Exiobase	RoW Middle East
19	Eastern Europe	Eurostat	Bulgaria, Czech Republic, Estonia, Latvia, Hungary, Poland, Romania, Slovenia and Slovakia
20	Norway	Eurostat	

Annex C

Classification of industries applied to index decomposition analyses

#	Type	Industry
1	Goods	A Agriculture, forestry and fishing
2	Goods	B Mining and quarrying
3	Goods	C10-C12 Manufacture of food products; beverages and tobacco products
4	Goods	C13-C15 Manufacture of textiles, wearing apparel, leather and related products
5	Goods	C16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
6	Goods	C17 Manufacture of paper and paper products
7	Goods	C18 Printing and reproduction of recorded media
8	Goods	C19 Manufacture of coke and refined petroleum products
9	Goods	C20-C21 Chemical and pharmaceutical products
10	Goods	C22 Manufacture of rubber and plastic products
11	Goods	C23 Manufacture of other non-metallic mineral products
12	Goods	C24 Manufacture of basic metals
13	Goods	C25 Manufacture of fabricated metal products, except machinery and equipment
14	Goods	C26 Manufacture of computer, electronic and optical products
15	Goods	C27 Manufacture of electrical equipment
16	Goods	C28 Manufacture of machinery and equipment n.e.c.
17	Goods	C29 Manufacture of motor vehicles, trailers and semi-trailers
18	Goods	C31-C33 Other manufacturing and repair
19	Goods	D Electricity, gas, steam and air conditioning supply
20	Goods	E Water collection, treatment and supply
21	Goods	F Construction
22	Services	G Wholesale and retail trade; repair of motor vehicles and motorcycles
23	Services	H49 Land transport and transport via pipelines
24	Services	H50 Water transport
25	Services	H51 Air transport
26	Services	H52Warehousing and support activities for transportation
27	Services	H53 Postal and courier activities
28	Services	I Accommodation and food service activities
29	Services	J Information and communication
30	Services	K Financial and insurance activities
31	Services	L Real estate activities
32	Services	M Professional, scientific and technical activities
33	Services	N Administrative and support service activities
34	Services	O Public administration and defence; compulsory social security
35	Services	P Education
36	Services	Q Human health and social work activities
37	Services	R Arts, entertainment and recreation
38	Services	S Other service activities

Annex D

International trade; history of Dutch import and export in billion euro

	2008	2010	2012	2014	2016
Total import	336	332	389	382	373
Total export	370	372	430	433	425

Annex E

Greenhouse gas footprint; comparing CBS and Eurostat's methods excluding re-exportation, 2014

		Eurostat		CBS
	Unit	Including re-exports	Excluding re-exports	Excluding re-exports
Emissions by residents	Mln kg CO2-equivalents	222430	222430	222864
Emissions attributed to import	Mln kg CO2-equivalents	234880	123240	185627
Emissions attributed to export	Mln kg CO2-equivalents	286584	173948	164983
Footprint	**Mln kg CO2-equivalents**	**170725**	**171722**	**243509**

Greenhouse gas footprint, comparing CBS and Eurostat's methods[22]

		Unit	2010	2012	2014
Eurostat	Emissions by residents	Mln kg (CO2-equivalents)	245845	230175	222430
	Environmental balance of trade	Mln kg (CO2-equivalents)	51236	52273	51704
	Footprint	**Mln kg (CO2-equivalents)**	**194609**	**177902**	**170725**
CBS	Emissions by residents	Mln kg (CO2-equivalents)	245349	229489	222864
	Environmental balance of trade	Mln kg (CO2-equivalents)	-44948	-38959	-20645
	Footprint	**Mln kg (CO2-equivalents)**	**290296**	**268448**	**243509**
Differences	**Footprint**	%	49,2%	50,9%	42,6%

[22] CBS method excludes re-exportation, this adjustment is not required for Eurostat's tool which includes re-exportation.