STATISTICS DENMARK

Can Environmentally Extended Multiregional Input-Output Tables Contribute to Green National Accounting?

by

Peter Rørmose Jensen

April 2017

Statistics Denmark
Sejrøgade 11
DK-2100 Copenhagen
Denmark

Statistics Denmark
February 2017

Peter Rørmose Jensen

Senior Adviser
National Accounts
Phone: +45 39 17 38 62
E-mail: prj@dst.dk

Preface

This report has benefited from funding by the European Commission, Eurostat, through grant agreement no. 05123.2015.001-2015.539.

Contents

1. Introduction 7

2. Creating a better basis for policy decisions – what role do MRIOs play? ..8

2.1. Discussion of responsibility for carbon emissions.................................... 10

3. IO techniques used in Danish environmental accounting 13

4. Review of MRIO models. 14

4.1. Do the models provide reliable and similar results? 17

4.2. Are Danish data well represented in WIOD?. 18

4.3. What can single countries do to get more reliable results? 23

5. Review of environmental extensions of the MRIOs..................................24

6. Application of MRIOs for environmental purposes..................................26

6.1. Methodology for calculating footprints 26

6.2. Applications to Danish data 30

7. Conclusion..36

8. References 37

9. Appendices 39

Summary

Green national accounting as it is recommended by the SEEA manual (UN, 2014) is to a large extent based on the framework of Production Based Accounting (PBA) it means that emissions are measured and ascribed to the producers that cause the emissions by their production facility. When the Kyoto protocol was introduced this principle was applied together with the “territorial” principle saying that only production that takes place on the domestic territory should be accounted for. It has been shown in the literature that this combination has led to some degree of carbon leakage. It means that production was moved from Annex B countries to non-Annex B countries and thereby avoiding emissions in the Annex B countries’ accounts and the subsequently importing from the non-Annex B countries.

This carbon leakage and some other problems has clearly undermined the value of the production based emissions accounts and especially issues on equity and fairness between countries has increased the need for a better accounting principle. For a long time discussion has therefor been going on to find a solution to this problem. A lot of suggestions have come up and they all seem to have some nice features but they also all seem to have some drawbacks. This report provides a brief overview of some of the suggestions and presents the pros and cons to them. One of the most prominent ones is to change to CBA or consumption based accounting. It means, in principle, that consumers will be held responsible for emissions to a larger degree than before.

In order to work with CBA in practice it is more or less unavoidable to use a Multiregional Input-Output table MRIO. These databases are vastly time and resource consuming to build and it requires a big project with funding to even get started. In the recent 10 years a good handful of these has surfaced and some of them has been provided free of use for the public. In the report 5 of the databases are presented. They are all different, based on different assumptions, different data etc. and so the results that come out of them are bound to be different.

The data content of the WIOD model is chosen for closer inspection and the contents of its Danish input-output model is compared to a real input-out-put table as it is supplied by Statistics Denmark. The result is that there for years where it is possible the project very nicely fulfils one of its goals namely to keep data intact as far as possible. Some of the Danish data actually matched the data in the WIOD table. On the other hand, many of the data din not match. Due to differences in methodologies and some parts of the table is really different and it brings about a little bit of mistrust as to whether it is able to represent the Danish economy in the best possible manner.

Also a very general look at the results of footprint calculations by the different models indicated that there is no clear convergence in the results yet. So these findings added to the feeling that CBA may be the best alternative to PBA but are still not ready to fully take over.

The use of MRIOs for footprint calculations is mostly thought of as a general worldwide tool, and therefor single countries may find that the data and single country results that come from using the models are too far away from their statistical reality. To deal with that the Dutch statistical office CBS has come up with a method to adapt the WIOD database to be an exact match of the Dutch national accounts. This is a very promising (but also quite heavy in manpower) solution to the problem. It will definitely increase the domestic confidence in the model and the results that comes from it.

The last part of the report provide a series of graphical displays of some of the possibilities that lies in the enormous data set that comes out as the result of a full scale footprint calculation on one of the available MRIO databases.

Although a huge job has been done by the compilers of the MRIOs to provide data in a readily accessible form it is still a rather complicated task to run the model and be sure to get the right results for someone who is not familiar with this kind of IO-modelling. This is certainly one of the obstacles before the models can become even more widespread and accepted.

Some very nice remedies for solving this problem are first of all the dissemination by the OECD of a wide variety of the different results that the OECD ICIO model can provide. From their homepage it is, thus, possible to download a number of indicators that have been calculated with the model. The users are not required to know anything about the technicalities of modelling with MRIO databases.

A similar solution is the database www.environmentalfootprints.org that has a nice user interface that covers the biggest MRIO databases and is able supply the user with footprint results just by clicking around with the computer mouse. There are some limitations though meaning that you cannot get the same full set of results in all dimensions as you can when you use the full model.

Despite the fact that there are lots of challenges and problems in the use of MRIOs the last section of the report showed that there is a lot of valuable information to be extracted from these models. It is definitely possible to add to the already existing green national accounts and to provide some useful insights the may benefit the policy process.

1. Introduction

Introduction of Multiregional Input-Output Tables (MRIOs)

The world economy becomes more globalized. It means that production and consumption are increasingly spatially separated. Agricultural production is concentrated in some parts of the world, resource extraction and manufacturing in other parts, and the major part of consumption in yet another part of the world. In order to understand the full environmental effects of consumption in a globalized world economy, there is need for a tool to capture the full supply chains of products around the world. It turns out that Multiregional Input-Output Tables (MRIO[1]) appears to be a prominent suggestion for such a tool. "MRIO is emerging as a particularly comprehensive, versatile and compatible approach that promises to aid sustainability research with unprecedented detail and information." (Wiedmann et al, 2011).

The UN System of Economic and Environmental Accounts, SEEA; provides a suitable foundation for the environmental extensions required for MRIOs as it advances the compilation of economic and environmental data in a standardised framework.

Compilation of a (MRIO) is a huge and complicated job requiring a lot of insight into the mathematics behind it and huge amount of man hours to collect and organize all of the required data. Internationally there is now a good handful of these databases available to the public, some free of charge. More or less all of them have been compiled in the academic world and most of the applications of the data have been in the academic world as well. However, the availability of these databases and the demand for the insight that they are able to provide have started to interest even National Statistical Institutes (NSIs).

MRIO's used by NSI's in other countries

MRIO-based models have so far mostly been used by the academic world. But there is an increasing interest in this kind of models from national as well as international institutions. Mostly on an ad-hoc or experimental basis national statistical institutes (NSI's) have shown an interest as well. An overview of some of the work by NSI's that had been carried out until 2012 can be found in (Hoekstra, Edens and Wilting, 2012). In the period before 2012 there would be quite a large amount of work required in collecting, harmonizing and putting together all the necessary data for these kinds of calculations. However, after 2012 the introduction of a number of new MRIO's available to the public have made it less burdensome and has most likely increased the number of analyses carried out by NSI's to a large extent.

Little use by National Statistical Institutes

There are, however, still some major drawbacks to the use of these databases especially when it comes to single country results. The drawbacks may block a real acceptance by decision makers of the results created by applications of the data. Furthermore, the application of MRIOs requires some skills in input-output modelling especially if any changes or extensions to the basic calculations are required. There are not really any examples of regular use of these models for official statistics by NSIs. However, the insight that they will be able to provide when drawbacks are resolved makes it worthwhile even for a NSI to keep on exploring the possibilities and maybe to provide results on an ad-hoc basis.

[1] In the report "MRIO" refers to a multi-region input-output database that may have been extended with additional information like air emissions.

Green National Accounts for Denmark

But how can the use of MRIOs contribute to environmental accounting in Denmark? Statistics Denmark is well underway establishing a set of Green National Accounts for Denmark. In agreement with guidelines in the United Nations manual on green national accounts SEEA, focus is on creating relationships between environmental pressure measured in physical terms and Danish economic production activities broken down by industries. The Green National Accounts is established as a large and comprehensive set of satellite accounts to the national accounts. It is an important accomplishment that provides policymakers with valuable information that may lead to better environmental policy decisions.

The most highlighted part of environmental accounts is normally the part on air emissions, especially the greenhouse gas emissions. This is of course due to the international aspect of these emissions that contribute to one of the world's most serious problems; Global Warming.

As the activities in the global manufacturing industry gets more and more fragmented so does the air emissions that arise from it. It should be in the interest of any government in the world to see how the nation's production and consumption activities affect other countries in the world. It is necessary that green national accounting to some extent reflect how behaviour of households and industries actually affect global emissions of greenhouse gasses in the world. Policy makers must be able to see what effects national production and consumption activities along with environmental policies have on global warming. To provide such insight is one of the core properties of MRIOs.

This project deals with various aspects of the MRIO models ranging from what their roles are, their contents, some of the most important drawbacks, how they are used and of course also some results for Denmark

Content of the report

As mentioned previously section 2 digs in a little deeper in the discussion about possible alternatives to PBA, the production based accounting in order to put the use of MRIOs into a broader content. Section 3 take a look at what MRIO databases are available to users like Statistics Denmark.

2. Creating a better basis for policy decisions – what role do MRIOs play?

Territorial or residence principle?

National air emissions statistics are transmitted into international inventories of greenhouse gases. The frameworks and definitions vary. Data reported to the United Nations UNFCCC as continuation of the data transmission required under the Kyoto protocol, are classified according to the territorial principle. Thus, it regards emissions that have been generated on the national territory. For transmissions of air emission statistics to other international bodies like the EU and IEA the definition is a little different. Here it follows the residence principle which is in agreement with the national accounts definitions. It requires data on emissions from activities controlled by residents of the economy regardless of where in the world the emission actually have taken place.

Production Based Accounting (PBA)

Both of these definitions rely on the same Production Based Accounting (PBA) principle. According to this carbon emissions are accounted for on the basis of production activities, so producers are held responsible for emissions.

30 percent decrease in Danish Kyoto emissions

According to this production based statistics most developed western economies like Denmark has managed to lower our contribution to global warming problem since 1990 – the first year of the Kyoto protocol. The blue line in Figure 1 below show that Denmark has managed to cut down emissions of greenhouse gasses based on the Kyoto definitions by 30 percent from 1990 to 2014.

Dramatically increasing world trade

Since this principle was agreed upon some 25 years ago the world economy has changed a lot, especially in terms of the amount of foreign trade. Due to easier and more effective communication and transportation systems, goods and services can move around much more freely in the world now. It has had the effect that even smaller differences in the cost of production between countries can cause a change in location of certain production activities to countries where costs are lower. Subsequently the same goods will then be imported by the countries with higher costs of production. In terms of carbon emission statistics the emissions related to this particular production activity will now be put in the accounts of the new country as well as it will be removed from the accounts in the country of the original producer.

Carbon Leakage and Pollution Haven

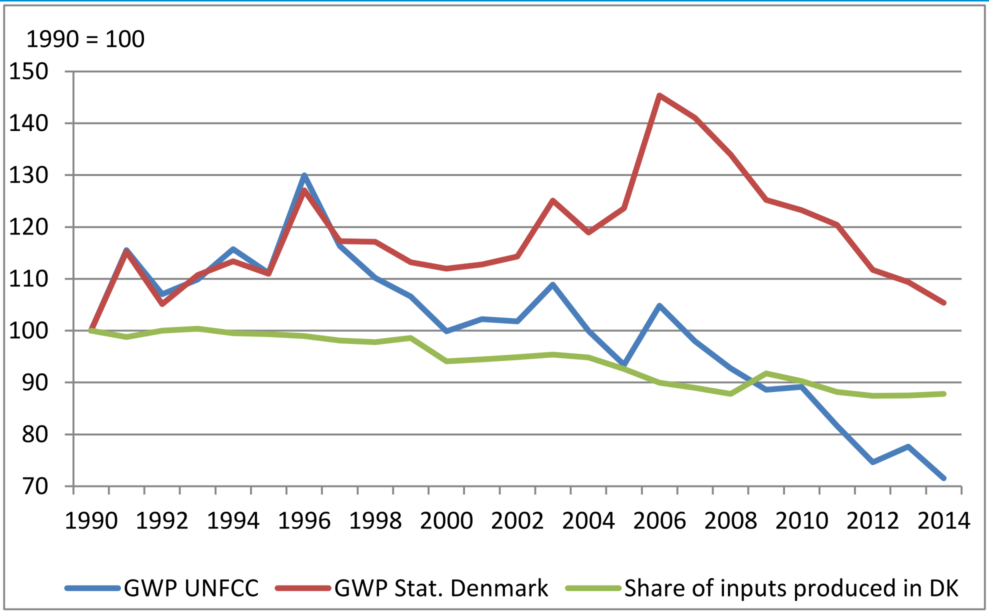
In addition stronger environmental regulation in some countries may cause production activities to move to countries with less strict regulation. This has been described in the literature as "carbon leakage", where an increased emission in one country (non-Annex 1 country) can be regarded as the consequence of a reduction in emissions in another (Annex 1) country. It has been concluded in a recent article that the Kyoto protocol has indeed led to carbon leakages. (Aichele R, Felbermayr G., 2015). In the strong definition, the carbon leakage is equivalent to the increase of CO_2 emissions in non-Annex 1 countries divided by the reduction of CO_2 emissions in Annex 1 countries, whereas in the weak definition, the carbon leakage corresponds to the CO2 emissions embodied in imports from non-Annex B countries to Annex B countries. (Peters G.P. and Hertwich E.G., 2008)

Thus, countries with cheap resources and labor and at the same time less stringent environmental regulation may benefit from attracting foreign investments and may then be labeled "Pollution Heaven".

Emissions from international transport

The Kyoto agreement was only concerned with emissions on the territory, so emissions from international transport activities abroad were not taken into account. The red line in Figure 1 shows that if the accounting principle is changed to the residence principle and, thus, international transport activities are taken into account, Denmark has experienced a small increase in emissions between 1990 and 2014.

Figure 1. **Danish emissions of greenhouse gases and the share of domestically produced input in total input in production**



By way of national IOTs it is possible to calculate the imported share as well as the domestically produced share of input in production. Represented by the green line the figure shows that the share of domestically produced input in production as a share of total input in production has dropped 12 percent in the same period as emissions has gone down.

More imported input leads to less emission

The increasing share of imported input in production is a natural consequence of the increasing division of labour on the world market. Imports, as well as exports increase in most countries. So the increasing import share in inputs should not be regarded solely as an attempt to avoid carbon emissions in Denmark. But even though avoiding carbon emissions may not be the cause it may be the consequence. So although much progress has been made in Denmark in order to reduce emissions it cannot be rejected that carbon leakage can have taken place to some degree. It has been suggested in a number of articles that Europe's compliance with the Kyoto targets are more or less due to a displacement of emissions. (Peters et al., 2011).

PBA must be replaced or supplemented

It is indicated in the discussion above that in the wake of the huge increase in global trade in recent years a need to replace or adapt the current PBA as the basic principle for compiling national as well as international statistics on carbon emissions has emerged. In the literature a huge debate has been going on for years trying to come up with the best alternative to PBA. The question about responsibility for emissions has been debated a lot in the literature for at least 20 years. It is decisive for the way statistics should be compiled and therefor it is discussed in a little more detail in the next section.

2.1. Discussion of responsibility for carbon emissions

Who is responsible for emissions?

One of the most important topics even in international climate negotiations is how to share the burden of reducing greenhouse gas emissions. It is a complicated ongoing discussion involving equity and justice concerns which is supported by a huge literature. There is no commonly agreed answers to the question if and with what the current dominating principles should be replaced. Nevertheless, it is important at the national as well as the international stage to reach an agreement about it because it has decisive consequences for the formation of environmental policies and the compilation of statistical tools to support and monitor the policy. Even for the conclusions in this report it is important to know what the options are. Therefore a brief overview of the most prominent principles is presented below followed by a presentation of the ongoing discussion of the pros and cons of the various principles.

Many different schemes for distribution of responsibility have surfaced

- CBDR. In 1992 the United Nations Framework Convention on Climate Change (UNFCCC) laid down the first responsibility principle. It is the principle of common but differentiated responsibility (CBDR), which acknowledges that countries have contributed by varying scales to the mounting problem of climate change, will be exposed to different levels of impacts, and have different capabilities (e.g., financial and technological) to mitigate emissions (Afionis et al., 2017). It has been said that this principle is unfair towards developed countries as undeveloped countries must bear their fair share as well and that there is a risk that some undeveloped countries might attract foreign investment and therefore see an economic benefit in acting as "pollution havens".

- PBA (Production Based Accounting) means accounting for emissions that are physically produced mainly through the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation within the jurisdiction of a given state. PBA allocate emissions to production activities and include all emissions from domestic production, regardless of whether it is to serve domestic or overseas markets i.e. emissions arising from the production of goods and services within a country's borders.

- CBA. The Carbon Based Accounting approach is also called carbon footprint. It accounts for emissions at the point of consumption, meaning that it is the end consumer, instead of the producer, of goods and services who is allocated these associated emissions. Consumer responsibility allocate emissions to consumption, explicitly take into account emissions embedded in international trade flows, and include emissions embedded in imports but exclude emissions from goods and services produced to serve overseas markets. It means that a country accepts its responsibility for emissions abroad driven by its consumption as well as domestic emissions related to domestic consumption and investments.

- TCBA is short for Technology adjusted CPA. It deals with the weakness in the CBA accounting scheme that arises because it is insensitive to changes in the carbon efficiency in the export sector. The CPA does not credit countries that make an effort to reduce emissions from their export companies. (Kander et al, 2015) propose an improvement to CBA that takes technology differences in export sectors into account. Their idea is to calculate global average carbon intensities by industry and to adjust the CBA results with the deviation from the global average of emissions from the export sector. Thus, if a country manages to clean it export sector completely to a level much better than the world average it will get to deduct the difference from their CBA account.

- Income based accounts of carbon emissions. This principle resembles CBA quite a lot in a technical manner in that it also accounts for emissions generated through trade. It is a so-called downstream measure that ties emissions to the incomes earned in the generation of them. It covers all types of income to capital, wage owners and the government. Those who will gain from the activities that create emissions are also those who will be held responsible. One effect is that e.g. workers in a power plant will be taxed much harder than workers in the service sector. There may be some theoretical reason in this but it has a somewhat unattractive appeal to it for many people. Consequently, it has not generated much attention in the literature but is well presented in this article (Marques et al., 2012).

- Shared responsibility. There is quite a lot of different ongoing research under this headline. One of the ways discussed is to introduce a carbon border tax "which means a country would place an extra tax on goods coming in from jurisdictions that do not have their own carbon tax, and also which would exempt a country's own exports from a domestic carbon tax as they left the country. In this way, even if just some governments around the world implement a carbon tax, then they won't be placing their own industries at a competitive disadvantage vis-à-vis unregulated firms around the world" (Institute for Energy Research, 2016). However this kind of tax-arrangement is seen by many to be way too complicated to administer.

Discussion

Consumption-based and production-based emissions are two sides of the same coin – total consumption-based emissions must be equal to total production-based emissions at the global scale; the only difference is allocation. But from the perspective of an individual country the two measures can differ quite a lot depending on the nature and extent of international trade the country engages in. Currently UNFCCC collects data based on PBA which has some flaws.

The CB accounting literature has pointed at a number of benefits that could accrue from basing GHG emissions data collection on the basis of CBA instead of PBA, mostly on the grounds of (see (Afionis et al, 2017) for a good discussion on these benefits)

- **Increased emissions coverage.** The CBA scheme will cover all emissions including those that are off-shored no non-Annex 1 countries and thereby putting an end to the possibility of carbon leakage. Moreover, the CBA scheme will bring more focus on the highly carbon intensive export sector in undeveloped countries, which in itself will be a big achievement.

- **Encouragement of cleaner production practices.** Also here focus is on the export sector in the undeveloped world. The increased focus due to the CBA scheme will ease the diffusion new and cleaner technologies in the undeveloped countries.
- **Political acceptability.**
- **Equity and justice.** Naturally, this is a very important aspect of the discussion at the global scale. Developing countries must be considered in negotiations although their voice may not be so strong.

Taken together, proponents of CBA argue that its adoption could enable the international community to move closer toward achieving the ultimate objective of the UNFCCC of limiting climate change.

Others show more scepticism based on a wide range of complications that would interfere with or prevent initiation of implementing policies. These could be grouped into three main categories:

- **Effectiveness**. It has been argued by (Liu, 2015) that CBA and PBA share the same goal; namely reducing emissions. It would be done more effective by addressing producers directly than indirectly through consumers first.

Can multiregional input-output tables be trusted for calculations of footprints comparable between countries?

- **Efficiency concerns, practical impediments.** This argument partly concerns the necessary use of databases of Multiregional Input-output tables and all of the problems related to constructing them as well as to the huge variations in results depending on which database is applied.
- **Political incompatibility**. Results from CB accounting may very well indicate which kinds of consumption and eventually production that needs to be regulated, but to a large extent this involves economic activities in other countries which will be hard for individual countries to regulate. So in the end a regulation based on CBA do require a supernational body with the right to impose taxes or legislation in all countries.

Thus, there are numerous arguments in both directions and there is absolutely no clear winner in this debate. Due to a range of technological and policy-related uncertainties, it seems that the CB accounting approach is unlikely to replace its established PB counterpart, at least in the foreseeable future. That said, the CB accounting approach represents an invaluable tool for the international community to better understand the effect of consumption patterns on emissions and take the response measures necessary to address emissions embodied in trade (Afionis et al., 2017)

Conclusion and motivation for working with MRIOs

To conclude the introduction it has been argued that there is a need to at least supplement the PBA accounts of carbon emissions with other views of how the responsibility for the carbon emissions should be accounted for. The most prominent alternative in the literature so far is CBA Because CBA requires calculations based on a MRIO model there is a motive for Statistics Denmark to start using such models.

Thus, even though it does not seem that PBA will be replaced by CBA in the near future, the motivation for Statistics Denmark to bring multiregional input-output tables onboard and start compiling consumer based accounts and carbon footprints, is the conclusion about this being an invaluable tool to the international community and it will be to the Danish community as well. It has the potential to supplement the already published PBA based data with some interesting angels that have the potential to lead to better environmental policy decisions.

3. IO techniques used in Danish environmental accounting

Input-output and environmental accounts

Input-output modelling is an obvious way to integrate environmental statistics with economic statistics. It enables the user of the final statistics to do a variety of analyses where the environment measured in physical terms is combined with economic structures and development. The concept of emission intensities or productivity where emissions in physical terms are divided by total output broken down by industries is the link between the two types of statistics. Input-output tables and input-output models is one of the most useful tools for analyses of the connection between environmental pressure and economic production by industry. The use of input-output models can give very detailed insight into what economic activities drives the development in emissions.

Global multipliers calculated with domestic technology assumption

Based on a national Danish input-output model Statistics Denmark has for the past 20-25 years calculated and published multipliers for employment, imports, energy use, emissions of CO_2 and other types of air emissions. The multipliers were domestic as well as "global", where the latter was supposed to cover emissions in the rest of the world due to Danish final demand. The calculation of the global multipliers was based on the so-called domestic technology assumption in a model that assumed that all imported goods had been produced with the same technology and the same emission intensities as if they had been produced in Denmark. As Denmark is among the countries with the lowest emission intensities this was obviously not a very relevant calculation. It has been argued, though, that it measured the amount of emissions that was avoided through imports. Another appealing aspect about it is that all the data necessary are the domestic IO tables and some environmental pressure by industry.

Structural Decomposition Analyses (SDA)

For many years Statistics Denmark has been using SDA as a tool for analyses of especially air emissions. It is an effective method to get behind the development in the long time series of energy and emissions data available to us. It is a way to point out the driving factors behind the development. In the literature there are examples of the use of SDA in a framework of MRIO's that we hope to be able learn from, at a later stage.

Previous EU-grant on footprint calculations

In an earlier project funded by an EU grant in 2009 (Rørmose, Olsen and Hansen, 2009, 2010) a unidirectional trade model was applied in order to calculate the Danish carbon footprint. For 51 different countries it was calculated how much CO_2 emission the production of Danish imports would generate. For the calculation different national IO tables was used as well as country specific emission intensities. In the lack of availability of a true MRIO it turned out to be quite a reasonable approximation which is also concluded by (Andrews, Peters and Lennox, 2009).

Nevertheless, now that a number of MRIOs are available there is no reason not to go for the full model, because it will take care also of emission embodied in indirect trade between countries that is caused by Danish final demand. This is an aspect that is not covered by the unidirectional trade model. Moreover, a fragmentation of production has increased international trade drastically in recent years since the previous report was made so there is definitely an increased need for a tool that also incorporates the indirect trade between countries as well.

4. Review of MRIO models.

Only the very largest projects with really big funding engage in building their own multiregional IO table for the project. It is an enormous job to collect all the relevant data, balance them and make them fit together in the same framework. Therefore must users are very pleased to see that a bunch of different databases have already been compiled and made available to users.

1. EXIOPOL database

Name	EXIOBASE
Homepage	http://www.exiobase.eu/index.php
Description	EXIOBASE is a global, detailed Multi-regional Environmentally Extended Supply and Use / Input Output database. It is characterized by concentrating on a single year but on the other hand a very high degree of detail for that particular year. EXIOBASE is unique in the world with respect to the detail and variety of environmental information it offers to its users. The international input-output table can be used for the analysis of the environmental impacts associated with the final consumption of product groups. This is in contrast to other databases that typically operate with consumption aggregated to only household and government consumption.
License required	As of the release of EXIOBASE2 (year 2007 data) the EXIOBASE partners have decided to make the database 'as is' available for free under licence In order to download data you need to register and obtain a username and password.
Data detail	• 43 countries, 5 RoW regions (and its 10% of the global GDP) Base year 2007 • 200 products • 163 industries • 15 land use types • Employment per three skill levels • 48 types of raw materials • 172 types of water uses
Environmental extension	Yes. Has an extensive amount of environmental extensions
References	Tukker et al. (2013), Wood et al. (2015)

2. GTAP database

Name	GTAP
Homepage	https://www.gtap.agecon.purdue.edu/
Description	GTAP (Global Trade Analysis Project) is a global network of researchers and policy makers conducting quantitative analysis of international policy issues. GTAP's goal is to improve the quality of quantitative analysis of global economic issues within an economy-wide framework. The central part of GTAP is the GTAP Data Base, a fully documented, publicly available (for a fee) global data base which contains complete bilateral trade information, transport and protection linkages
License required	License and fee is required for use of data. The newest version GTAP 9 Data Base is around 6,000 US$ for a European NSI to use.
Data detail	The current release, the GTAP 9 Data Base, features 2004, 2007 and 2011 reference years as well as 140 regions for all 57 GTAP commodities.
Environmental extension	Have tables with detailed data on energy and CO2 as well as emissions of other greenhouse gasses. Requires license for GTAP.
References	

3. OECD ICIO table

Name	OECD ICIO (Inter Country Input-Output)
Homepage	http://www.oecd.org/sti/ind/input-outputtablesedition2015accesstodata.htm
Description	The OECD inter-country input-output (ICIO) table was first constructed for the calculation of Trade in Value Added (TiVA) indicators during a joint OECD-WTO project. TiVA indicators are designed to better inform policy makers by providing new insights into the commercial relations between nations. However, the ICIO can be used as the standard IO table it is. In their homepage the OECD is providing a vast amount of tables with data that have been calculated on the ICIO model, so the users do not have to do it on their own.
License required	The model can be downloaded free of charge from the OECD homepage.
Data detail	The 2015 edition of the ICIO database includes 61 economies covering OECD, EU28, G20, most East and South-east Asian economies and a selection of South American countries. The industry list has been expanded to cover 34 unique industrial sectors, including 16 manufacturing and 14 services sectors. A time series from 1995 to 2011 is available.
Environmental extension	Extensions to the ICIO regarding CO2 emissions from fuel combustion (based on IEA CO2 data), energy used for electricity production (based on IEA energy balances) and trade in employment are not readily. A payment is necessary to obtain the IEA data that the OECD ICIO is based on. (See appendix 2 for details). However, most NSIs already have an account with the IEA so for NSIs data can normally be obtained free of charge. However, data are not ready for use directly from the IEA. Their classification and sectoral distribution is quite far from what is needed to run the ICIO model. A recipe can be found in Wiebe et al. (2015) Moreover, the emissions data related to the OECD ICIO model is <u>only</u> CO_2 emissions and <u>only</u> those emissions that come from the burning of fossil fuels. Therefor by definition results from the OECD model are always smaller than from the models covering all greenhouse gasses and CO_2 emissions from other sources.
References	

4. EORA Database

Name	EORA
Homepage	http://worldmrio.com/
Description	The Eora multi-region input-output table (MRIO) database provides a time series of high resolution IO tables with matching environmental and social satellite accounts for 187 countries (to 190 in some datasets). A fully harmonized world MRIO for all 187 countries at the 26 sector level is supplied as well.
License required	The model and data is free for use by academic institutions issuing degrees to student. All other users have to sign a contract and pay a fee before publishing any results. Fees are quite high and would amount to approximately 25,000 Euros for a European NSI.
Data detail	187 individual countries represented by a total of 15,909 sectors continuous coverage for the period 1990-2013.
Environmental extension	The database comes with a large environmental extension including 35 types of environmental indicators covering air pollution, energy use, greenhouse gas emissions, water use, land occupation, N and P emissions, 172 crops,
References	

5. WIOD database

Name	WIOD
Homepage	http://wiod.org/
Description	WIOD has been constructed in a clear conceptual framework on the basis of officially published input-output tables in conjunction with national accounts and international trade statistics. All data from the various steps in the compilation procedure are made available at the home page. Thus national SUT's as well as international SUT's and finally world SUTs are available. WIOD is available in two versions. The first one which was released in 2013 covers 40 countries by 35 industries and the newer version that was released in November 2016 covers 43 countries by 56 sectors. This version covers the new NACE rev. 2 classifications of industries as well as the new SNA 2008. One distinct feature about WIOD is that tables in previous years prices along with current prices. This is a nice feature that enables a bunch of analyses that are not possible with other databases.
License required	The model and data can be downloaded completely free of charge from the WIOD homepage.
Data detail	• Version 2013 covers the years 1995-2009, 40 countries and 35 sectors. • Version 2016 covers the years 2000-2014, 43 countries and 56 sectors.
Environmental extension	The 2013 version of WIOD comes with a satellite account covering energy, various types of air emissions and use of water. However, sadly enough it has not been possible to rise funding for an update and extension of the satellite accounts to fit with the new 2016 version of the model. It would be a great step forward to have the environmental satellite account consistent with the new version of WIOD!
References	Timmer et al. (2015)

Thus, there is a variety of models to choose from which are all different. There is no international agreement as to which of the models that give the best and most reliable results. So for someone starting to use a MRIO there is a number of parameters to decide on

- The price – is it free or is there a payment?
- Time period covered
- Price levels offered – only current prices or PYP as well?
- Sectoral detail
- Spatial detail – few countries and large RoW or all countries covered?
- The extent of the satellite accounts that come with the model
- Underlying methodology
    - Preservation of underlying country data
    - Transparency of compilation methodology

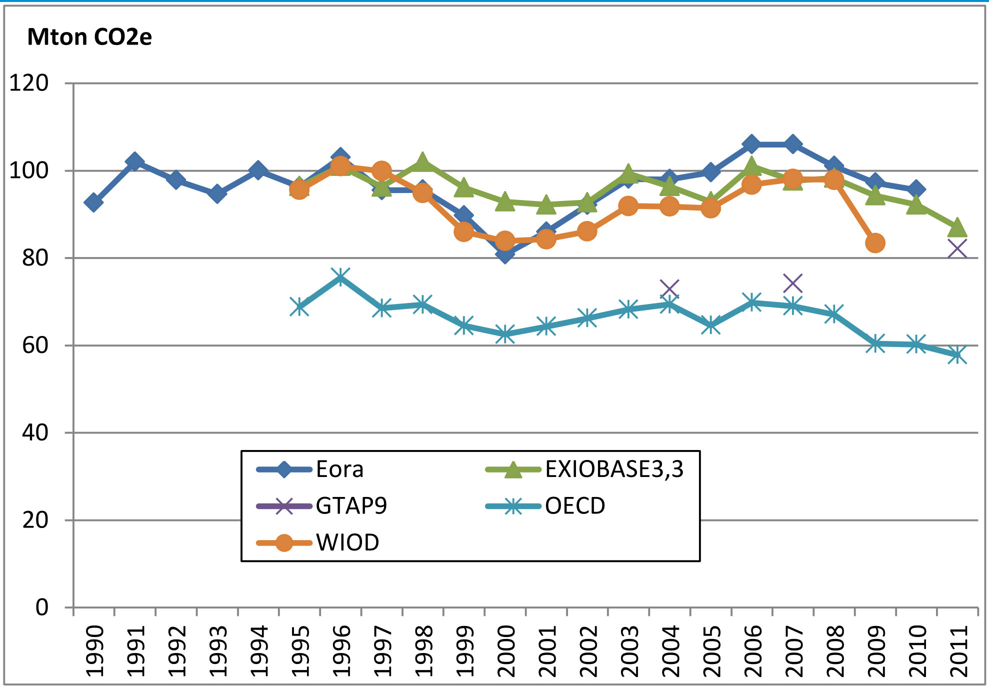
All of these parameters may give the user a hard time choosing. At the same time it is obvious that with so many and such large differences the results are bound to differ quite a lot as well. As this is one of the main objections to the use of these models for giving policy advice the next section will take a brief look at the differences in results provided by these models for the same question.

4.1. Do the models provide reliable and similar results?

In recent years a convergence seems to have been reached concerning the use of global multi-regional input–output (MRIOs) for CBA or footprint accounting. The MRIOs are gaining ground as a tool to measure environmental performance. But there does not seem to be so much focus on the divergence in the results coming from the various models.

In order to see how large a divergence there is in the CBA or footprint measure for Denmark coming from a handful of the available MRIOs an extraction has been made from "The Environmental Footprints Explorer" a fantastic database that works like a user-friendly to all of the large MRIO models at the same time.(Stadler et. al., 2015).

Figure 2 **Comparison of Danish footprints**[2]



Source: Extraction from environmental footprint database.(Stadler et. al., 2015)

3 out of 5 models agree well

The figure shows the size of the Danish Greenhouse Gas footprint in million tons of CO_2 equivalents. The results appear to agree quite well on the size of the Danish footprint. Two models stand out. First of all the GTAP model which is only represented by three observations (2004, 2007 and 2011) show an increasing trend from 2004 to 2011 contrary to the other models that are either more stable or displaying a downward trend. The other model that deviates from the average is the OECD ICIO model. Their results are some 30-40 percent lower which comes as no surprise given the description of the model above. Some emissions (non-CO_2 and non-fossil fuel based) are not captured by the OECD (IEA) data, so the result is bound to be lower.

In the light of the large differences one would expect the results are surprisingly alike. It is necessary to mention, that the results in the "Environmental Footprints Explorer" database converges better than the actual results from the various models. The environmental satellite accounts to the models that by many researchers are supposed be the main source of divergence between the results, have been harmonized or standardized to facilitate a better comparison.

[2] The results from the EORA26 model have been left out of this graph because they were more than twice as large as the others. This must be due to some kind of error in data or calculation procedure.

Comparisons done for other countries have shown much larger divergence between the results from different models. In a number of papers from CBS in the Netherlands a graph similar to the one above shows for the Netherlands an enormous variation in results

Figure 3 **Dutch carbon footprint with 6 different models**.

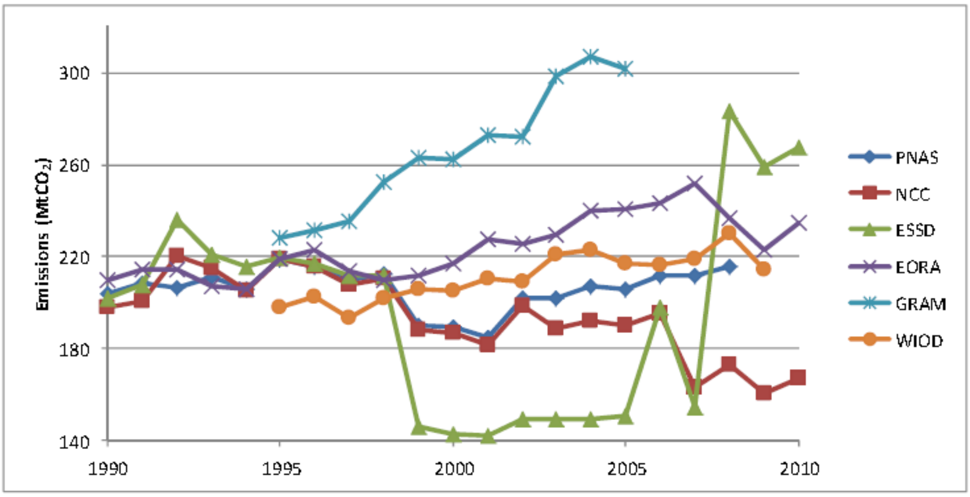


Figure 1. Dutch carbon (CO_2 only) footprint from 6 MRIO studies

Source: (Hoekstra et al., 2013).

For the Netherlands the comparison shows results varying between 14 and 300 Mt CO_2e which is too much for it to be a useful and trustworthy statistics. At closer look the three most extreme series in this graph are from models that are not represented in the Danish comparison. So the result for Denmark may have looked just as bad if those models had been represented there as well.

As mentioned, many researchers have had the hypothesis that the differences in the environmental satellite accounts are the main reason for the different results. In a reason study by (Moran and Wood, 2014) it was not possible to verify this. Even when the environmental satellite was harmonized between all of the participating models there were still large and significant differences in the results.

So despite the relatively heartening resemblance between the Danish footprints in figure 2 there is definitely room for a lot more convergence in the results before they can become a trustworthy basis for environmental policy decisions.

In the next section we take a look at how well the Danish data are represented in the WIOD model as an example. Some of the differences in results between the models may wary well be a consequence of how well they represent the actual national data.

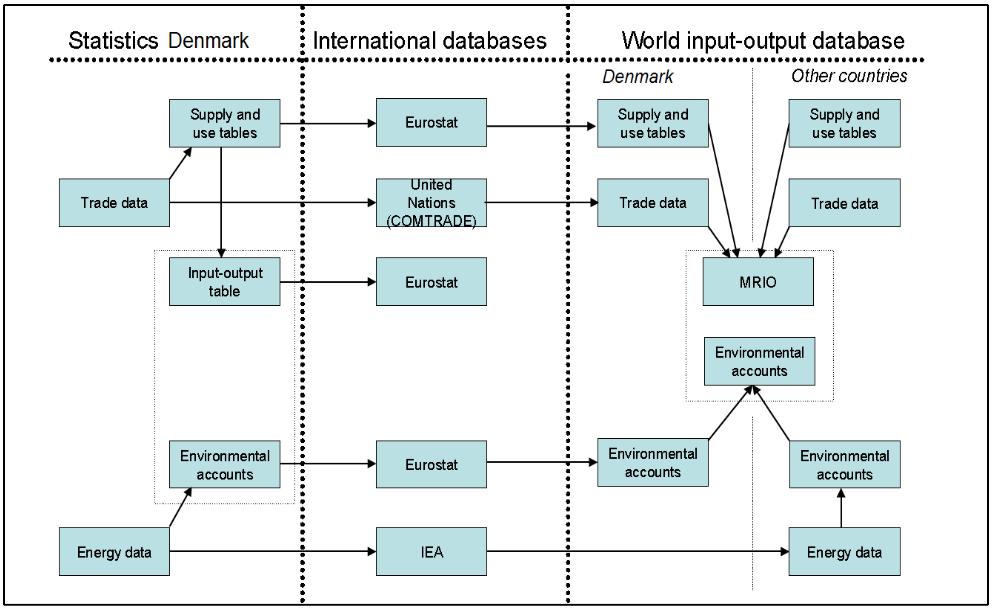
4.2. Are Danish data well represented in WIOD?.

As concluded above WIOD is one of the most accessible of the MRIOs that are available in the world at the moment. Furthermore, it has the environmental satellite account readily available. For that reason it was decided to investigate the resemblance between the data in this model and the Danish counterpart of the same data.

Basic principle that national data can be traced back to national statistics

There were 8 underlying basic principles behind the construction of WIOD (Dietzenbacher et al., 2013). The fourth principle stated that the data used in the project should be publicly available in order to assure that users are able to trace the construction process back to published national data. This is a very nice feature. It makes users of the tables more comfortable when official statistics can be recognized as far as possible. It also makes the results more trustworthy and convincing.

Figure 4. **The flow of data from Statistics Denmark to WIOD**



Copied/adapted from Hoekstra, R. B. Edens and H. Wilting, (2012)

As this figure shows the Danish part of WIOD can be almost entirely based on official published data that originates from Statistics Denmark. Of course these data does not always fit very well with data from other countries even though they are published data, so the necessity of mathematical balancing still prevails.

Official data like output, gross value added etc should be fixed and used as constraints

The third principle concerned the aim to construct a time series of tables. As not so many countries publish SUT's and IOT's annually this required a procedure for estimation of tables for years not covered by official statistics. For this purpose the so-called SUT-RAS procedure was used. Procedures of the RAS kind require a set of new row and column totals to be used as constraints in the update of the contents of a matrix to the new levels. Among these totals are variables like gross output and value added by industry, total imports and exports and final use by category. So it was decided to investigate the difference between the Danish IOT and Danish data in WIOD. In order to do that some considerations had to made first

- Later on in the report the first (2013) version of WIOD will be applied for environmental analyses, which is not possible with the new version (2016) because of the lack of environmental extension. Therefor a table from one of the years in the 2013 version is compared to Danish IOT for that particular year.
- In the process of compiling WIOD, national SUTs were converted into tables with 59 products (based on the international classification of products by activity, CPA) and 35 industries (based on the NACE revision 1). The most recent year for which a Danish IOT based on NACE rev. 1 was published is 2007. So in order to make the fairest comparison 2007 was chosen.
- A positive aspect of choosing a year with a Danish table also in NACE rev. 1 classification is the possibility to recreate the bridge between the Danish industry classification and WIOD 35 industry classification. Based on the actual data for output by industry it has been possible to calibrate the bridge between the Danish 130 industry tables and the WIOD 35 industry classification so the results are similar to those in WIOD. It is just a simple aggregation of industries at the 130 industry level to the 35 industries.
- The Danish data has been converted from national currency DKK to US$ using the table of exchange rates given at the WIOD homepage http://www.wiod.org/protected3/data13/update_sep12/EXR_WIOD_Sep12.xlsx
- The result of the comparison is given in table 1 below. The lower part of the table is the import matrix showing how much foreign industries have delivered as input in Danish production and Danish final demand while the upper half of course is the part produced in Denmark.

Table 1. Comparison between 2007 data from the Danish IO table and WIOD.

2007	Danish Input-output								WIOD							
	Input	C	NPISH	G	I	L	E	Output	Input	C	NPISH	G	I	L	E	Output
AtB	9.418	639	0	200	-30	130	2.432	12.788	6.814	2.360	0	118	-21	147	3.370	12.789
C	6.234	33	0	0	5	514	5.317	12.104	5.468	65	0	0	70	538	5.963	12.104
15t16	6.158	5.346	0	3	35	145	13.862	25.549	5.607	2.970	0	11	17	119	16.825	25.549
17t18	367	178	0	5	82	44	1.284	1.960	18	6	0	0	2	76	1.858	1.960
19	2	9	0	0	2	6	50	69	1	0	0	0	0	31	36	68
20	1.933	62	0	0	149	51	888	3.083	1.488	260	0	0	127	57	1.150	3.083
21t22	5.917	1.273	0	14	125	-19	1.111	8.421	4.909	1.666	0	19	92	-11	1.746	8.421
23	1.652	1.020	0	0	2	222	2.732	5.628	1.653	834	0	0	0	69	3.071	5.628
24	1.737	187	0	88	71	232	10.042	12.357	284	61	0	1	23	220	11.768	12.357
25	2.522	165	0	4	76	39	2.222	5.028	1.385	163	0	0	84	68	3.327	5.028
26	3.239	103	0	0	52	93	931	4.418	2.413	297	0	0	82	101	1.525	4.419
27t28	7.747	86	0	1	311	191	3.531	11.866	5.448	356	0	0	245	293	5.524	11.866
29	3.482	119	0	0	2.515	245	9.559	15.921	926	114	0	1	323	395	14.161	15.921
30t33	5.233	218	0	72	1.522	339	8.744	16.128	2.817	267	0	1	428	455	12.160	16.128
34t35	665	67	0	5	1.059	27	1.838	3.660	151	209	0	4	176	348	2.772	3.660
36t37	944	606	0	9	664	58	3.359	5.640	869	128	0	2	70	244	4.327	5.640
E	4.442	4.041	0	0	52	42	1.999	10.577	3.861	4.411	0	0	27	100	2.179	10.577
F	10.702	754	0	1.238	28.118	0	276	41.089	10.560	662	0	1.143	28.424	1	299	41.089
50	2.192	4.751	0	14	994	40	340	8.332	3.577	3.945	0	56	613	95	45	8.332
51	14.236	6.204	0	209	2.922	253	15.958	39.782	18.778	10.963	0	404	4.511	699	4.427	39.782
52	1.973	13.849	0	292	681	0	9	16.805	8.476	5.783	0	186	2.030	316	14	16.805
H	3.394	5.917	0	0	5	0	213	9.529	3.348	6.031	0	0	5	0	144	9.529
60	8.263	2.580	0	82	25	0	3.427	14.377	9.790	1.139	0	38	8	0	3.403	14.377
61	1.343	226	0	0	9	0	29.976	31.554	1.313	109	0	0	3	0	30.130	31.554
62	635	37	0	0	10	0	2.972	3.654	660	43	0	0	3	0	2.949	3.654
63	3.966	2.225	0	60	41	0	2.229	8.520	5.776	501	0	13	12	0	2.217	8.520
64	8.367	2.287	0	0	287	0	1.301	12.242	8.004	2.703	0	0	172	0	1.363	12.242
J	12.716	10.375	0	42	578	0	1.125	24.836	13.062	10.355	0	41	173	1	1.204	24.836
70	9.412	27.873	0	0	1.900	0	131	39.317	9.429	27.595	0	0	2.159	0	134	39.317
71t74	38.509	1.226	0	851	4.027	70	6.439	51.123	35.808	1.925	0	715	5.338	61	7.275	51.123
L	2.177	428	0	22.866	129	0	242	25.842	3.211	459	0	21.863	62	0	246	25.842
M	1.191	1.183	0	16.706	67	0	29	19.177	614	1.301	0	17.196	21	0	45	19.177
N	1.119	5.192	463	33.844	21	0	55	40.694	1.041	5.189	461	33.931	6	0	64	40.694
O	7.184	6.632	1.738	2.880	532	0	312	19.278	7.056	5.704	1.752	2.669	326	182	1.588	19.278
P	0	256	0	138	0	0	0	394	0	257	0	137	0	0	0	394
AtB	1.415	776	0	0	0	79	241	2.510	2.224	803	0	31	2	0	0	3.059
C	2.155	12	0	0	0	195	34	2.397	2.114	37	0	1	4	0	0	2.156
15t16	5.564	3.130	0	13	0	42	1.767	10.517	2.324	6.928	0	15	4	0	0	9.271
17t18	831	1.688	0	3	76	144	3.145	5.887	607	1.742	0	16	108	0	0	2.473
19	137	418	0	1	9	86	518	1.169	63	475	0	1	7	0	0	546
20	2.064	152	0	0	74	30	127	2.446	1.995	55	0	1	10	0	0	2.060
21t22	2.110	342	0	62	31	2	625	3.171	2.333	509	0	58	26	0	0	2.927
23	1.898	677	0	0	0	-95	1.107	3.587	5.591	2.769	0	20	4	0	0	8.384
24	6.064	912	0	664	3	126	1.530	9.299	5.958	1.904	0	790	55	0	0	8.706
25	2.898	160	0	7	49	47	589	3.750	2.541	542	0	4	38	0	0	3.126
26	1.250	152	0	0	58	34	184	1.677	1.424	149	0	2	13	0	0	1.588
27t28	7.423	152	0	1	545	176	1.784	10.081	8.837	353	0	8	323	0	0	9.521
29	5.243	714	0	0	3.836	245	2.651	12.689	5.010	1.163	0	15	4.026	0	0	10.215
30t33	6.209	1.632	0	84	2.848	300	4.072	15.146	6.209	2.425	0	150	3.066	0	0	11.850
34t35	2.172	3.550	0	58	3.409	419	1.673	11.280	2.188	3.796	0	54	3.932	0	0	9.970
36t37	938	1.051	0	10	756	109	810	3.673	880	1.686	0	20	729	0	0	3.314
E	153	99	0	0	0	10	84	346	518	102	0	1	16	0	0	637
F	134	4	0	1	0	0	0	139	373	54	0	31	33	0	0	491
50	63	1	0	0	0	0	0	63	212	40	0	1	8	0	0	261
51	1.604	3	0	0	15	0	8	1.630	2.130	431	0	15	119	0	0	2.694
52	2	0	0	0	-3	0	7	7	396	121	0	3	23	0	0	543
H	71	0	0	0	0	0	0	71	30	34	0	0	1	0	0	65
60	2.601	47	0	1	0	0	0	2.649	2.761	501	0	18	5	0	0	3.285
61	1.554	3	0	0	0	0	409	1.966	1.873	152	0	0	1	0	0	2.026
62	1.148	75	0	0	0	0	0	1.224	1.289	86	0	1	9	0	0	1.385
63	27.973	19	0	0	0	0	0	27.992	18.220	1.578	0	42	8	0	0	19.848
64	703	226	0	0	12	0	1	943	2.356	295	0	7	12	0	0	2.671
J	1.520	187	0	3	0	0	0	1.709	1.658	285	0	1	12	0	0	1.957
70	0	0	0	0	0	0	0	0	41	4	0	1	1	0	0	47
71t74	6.433	120	0	0	831	1	53	7.439	6.591	400	0	140	885	0	0	8.016
L	7	3	0	0	0	0	0	9	507	58	0	9	4	0	0	578
M	51	52	0	0	0	0	0	103	85	5	0	34	3	0	0	127
N	11	13	0	5	0	0	0	30	41	8	0	14	3	0	0	67
O	640	92	23	0	28	1	17	801	1.254	251	3	71	9	0	0	1.587
P	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Total interm. cons.	282.114	122.612	2.224	80.536	59.612	4.672	156.371	708.141	275.252	128.574	2.218	80.122	59.111	4.605	147.312	697.193
taxes less subs. on prod.	12.505	25.761	0	402	8.577	16	-107	47.154	19.983	18.584	6	780	7.958	446	0	47.757
Cif/ fob adj. on exports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dir. Purch. abroad by res.	3.018	6.910	0	0	0	0	0	9.929	0	6.910	0	0	0	0	0	6.910
Purch. dom. ter. by non-res.	0	-6.585	0	0	0	0	6.585	0	0	-6.585	0	0	0	0	0	-6.585
Value added at basic prices	264.103	0	0	0	0	0	0	264.103	264.103	0	0	0	0	0	0	264.103
International transp. marg.	0	0	0	0	0	0	0	0	2.402	1.214	0	37	757	0	0	4.410
Output basic prices / use purchasers prices	561.741	148.699	2.224	80.939	68.189	4.688	162.849		561.740	148.698	2.224	80.938	67.826	5.050	147.312	

Many aggregates have the same value

It appears from table 1 that the compilers managed to keep a number of variables intact from the original data.

- All output values by industry (row sums in the upper half of the table) have been maintained.
- Therefore also the total output in the lower left corner is the same.
- Value added by industry is equal to the official Danish values for all industries
- The totals in purchaser's prices for household consumption, NPISH and government consumption are also the same as the Danish.
- For investment and changes in stock is seems that around 500 mill. US$ has been recorded by the WIOD team as changes in stocks instead of gross fixed capital formation.
- Tourist expenditures and income in household consumption are exactly the same.

At the same time many numbers differ, also at the level of totals. Due to a number of inconsistencies between countries concerning foreign trade it is clearly unavoidable that some parts of the country tables must differ but it is interesting to see by how much. But a number of more systematic changes have been made to the original data as well some of which are methodological changes required in order to build a MRIO in any case.

Problematic treatment of re-exports

- Total Danish exports are around 15 billion US$ less in WIOD in 2007 than in the Danish national accounts. This amounts to approximately 10 percent which is actually quite a lot.

  One obvious reason for this is that re-exports which amounts to more than 20 billion US$ in the Danish table is absent from WIOD. This is not specific for the Danish part of WIOD but a technicality about the way that these MRIOs are built. To crucial assumptions are made
    - Exports only comes from domestic production
    - Re-exports are assumed not to be part of the domestic production process.

  In the cases where re-exports in the SUTs were unavoidable e.g. when imports were larger than total domestic use the compilers would lower imports until all of it could be covered by domestic consumption. The problem of omitting re-exports is considered to be minor in (Dietzenbacher et al., 2013), because the share of re-exports over total exports is small in many countries. In countries like The Netherlands and Denmark, however, the share is at least 15-20 percent, which is among the higher shares in the world, so here it is <u>not</u> negligible.

Consumption on the territory by non-residents

- Another difference is that the 6.8 billion US$ consumption by non-residents in Denmark that is removed from total household consumption in both tables does not seem to be added to exports in WIOD as it is the case in the Danish table[3].

Large reallocations of taxes on products

- The row total of the item "Taxes less subsidies on products" is very close to the Danish total, but within the row there are huge differences. Thus, around 7.5 billion US$ or close to 30 percent has been moved from household consumption to input in production for reasons that are quite hard to understand.

Dramatic change in the Wholesale trade row

- Moving to the interior of the table there is a large amount of relatively large differences between the same cells in the two versions. The row totals (output) are there same but some redistribution has been going on within the rows.

---

[3] It may have been added as the exports from the various Danish industries it was produced by, but such a procedure has not been possible to verify in any document about WIOD

Most notably in the industry 51 Wholesale, where Danish exports have been cut down by 75 percent and added to investment, household consumption and input in production. This may be due to a different treatment of wholesale trade margins and of exports but it is difficult to understand the reason.

From investment to exports

- Another striking difference is that in the 4 manufacturing industries from 29 to 36t37 almost all deliveries to investment has been removed and added to exports. Although it is probably not a deliberate choice, but a consequence of the balancing procedure is a little strange and may change the outcome of certain analyses and lower the confidence in results somewhat.

2011 comparison (Appendix 3)

As put earlier, 2007 is the most recent year available where Statistics Denmark published an IOT in NACE rev. 1 classification. It was concluded above that even between the comparable 2007 tables there were some major differences between WIOD and Statistics Denmark. So how will it change in the subsequent years? Tables still have to be compiled in the NACE rev. 1 classification but no official data is available?

In order to make the entire time series of input-output tables comparable over time the tables with Danish data for the years 2008-2011 must have been made using some kind of updating procedure based on the 2007 version in order to compile a NACE rev. 1 type table. Even the row and column totals needed for the updating may not have been available in the NACE rev. 1 classification and some conversion from NACE rev. 1 data to NACE rev. 2 data must have been required. Despite the fact that they are to some extent two different things, the 2011 WIOD NACE rev.1 table for Denmark has been compared with the actual 2011 NACE rev. 2 table for Denmark. Results can be seen in Appendix 3.

Ad hoc aggregation of Danish data

In order to make the comparison between the detailed industries the Danish data had to be aggregated from the new 117 industry NACE rev. 2 based classification to the 35 NACE rev. 1 industries in WIOD. This aggregation has been done on an ad-hoc basis just trying to lower the differences in output by industry, because a bridge between the Danish NACE rev. 1 and NACE rev. 2 classifications does not exist for2011.

All cells differ, but not as much as expected

As expected there are no cells that are equal between the two tables. On the other hand the match between the two sets of tables is not as far apart as one would have expected.

At the general level exports and investments differ the most

At the general level some of the same objections arise. Re-exports is missing and so total exports is considerably lower in WIOD than in the Danish table. That is even despite the fact that also for 2011 a large amount of investment has been redistributed from investment to exports. Consequently, investment is also in the 2011 version considerably lower in WIOD than in the Danish SUIOT.

Conclusion on the comparisons

To conclude, the comparison of the two tables from 2007 it can be stated that the fact that a number of the macroeconomic aggregates and central variables by industry from the national IOT's can be recognized in WIOD is commendable. It brings a certain trust in the tables and in the results that can be derived from them. On the other hand the large deviations in some cells draw the trust in the opposite direction. The fact that it is rather complicated to understand how the tables are actually compiled and what has caused the deviations does not help either.

Despite the fact that the 2011 version did not even have a Danish NACE rev. 1 table to lean on it is not as far from the Danish table as expected. However, conducting analyses based on a table where total exports is at least 10 percent below will not be the best starting point.

The 2016 version of WIOD has not been compared with Danish data. It may be a better match. The new version is based on NACE rev. 2 so at least for the newer years it is probably closer to the Danish table, and so here it might be possible to find exact matches for output by industry etc. again.

The question whether or not the deviations between the national tables and WIOD are too large for one country to build its analyses on will be discussed briefly in the next section.

4.3. What can single countries do to get more reliable results?

From the viewpoint of a national statistical institute there are generally two major issues that may hamper the use of MRIO models for official statistics.

1. The large variance in footprints generated by the different MRIOs
2. The differences between the data in the national Statistics and the MRIOs.

These two issues are more or less overlapping. The solution to the first issue is not something that the NSIs really can do anything about. Existing MRIO databases and especially their environmental satellites can be improved and streamlined with the aim of a convergence between the results. However, given the many difference in data, methodology and also the final aims of the models it is probably not something that really can be changed. One solution could be to nominate one of the models to be the one that all countries turn to for their official footprint calculation. Then the other models could specialize in various aspects of the calculations.

The second issue can be dealt with by NSIs, but only very few examples exist so far.

Swedens Prince Project

In the Swedish project "Prince" www.prince-project.se it has been chosen to use a two-step procedure. Firstly MRIO results concerning the environmental pressure related to Swedish imports from various countries is recorded. In the second stage this information is applied to actual Swedish imports from those countries as recorded by the Swedish foreign trade Statistics. It is a relatively simple calculation but it is stated that there is a minor drawback concerning calculation of emissions from goods sent abroad for processing. However, it has been assessed in the Prince project that this problem will not significantly affect the overall results.

CBS: WIOD can be used for official statistics

CBS Netherlands has stated (Hoekstra et al., 2013) that despite the huge differences between WIOD and CBS data it ".. *is conceivable that the WIOD database could still be made useful for official statistical purposes*".

SNAC footprint

Therefore they suggest calculating the so-called SNAC footprint (Single country National Accounts Consistent). This method is based on WIOD methodology and data. The reason for working with WIOD and not one of the other MRIOs is that WIOD is the most open project with a fully transparent production process and availability of SUTs from the various steps of the process.

The method is to intervene at the stage in the WIOD production process where the "intSUTs" (international SUT's) are compiled. At this stage it is possible to replace trade data, so trade data consistent with the national accounts are inserted. Then the entire WIOD table is rebalanced keeping the newly inserted Dutch data intact. The process is described in more detail here (Hoekstra et al., 2013).

SNAC leads to changes in the footprint

The new and adjusted version of WIOD leads to some significant changes in the footprint calculation results. For 2009 the Dutch footprint only drops by 4 percent, but this covers a 9 percent increase in domestic emissions and a large 22 percent decrease in emissions abroad. These results are due primarily to an altered treatment of Dutch re-exports.

5. Review of environmental extensions of the MRIOs

It has often been argued that the main reason for variations in footprint calculation results can be traced back to differences in the emissions data used (Owen et al., 2014). Therefore it is important to pay attention to the exact origin and nature of the emission data applied.

There exists a wide variety of different databases with air emission statistics and accounts. The most important is probably the UNFCCC data inventory that has been collected since the Kyoto treaty was put into force. This is concerned only with territorial emissions and thereby it is not in agreement with the SNA. Many other databases report only territorial emissions as well.

The UNFCCC maintains a comprehensive list of available databases with air emissions http://unfccc.int/ghg_data/ghg_data_non_unfccc/items/3170.php

Other databases like the IEA is based on energy data which in turn is converted to emissions data using IPCC emission factors. Eurostat supplies the SEEA based data by industry. A major source for some models is the EDGAR database provided by an EU Joint Research Center. This database does not have its own data collection but builds upon existing databases. Data are being adjusted for inconsistencies.

The following overview of which databases are used by the various MRIOs is copied from (Wiebe et al., 2015), which also has references to papers where the MRIOs use of environmental data is described.

MRIO	Emissions database used
WIOD	EU SEEA based emissions, IEA energy balances, IPCC emission factors
GTAP	IEA energy data and IPCC
EORA	EDGAR
ICIO OECD	IEA CO_2 emissions, only from fuel combustion
EXIOBASE	IEA energy balances, IPCC etc.

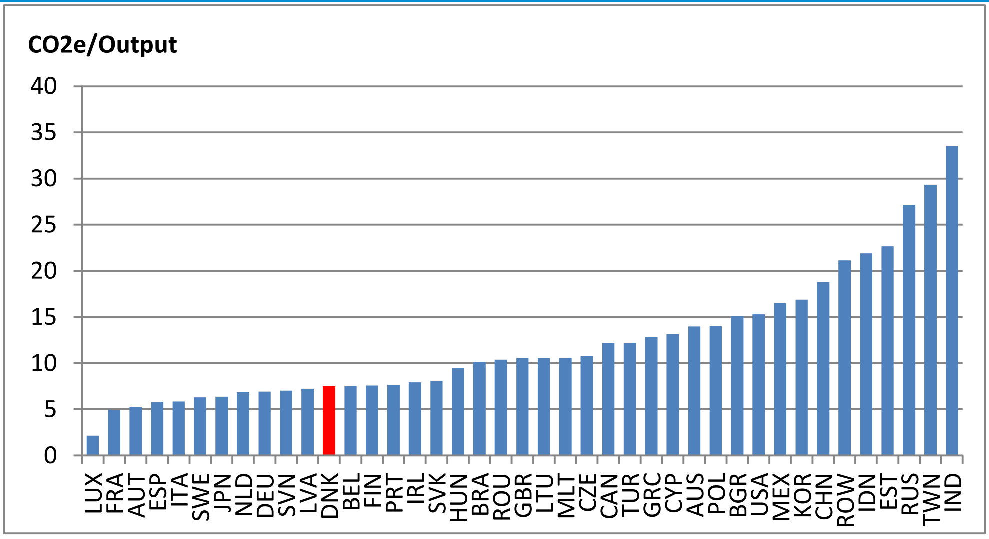
For the models EORA and EXIOPOL a lot of other environmental extensions exist like water consumption, energy, land use etc.

How environmental data are used in the MRIOs

The environmental data necessary for footprint calculations is the national emissions divided by households and the industrial classification used in the particular model. This series of data is then divided by output by industry in order to get the emission intensities that is required as input in the model.

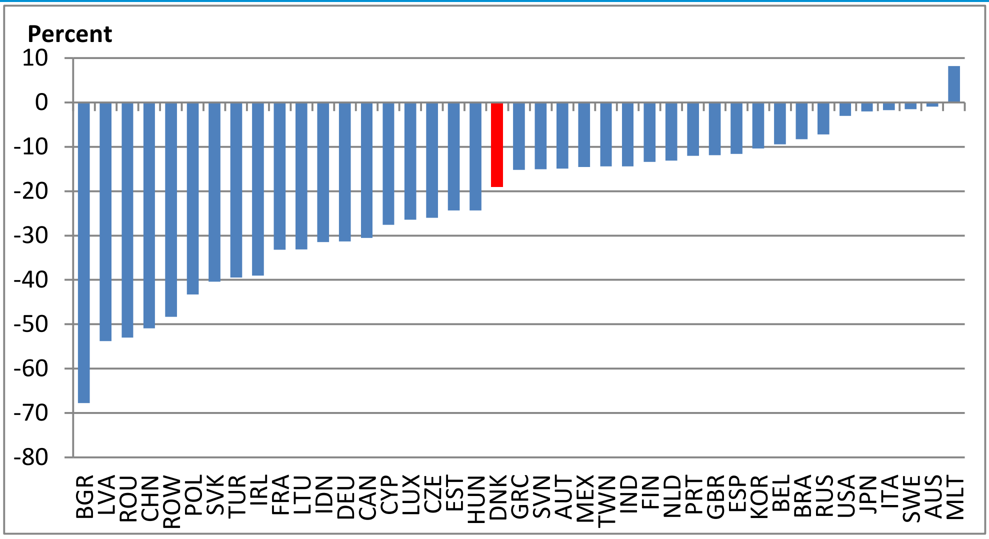
Actually the emission intensities are interesting data as well. The figure below shows the intensities in WIOD 2009.

Figure 5. **GHG emission intensities in WIOD 2009.**



The figure shows that there is a very large variety between countries with regard to the aggregated GHG intensity. Rather low emissions in Luxembourg divided by high outputs leads to the absolutely lowest emission intensity. In the other end we find countries like India, Taiwan and Russia with intensities that are 10-15 times higher than in Luxembourg. It is obvious that in a calculation of carbon footprints it matters really much which countries the main part of your import comes from

Figure 6. **Change in aggregated emission intensities between 1995 and 2009. Total output measured in chained 2005 prices.**



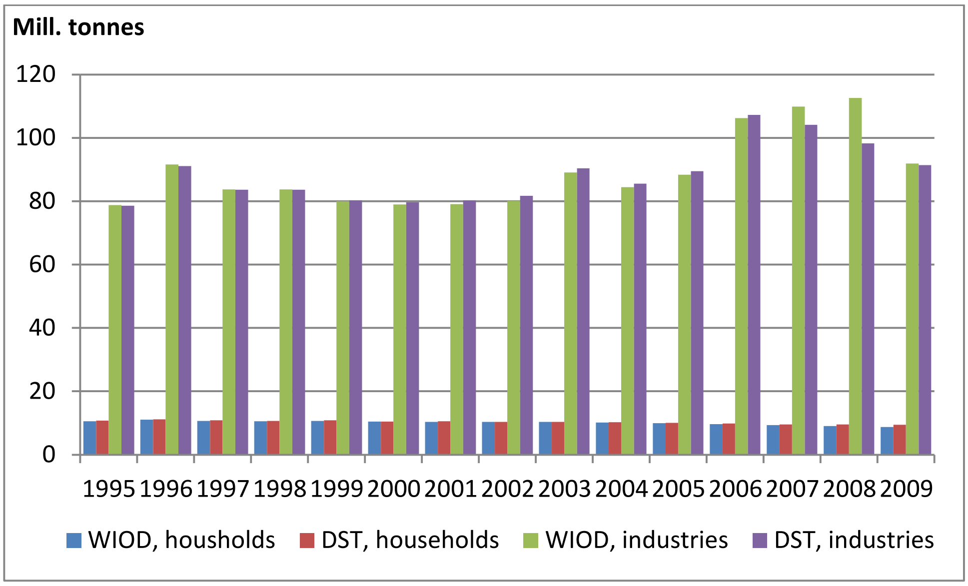
Development in intensities 1995-2009

Another way to look at emission intensities is their development over time. In figure 4 a series of emission intensities in chained 2005 prices is displayed. The fact that WIOD also offers tables in previous years prices (PYP) facilitates this calculation. It is seen that Bulgaria has managed to decrease its general emission intensity by almost 70 percent in the period from 1995 to 2009. China has lowered GHG emissions per output by more than 50 percent in the period. Some of the most developed economies like US, Japan, Sweden etc. have maintained the same emission intensity throughout the period.

Comparison of WIOD emissions data and Statistics Denmark

The WIOD environmental satellite account is for the EU28 countries based on Eurostat air emission accounts and therefore differences between WIOD and Statistics Denmark is not expected. The figure below shows that this assumption is just about right. There is a small disagreement between the two sources, but it is most certainly due to differences in the versions that have been used in this comparison.

Figure 7. **GWP data in WIOD and Statistics Denmark**



Notice that the significant drop in the Danish footprint calculated by WIOD in table 4.1 would have been avoided if the environmental data had been updated to the newest revised version that is used in figure x.

Clearly, it would have been more relevant to compare the Danish data with the data used in other MRIOs than WIOD since they build on other sources than the Eurostat data.

6. Application of MRIOs for environmental purposes

The development of a number of environmentally extended MRIO databases in recent years has fostered a lot of applications published in journal articles (Minx, et al., 2009) and Wiedmann, 2009). The vast majority of these applications are footprint calculations. It is inherent in the construction of the MRIOs that this is the main application. Some studies have built a structural decomposition analysis (SDA) on top of the footprint (Xu and Dietzenbacher, 2014)

So therefore, the next section is devoted to a description of how these MRIOs can actually be applied in practice to calculate footprints for the Danish Economy. In the next section we will take a closer look at the methodology for calculating footprints and later a number of results for the Danish economy are given.

Why make own calculations?

It could be asked why one should bother with this rather complicated data management and algebra programming when footprint results are readily available from the OECD webpage or from the new Environmentalfootprints.org calculator. There are of course arguments in favor of both. It depends on the one hand what you want to use the results for and how detailed and in how many dimensions you want the results to be, and on the other hand if you want to have to possibility to carry out own analyses of how the footprints act to various shocks to the final demand domestically as well as abroad.

6.1. Methodology for calculating footprints

The organization of input-output data in a MRIO is similar to what is known from the normal single country models but has its own specialties as well.

In a single country case we have that

$$\boldsymbol{x} = \sum_1^n \boldsymbol{Z_{i,j}} + \sum_1^m Y_{\boldsymbol{i,k}} \tag{1}$$
$$\boldsymbol{x} = \boldsymbol{z} + \boldsymbol{y}$$

where

x a column vector x_i i=1,....n of output by n industries
Z a matrix $Z_{i,j}$ i,j = 1, ...n, of intermediate deliveries from industry i to industry j.
Y a matrix Yi,k i=1,....n and k=1,...m with deliveries from industry i to final demand category k. There are m different categories of household consumption, NPISH, government consumption, investment, changes in stocks and exports.
i is a summation vector consisting of ones with the length n

Dividing the matrix **Z** by the output vector gives us the coefficient matrix A

$$\boldsymbol{A} = \boldsymbol{Z}\widehat{\boldsymbol{x}^{-1}} \tag{2}$$

Now we can calculate the Leontief inverse matrix

$$\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-1} \tag{3}$$

Where **L** is the famous matrix of input-output multipliers.

We now calculate a vector of CO_2 emission intensities

$$\boldsymbol{e} = \boldsymbol{c}\widehat{\boldsymbol{x}^{-1}} \tag{4}$$

Where

e is a column vector of CO_2 emission intensities by industry
c is a column vector of CO_2 emissions by industry

So now we can introduce an input-output model that gives us total emissions of CO_2 by industry

$$\boldsymbol{c} = \boldsymbol{e}'(\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y} \tag{5}$$

where

I an identity matrix of zeros with ones in the main diagonal

In order to get the total emission of CO_2 in the economy we need to add the direct emissions by households. Here we will insert them in a vector

f A vector of zeros with direct emissions by households (electricity, heating fuel for transport equipment) inserted by the industries that delivered them

So finally we insert it into (5)

$$\boldsymbol{c} = \boldsymbol{e}'(\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y} + \boldsymbol{f} \tag{6}$$

So this model can tell us how much the domestic emission of CO_2 by industries will increase if we increase final demand of y by Δy. Naturally, we can let y be the entire final demand including exports or we can omit exports and go with domestic final demand alone.

From domestic emission to carbon footprint

By expanding the single country input-output table to a multiregional input-output table / model we would like to be able to get an answer to the question “How much is the emission of CO_2 in the world as a consequence of the Danish domestic final demand?” The answer to that will be the Danish carbon footprint.

Organisation of the MRIO

In the figure below the typical organization of a MRIO model is displayed. In this case it only consists of three countries; Denmark and two other countries. Typically the MRIOs will have Rest of World (RoW) as one of the countries.

Figure 8. **Typical organization of a MRIO table**

	Intermediate consumption			Final demand			
	Country 1 1,….n	Denmark 1,….n	Country 3 1,…..n	Country 1 1,..m	Denmark 1,…m	Country 3 1,…m	Total use
Country 1 1,…n	..	Danish intermediate inputs imported from country 1	..	..	Danish domestic final demand imported from country 1	..	
Denmark 1,…n	Danish exports of intermediates to country 1	Danish intermediate inputs produced in Denmark	Danish exports of intermediates to country 3	Danish exports to final demand in country 1	Danish domestic final demand produced in Denmark	Danish exports to final demand in country 3	
Country 3 1,…n	..	Danish intermediate inputs imported from country 3	..	..	Danish domestic final demand imported from country 3	..	
Taxes							
GVA							
Output							

Now cells are matrices

The matrix **Z** that we had in the single country case is now placed in diagonal of the MRIO. Here the Danish Z table with deliveries of intermediate inputs from one Danish industry to another is situated in the middle of the table in the intersection between Denmark and Denmark. We see that these are not just cells they are full (n,n) sized matrices, where n indicates the number of industries common for the specific MRIO.

Danish Imports

The entry in row one, column 2, is a (n,n) matrix of all deliveries from country 1 to Denmark. That means all of the Danish imports from country 1 that is used as intermediate inputs. This is the same in row 3, column 2 where intermediate inputs from country 3 to Denmark is recorded.

Danish exports

Entry (2,1) contains a matrix of Danish exports to country 1 that is used as intermediate consumption. And the same thing goes for the entry (2,3) which is for country 3.

Thus, the first (3,3) matrix is the equivalent of the Z matrix in the single country example above. There is the difference, that this full matrix (3n, 3n) now includes exports. Normally exports in the single country model is exogenous just like the other parts of final demand, but here the part of exports which is used as inputs in production is endogenous. It has become part of the matrix that will be used to calculate the Leontief inverse of this MRIO. It means that the math for doing the modelling must be changed slightly.

Final demand

For the final demand part the same structure applies. It is indicated in the figure that final demand is split into m categories. In the single country models this m can be quite large including many categories of household consumption, government consumption investment. In the full Danish model m is 136. But in all of the MRIOs we have seen so far final demand is typically only 5 categories i.e. the total household consumption, NPISH, government consumption, capital formation and changes in stocks. In the figure we have in the Danish final demand the domestically produced part in entry (2,2) and the imports just for final demand in entries (1,2) and (3,2).

Notice, that in some MRIOs the final demand is organized differently. There we will have e.g. household consumption first by all the countries in the model and after that NPISH by all the countries in the model etc.

Output by industries

At the right hand end of the table we have a (3n,1) vector of output by n industries in the three countries involved here.

A mathematical extension of this table into a world model that is the counterpart of (6) above could be the following. Adapted from (Wiebe and Yamano, 2015), The three country example is carried forward.

The MRIO model in math

$$\begin{bmatrix} \boldsymbol{c}^{11} & \boldsymbol{c}^{12} & \boldsymbol{c}^{13} \\ \boldsymbol{c}^{21} & \boldsymbol{c}^{22} & \boldsymbol{c}^{23} \\ \boldsymbol{c}^{31} & \boldsymbol{c}^{32} & \boldsymbol{c}^{33} \end{bmatrix} = \begin{bmatrix} \widehat{\boldsymbol{e}^1} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \widehat{\boldsymbol{e}^2} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \widehat{\boldsymbol{e}^3} \end{bmatrix} \begin{bmatrix} \boldsymbol{I}-\boldsymbol{A}^{11} & \boldsymbol{I}-\boldsymbol{A}^{12} & \boldsymbol{I}-\boldsymbol{A}^{13} \\ \boldsymbol{I}-\boldsymbol{A}^{21} & \boldsymbol{I}-\boldsymbol{A}^{22} & \boldsymbol{I}-\boldsymbol{A}^{23} \\ \boldsymbol{I}-\boldsymbol{A}^{31} & \boldsymbol{I}-\boldsymbol{A}^{23} & \boldsymbol{I}-\boldsymbol{A}^{33} \end{bmatrix}^{-1} \begin{bmatrix} \boldsymbol{y}^{11} & \boldsymbol{y}^{12} & \boldsymbol{y}^{13} \\ \boldsymbol{y}^{21} & \boldsymbol{y}^{22} & \boldsymbol{y}^{23} \\ \boldsymbol{y}^{31} & \boldsymbol{y}^{32} & \boldsymbol{y}^{33} \end{bmatrix} + \begin{bmatrix} \widehat{\boldsymbol{f}^1} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \widehat{\boldsymbol{f}^2} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \widehat{\boldsymbol{f}^3} \end{bmatrix}$$

Here we have the c_i^{rs} which are

$\mathbf{c^{rs}}$ is a (3,1) vector of CO_2 emissions related to final demand in country *s* emitted by industry *i* in country *r*.
$\widehat{\mathbf{e^r}}$ is a (3,3) matrix of zeros with e^r in the diagonal indicating the emission intensities by industry i, i=1,..3 in country r.
$\mathbf{A^{rs}}$ is the (3,3) coefficient matrix of country r's input into country s' production.
$\mathbf{y^{rs}}$ is the (3,1) vector of demand in country *s* for final products produced by country *r*
$\widehat{\mathbf{f^r}}$ is a (3,3) matrix of zeros with f^r in the diagonal indicating the direct emissions by households included under supplying industry i, i=1,..3 in country r.

The result

So the result of this calculation is a (9,3) matrix

$$\begin{bmatrix} c_1^{11} & c_1^{12} & c_1^{13} \\ c_2^{11} & c_2^{12} & c_2^{13} \\ c_3^{11} & c_3^{12} & c_3^{13} \\ c_1^{21} & c_1^{22} & c_1^{23} \\ c_2^{21} & c_2^{22} & c_2^{23} \\ c_3^{21} & c_3^{22} & c_3^{23} \\ c_1^{31} & c_1^{32} & c_1^{33} \\ c_2^{31} & c_2^{32} & c_2^{33} \\ c_3^{31} & c_3^{32} & c_3^{33} \end{bmatrix} \tag{7}$$

Production based result

Now if we assume that Denmark is country number 2 we can get from this matrix, the total production based emissions by industry by summing the three Danish rows

$$\begin{bmatrix} \mathrm{c}_1^2 \\ \mathrm{c}_2^2 \\ \mathrm{c}_3^2 \end{bmatrix} = \sum_{s}^{1;3} \mathrm{c}_\mathrm{i}^{2,\mathrm{s}}$$

Consumption based result

In order to get the final result for the consumption based emission or the carbon footprint we have to sum the entire second column

$$\begin{bmatrix} c_1^2 \\ c_2^2 \\ c_3^2 \end{bmatrix} = \sum_{r}^{1;3} c_i^{r,2}$$

which is the Danish footprint by industry, domestic as well as foreign. Or we can sum over industries so we get the footprint by country

$$\begin{bmatrix} c^1 \\ c^2 \\ c^3 \end{bmatrix} = \sum_{i}^{1;3} c_i^{r,2}$$

So in this vector c^2 is the domestic emission caused by the domestic final demand while c^1 and c^3 are the emissions in countries 1 and 3 respectively caused by imports that is required for the Danish domestic final demand.

Footprint result as a matrix

Naturally, the (9,1) vector of footprint results can be converted to a (3,3) matrix that gives the footprint by country as well as industry, which may be a useful result.

Further use of the model

It is obvious that the footprint model above can be used not only with the full final demand vector of all countries but various shocks to the model can be made, like e.g. using only the investment part of final demand or a shock to household consumption delivered by a certain industry and so on.

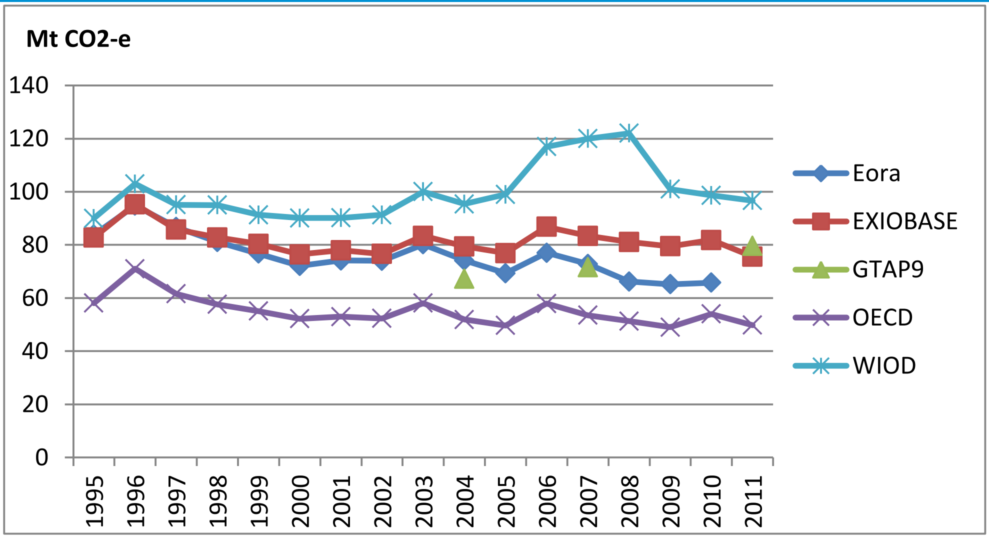
6.2. Applications to Danish data

In the following section a number of different results are show that are the results of running the WIOD model and it is mixed with results from the OECD ICIO model that have been downloaded directly from the OECD homepage (so it is not necessary to run the model yourself except if more special analyses are conducted). Also results from the aforementioned new user interface to a number of the large MRIOs will be applied.

Extension of the CO_2-e series of data supplied with the WIOD model from 2009 through 2011

Many users of WIOD are sad that the environmental satellite only covers a period up till 2009. In the present project the series was extended to 2011 by applying real emissions data from Statistics Denmark for calculating the Danish CO_2-e emission intensities. For the rest of the countries the growth rates 2009-2011 that can be found in the OECD series of emission intensities, was applied to the WIOD 2009 data in order to extent the series. The OECD series of emission intensities was kindly supplied by the OECD. Naturally this is just a crude way of updating the numbers, but for this pilot study it was accepted.

Figure 9. **Production based emissions of CO_2-e in Denmark 1995-2011**



The first thing that we take a closer look at is the production based emissions. This statistics is not really something that a MRIO is needed for, but it gives a picture of the level of the emission extensions that are used within each of the models

OECD figures only cover emissions partly

The figure shows that there is a huge difference between the MRIO databases already concerning the satellite account of emissions data. As we know from before the OECD numbers are low because they only cover CO_2 burning from fossil fuels.

WIOD have the highest emissions

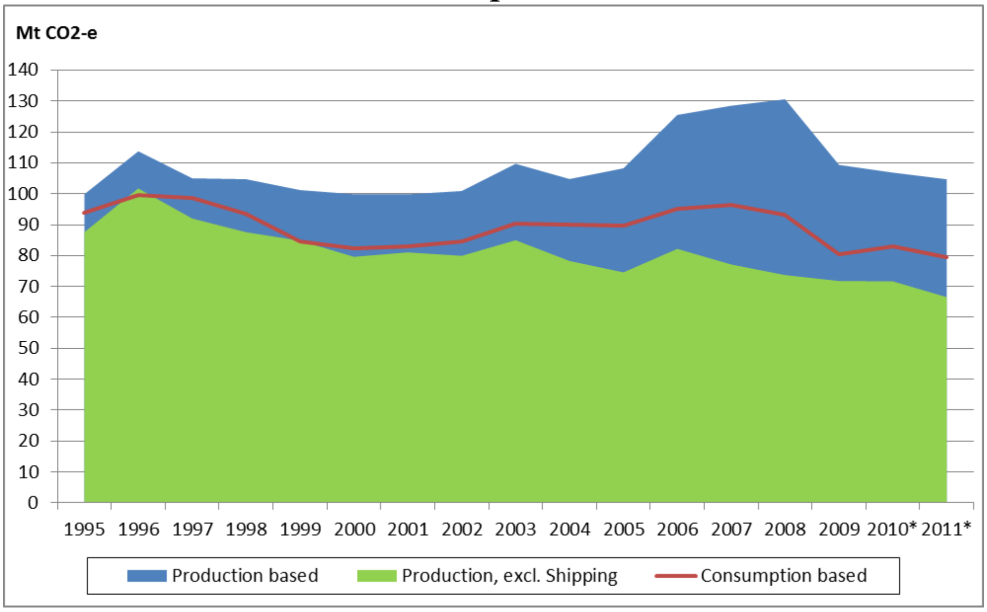
As the only ones the GTAP numbers are increasing between 2004 and 2011 but their level is pretty much in sync with some of the other databases. Emissions in EORA that comes from the EDGAR database is a somewhat lower than they are in EXIOBASE. Of all the databases WIOD have the by far highest numbers for Danish emissions.

Transport by sea is the difference

As mentioned previously the Danish emission data that goes into WIOD are those supplied by Statistics Denmark to Eurostat. They are compiled according to the SEEA guidelines and therefore contain the huge emissions that take place all over the world but in the end can be attributed to the Danish shipping companies. Already at this point it is clear that the footprint calculations are bound to yield quite different results as well.

The next graph is the result of own calculations in this project on the WIOD database.

Figure 10. **The Danish WIOD based CO2-e footprint.**



Note: Emission intensities for 2010 and 2011 is own calculation

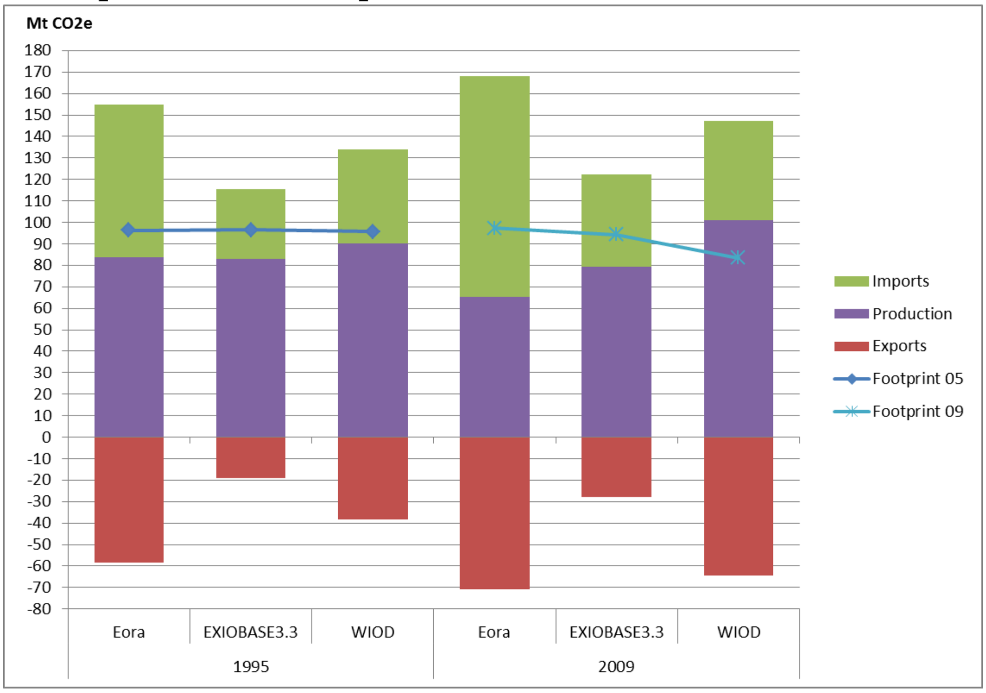
Danish CBA is LOWER than PBA

The figure show that contrary to most other western economies the Danish CO_2-e footprint or CBA is actually lower than the production based measure. If emissions from export of shipping services we have the more normal picture where the footprint is higher than the production based measure. There is a slight decrease in the footprint over time, but not as much as in the production based measure without shipping.

Footprint calculated with 3 different models

In the next graph the Danish footprint is calculated with three different models. This time the domestic production, and the Imports and exports are shown as well. This time only results for 1995 and 2009 are shown.

Figure 11. **Decomposition of the footprint calculation for Denmark**

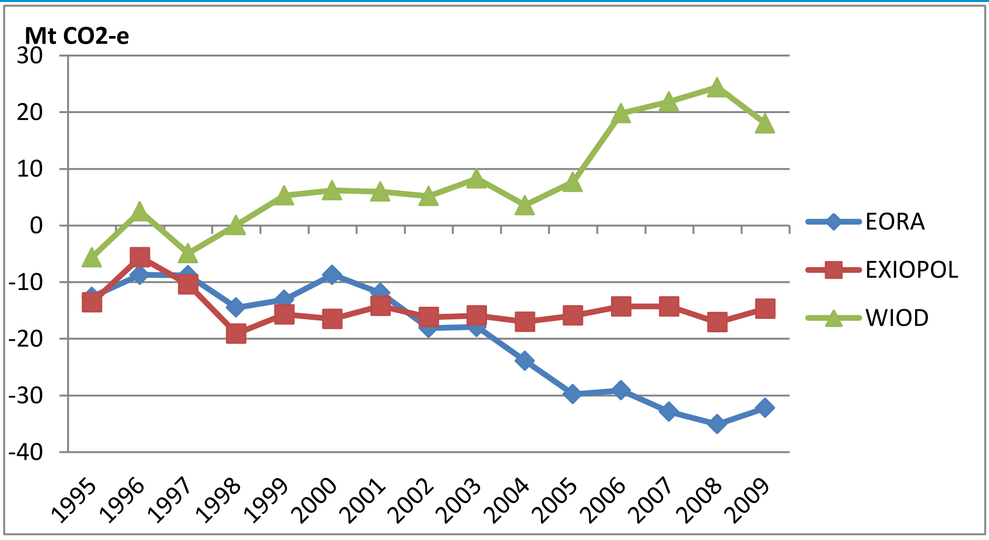


Lots of differences at a more detailed level.

Results show a remarkable resemblance between the footprints calculated by the three models in 1995 and to some degree in 2009 as well. When we look at it in a little more detail we see that there are huge differences between the models when it comes to calculation of emissions contents in the three components production, imports and exports. The EXIOBASE seem to ascribe a lot less emissions to the Danish foreign trade than the other two models.

For 2009 we note again that the footprint is lower than the WIOD emissions from production. We also see that the emissions that EORA finds in the Danish imports is very large compared to the other two models. It could be because the CO_2-e emissions include a lot of emissions from land use changes in EORA which are not the case for the other models.

Figure 12. **Difference between the emission content in Danish exports and imports.**



Denmark would gain from a change from PBA to CBA

This is another evidence of the effect that the Danish transport by ships sector has on the footprint results. It is included in WIOD and the result is that Denmark would reduce its official level of emissions if practice was changed from the production perspective to a consumption perspective.

There is in the calculations with WIOD the possibility to use parts of final demand instead of as is mostly always the case total domestic final demand. The two graphs below show the level of emissions embodied in household consumption, NPISH, Government consumption, gross fixed capital formation and changes in stocks

Figure 13 **CO_2-e emissions embodied in final demand by category**

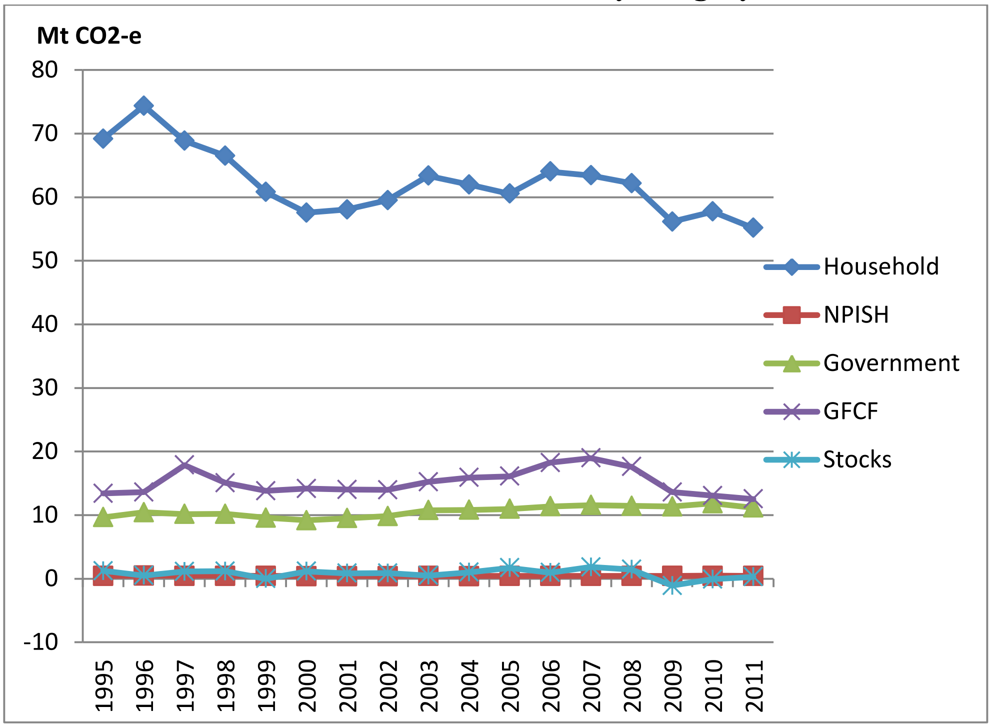
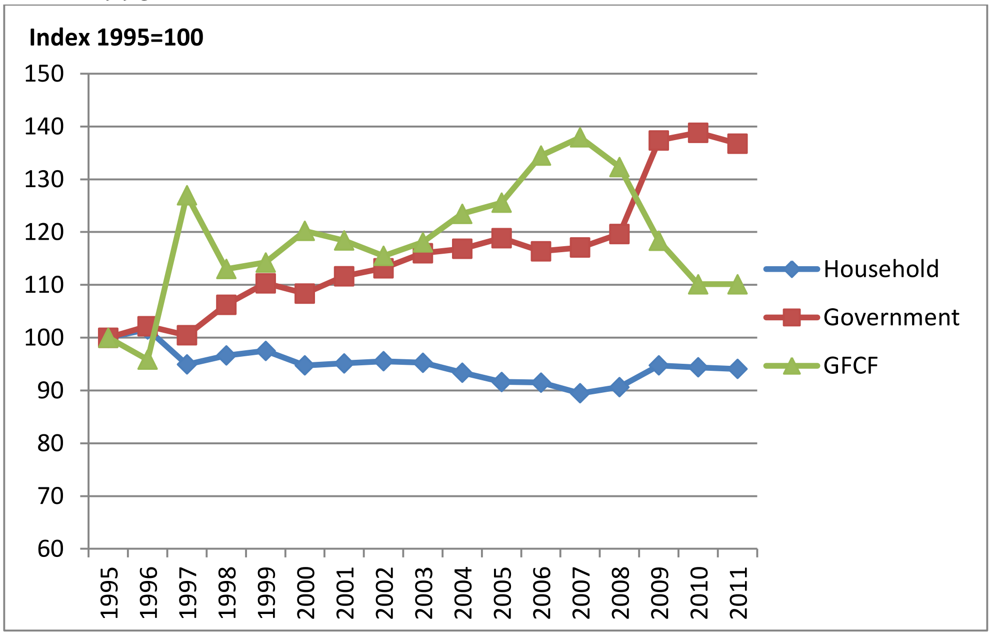


Figure 14. **Delopment in CO_2-e emissions embodied in final demand by category. Index 1995 = 100.**



The first graph shows that household consumption is a very dominating item in this account. Throughout the period around 70-75 percent of the Danish footprint can be attributed to household consumption. The gross fixed capital formation gives rise to some emissions as well, especially in the periods of growth in the economy (2005-2007).

Government consumption has increased its contribution

Although household consumption takes up such a large part it is actually decreasing slightly over time as shown in figure x. The government consumption on the other hand, has increased its contribution to the Danish footprint by more than 40 percent from 1995 to 2011.

Results by sector

Another possibility in the very detailed material that comes out of

Figure 15. **Contribution to the Danish footprint by the Energy sector in DK and RoW caused by Danish final consumption**

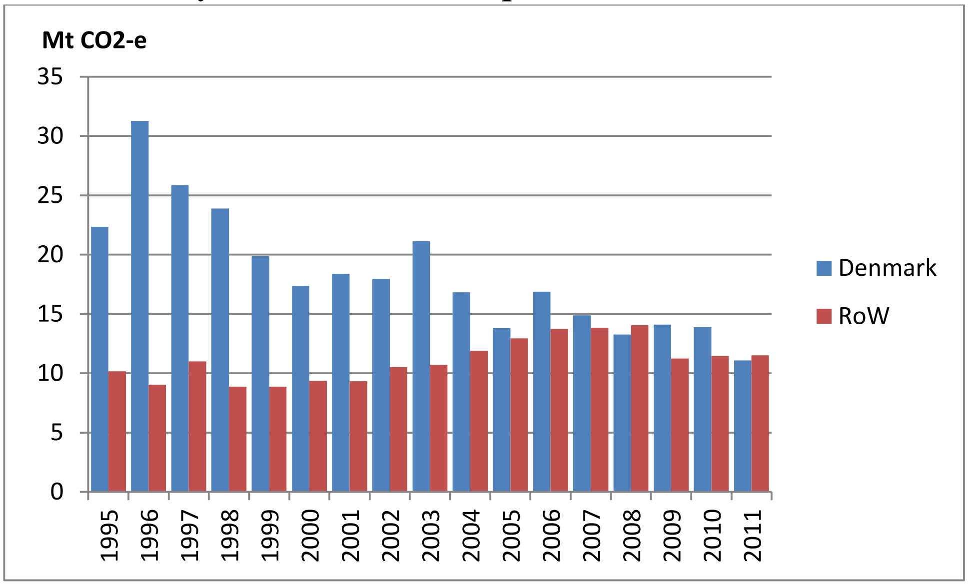
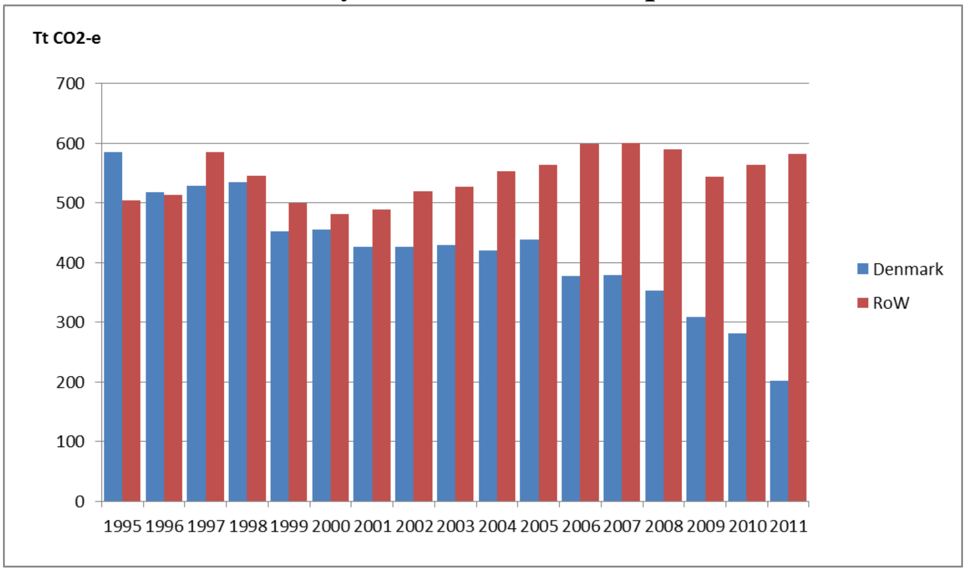


Figure 16. **Contribution to the Danish footprint by the Food and beverages sector in DK and RoW caused by Danish final consumption**



Decreasing contribution from Danish energy and slaughterhouses

The figure x show the contribution by the domestic Energy sector to Danish footprint caused by domestic final demand. It is obvious the Danish energy sector has really managed to produce energy in a less polluting way and at the same time demand for energy in general has come down as well. The contribution from the foreign energy sector has been more or less constant which probably covers some underlying increases in the amount of energy and a decrease in emissions per unit of energy.

The second figure shows a quite steep decrease in the emissions from the Danish food industry in recent years. This is probably due to the fact that a number of Danish slaughterhouses have been shut down and then opened up in other countries.

The last figures deals with the burdens that Danish domestic final demand put on various countries in the world

Figure 17 **Danish footprints 1995 and 2011 by country, WIOD.**

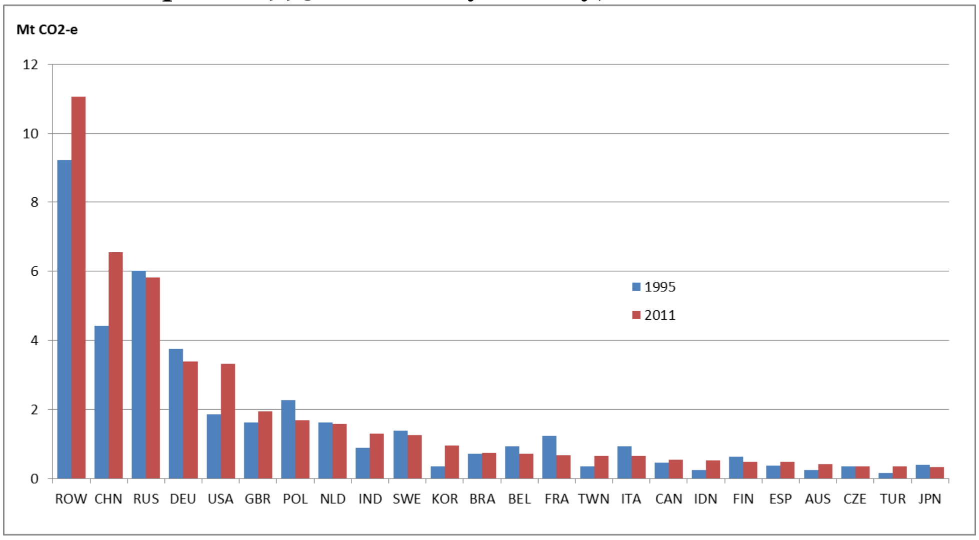
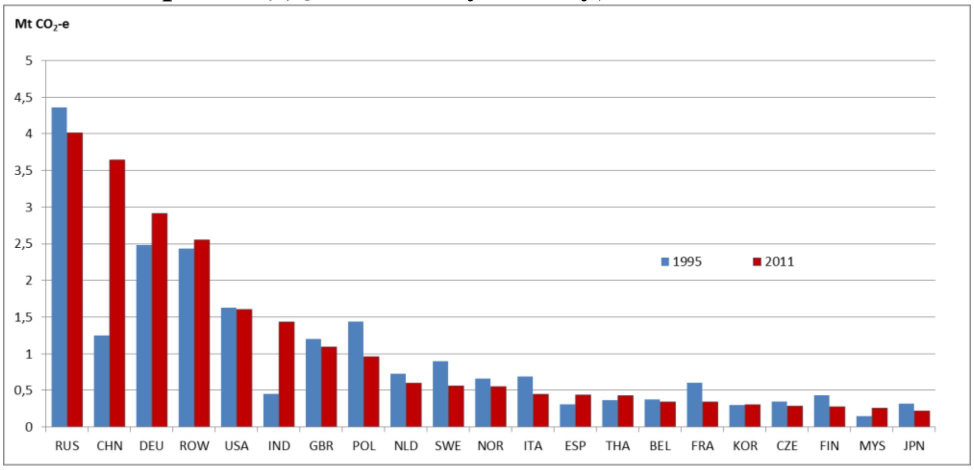


Figure 18 **Danish footprints 1995 and 2011 by country, OECD.**



Lots of "Danish" emissions in RoW

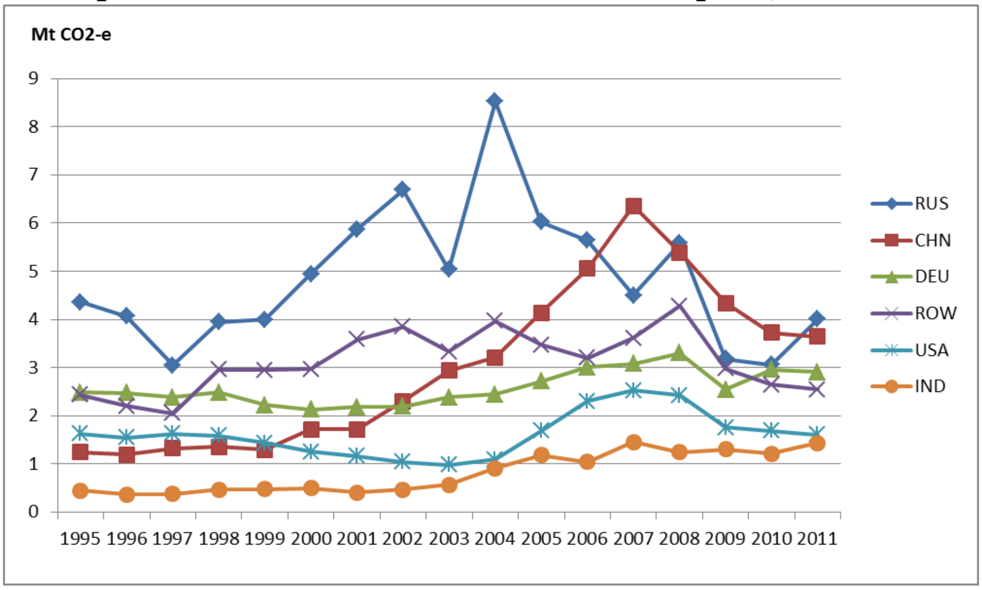
Again it shows that there is a huge difference between results obtained with WIOD and other models. The WIOD based calculation attributes around 10 percent of the total footprint to countries in RoW. It is a little surprising considering that although the model only covers about ¼ or less of all the countries in the world the Danish foreign trade must be concentrated between the countries actually inside the model. At closer inspection it turns out that emission from agriculture plays a large role here as well as output from electricity generation and crude (bunkering oil.)

Large emissions in Russia due to Danish consumption

It is somewhat surprising also, to see how much emissions in Russia are caused by the Danish consumption. In the Wiod version Russia ranks as number 2-3 whereas they are number 1 in the OECD version in 1995 as well as in 2011. There has been much talk about Danish emissions being exported to China but little has been said about the large burden that the Danish consumption activities put on the Russian production based emission account.

According to the WIOD version the countries where emissions is increased due to Danish consumption are Row, China, India and USA whereas the decreases are found in countries like Russia, Germany and Poland.

Figue 19. **Development in emissions embedded in Danish imports, OECD**



"Danish" emissions in Russia peaked in 2004

Between 1995 and 2011 quite some changes have happened to the amounts of emission caused by Danish consumption in other countries. Emissions in Russia doubled from 1995 to 2004 where after they have dropped again and are back at the initial level now.

The steep incline in emissions in China that everybody is talking about actually happened from 1995 to 2007 but since these emissions have dropped quite a lot again probably due to the financial crises but have not really picked up again after the crisis.

7. Conclusion

It has been argued in this project that there is a need to supplement the production based accounting method with something that is fairer and brings about more efficient environmental policies. After a brief review of the huge literature in this area it was concluded that there are some good alternatives being developed but none of them seems to be the golden answer everybody is looking for.

One of the most promising is the consumption based accounting which requires a multiregional input-output model to calculate. After a closer look at a handful of the models and a careful examination of the representation in WIOD of one of the Danish input-output tables it was concluded that the models are quite different in many aspects and so are the results. It was therefore concluded that work needs to be done to make the model results converge better or to adapt the model for country specific application to bring them in sync with the national accounts.

Finally it was concluded that despite the objections people may have to the MRIOs as a tool for compiling relevant and reliable information for environmental policy it is a wonderful tool. No matter if results are calculated directly on the models or they are retrieved from homepages or databases they constitute really useful insights into the world wide emissions of greenhouse gasses coming from domestic final demand. Such results are an obvious supplement to any green national accounting although the fact the newest results are from 2011 may cool down the interest somewhat. In order to be relevant as a tool for making international policy decisions, global MRIO databases need to be created and updated in a timely, continuous, consistent and cost-effective way (Wiedmann et al., 2011)

8. References

Afionis, S., Sakai, M., Scott, K., Barrett, J. and Gouldson, A. (2017), Consumption-based carbon accounting: does it have a future?. WIREs Clim Change, 8: n/a, e438. doi:10.1002/wcc.438

Aurélien Genty (ed) (2012), "FINAL DATABASE OF ENVIRONMENTAL SATELLITE ACCOUNTS: TECHNICAL REPORT ON THEIR COMPILATION", WIOD Deliverable 4.6, Documentation, downloadable at http://www.wiod.org/publications/source_docs/Environmental_Sources.pdf

Aichele R, Felbermayr G. (2015) Kyoto and Carbon Leakage: An Empirical Analysis of the Carbon Content of Bilateral Trade. Review Of Economics And Statistics [serial online]. March 2015;97(1):104-115. Available from: EconLit with Full Text, Ipswich, MA.

Dietzenbacher, E., Los, B., Stehrer, R., Timmer, M., & de Vries, G. (2013) THE CONSTRUCTION OF WORLD INPUT–OUTPUT TABLES IN THE WIOD PROJECT, Economic Systems Research, 25:1, 71-98, DOI: 10.1080/09535314.2012.761180

Hoekstra, R. B. Edens and H. Wilting, (2012). Footprint calculations from the perspective of National Statistical Institutes. Paper prepared for the final WIOD Conference: Causes and Consequences of Globalization, Groningen, The Netherlands, April 24-26, 2012.

Hoekstra, R., Zult, D., Edens, B., Lemmers, O., Wilting, H. and Wu, R. (2013) ”Producing Carbon Footprints that are Consistent to the Dutch National Accounts” Paper presented for the 21st International Input-Output Conference July 9-12th 2013. Kitakyushu, Japan.

Kander, A., Jiborn, M., Moran, D. D. & Wiedmann, T. (2015) “National greenhouse-gas accounting for effective climate policy on international trade” Nature Climate Change 5, 431–435 (2015) doi:10.1038/nclimate2555

Lenzen, M., Kanemoto, K., Moran, D., Geschke, A. (2012) "Mapping the Structure of the World Economy" Environmental Science & Technology, 46(15), pp.8374-8381, 2012.

Lenzen, M., Kanemoto, K., Moran, D., Geschke, A. (2013) "Building Eora: a Global Multi-Region Input-Output Database at High Country and Sector Resolution" Economic Systems Research, 25(1), pp.20-49, 2013.

Marques, A., Rodrigues, J., Lenzen, M., Domingos, T. (2012) “Income-based environmental responsibility”. Ecological Economics, Volume 84, December 2012 , Pages 57-65.

Minx, J., Wiedmann, T., Wood, R., Peters, G., Lenzen. M, Owen, A., Scott, K., Barrett, S., Hubacek, K., Baiocchi, G., Paul, A., Dawkins, E., Briggs, J., Guan, D., Suh, S. & Ackerman, F. (2009) INPUT–OUTPUT ANALYSIS AND CARBON FOOTPRINTING: AN OVERVIEW OFAPPLICATIONS, Economic Systems Research, 21:3, 187-216, DOI: 10.1080/09535310903541298

Moran, D., & Wood, R. (2014) CONVERGENCE BETWEEN THE EORA, WIOD, EXIOBASE, AND OPENEU'S CONSUMPTION-BASED CARBON ACCOUNTS,Economic Systems Research, 26:3, 245-261, DOI: 10.1080/09535314.2014.935298

Owen, A., K. Steen-Olsen, J. Barrett, T. Wiedmann and M. Lenzen (2014). "A structural decomposition approach to comparing MRIO databases", Economic Systems Research, 26(3), pp.262–283. DOI:http://dx.doi.org/10.1080/09535314.2014.935299

Peters G.P. and Hertwich E.G., (2008) CO2 embodied in international trade with implications for global climate policy, Environment Science and Technology, Accepted December 18, 2007

Peter G.P., Minx, J.C., Weber, C.L. and Edenhofer, O. (2011) “Growth in emission transfers via international trade from 1990 to 2008. *Proc. Natl. Acad. Sci. USA* **108**, 8903-8908, 2011.

Rørmose Jensen, P., Olsen, T., Hansen, D. (2009). "GHG emissions embodied in trade". Report to European Commission, DG Eurostat E3, Environmental Accounts. Grant Agreement No. 50304.2008.001. December 2009.

Rørmose, P. Olsen, T. Hansen, D. (2010), ” CO2 Emissions Embodied in Danish Import. A Unidirectional Trade Model with 51 Countries.” Paper prepared for the 19th International Conference on Input-output Techniques 21-25 June, 2010 in Sydney, Australia.

Stadler, K., Lonka, R., Moran, D., Pallas, G, Wood, R. (2015) The Environmental Footprints Explorer - a database for global sustainable accounting. The Environmental Footprints Explorer - a database for global sustainable accounting. EnviroInfo & ICT4S, Adjunct Proceedings (Part 2).

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R. and de Vries, G. J. (2015), "An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production", Review of International Economics., 23: 575–605

Tukker, A., de Koning, A., Wood, R., Hawkins, T., Lutter, S., Acosta, J., Rueda Cantuche, J.M., Bouwmeester, M., Oosterhaven, J., Drosdowski, T., Kuenen, J. EXIOPOL - DEVELOPMENT AND ILLUSTRATIVE ANALYSES OF A DETAILED GLOBAL MR EE SUT/IOT (2013) Economic Systems Research, 25 (1), pp. 50-70. http://www.scopus.com/inward/record.url?eid=2-s2.0-84874067056&partnerID=40&md5=c6b58178ca58c18e0dccfc9723a56740

Wiebe, K. and N. Yamano (2016), “Estimating CO2 Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015: Methodology and Results”, *OECD Science, Technology and Industry Working Papers*, 2016/05, OECD Publishing, Paris. http://dx.doi.org/10.1787/5jlrcm216xkl-en

Wiedmann, T. (2009). A review of recent multi-region input-output models used for consumption-based emission and resource accounting. Ecological Economics, 69(2), 211-222. DOI: 10.1016/j.ecolecon.2009.08.026

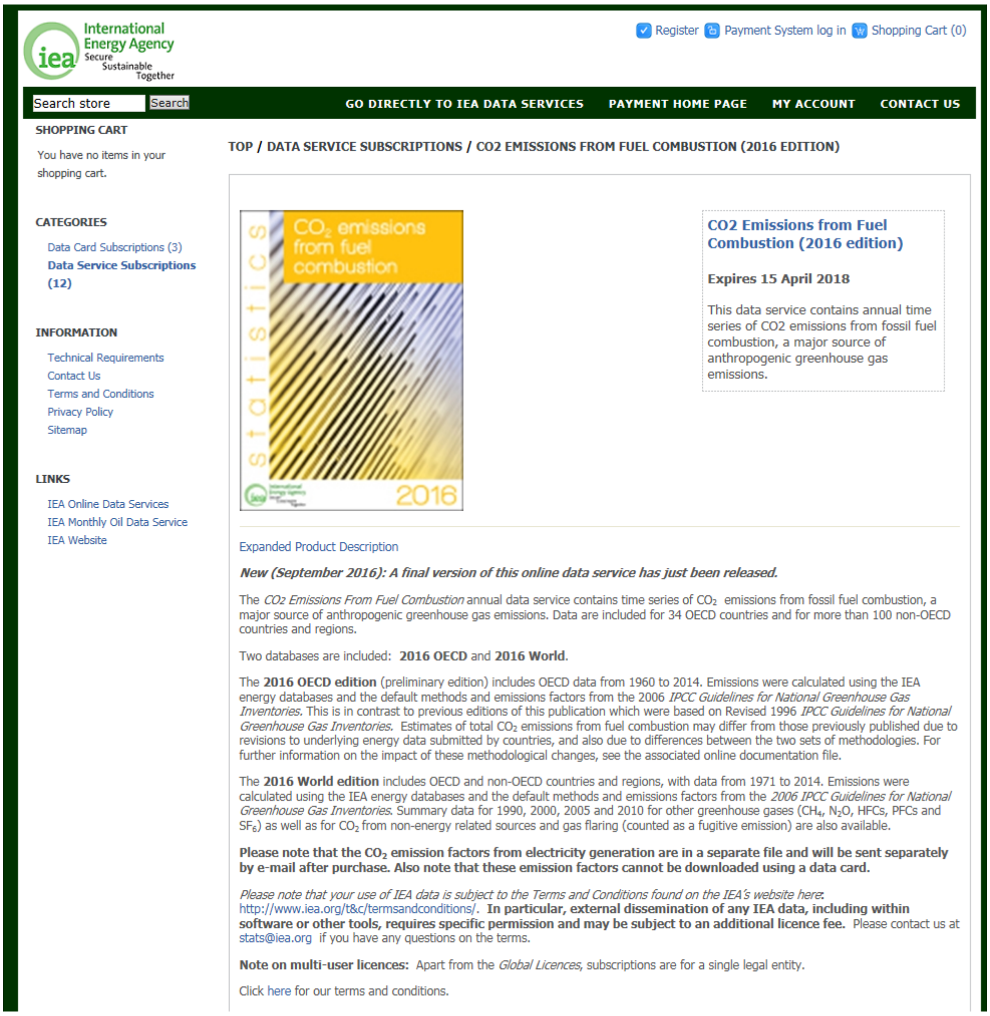
Wiedmann, T.; Wilting, H. C.; Lenzen, M.; Lutter, S.; Palm, V. Quo Vadis MRIO? Methodological, data and institutional requirements for multi-region input-output analysis. Ecological Economics. (2011); 70(11):1937-1945. https://doi.org/10.1016/j.ecolecon.2011.06.014

Wood, R., Stadler, K., Bulavskaya, T., Lutter, S., Giljum, S., de Koning, A., Kuenen, J., Schütz, H., Acosta-Fernández, J., Usubiaga, A., Simas, M., Ivanova, O., Weinzettel, J., Schmidt, J.H., Merciai, S., Tukker, A. Global sustainability accounting-developing EXIOBASE for multi-regional footprint analysis (2015) Sustainability (Switzerland), 7 (1), pp. 138-163. http://www.scopus.com/inward/record.url?eid=2-s2.0-84922476522&partnerID=40&md5=f037db6757a45173cbb6e5d787d74b9d

Xu, Y. & Dietzenbacher, E. (2014) A structural decomposition analysis of the emissions embodied in trade In : Ecological Economics. 101, p. 10-20 11 p

9. Appendices

http://data.iea.org/payment/products/115-co2-emissions-from-fuel-combustion-2016-edition.aspx


International Energy Agency
Secure Sustainable Together

Register | Payment System log in | Shopping Cart (0)

Search store | Search

GO DIRECTLY TO IEA DATA SERVICES | PAYMENT HOME PAGE | MY ACCOUNT | CONTACT US

SHOPPING CART

You have no items in your shopping cart.

CATEGORIES

Data Card Subscriptions (3)
Data Service Subscriptions (12)

INFORMATION

Technical Requirements
Contact Us
Terms and Conditions
Privacy Policy
Sitemap

LINKS

IEA Online Data Services
IEA Monthly Oil Data Service
IEA Website

TOP / DATA SERVICE SUBSCRIPTIONS / CO2 EMISSIONS FROM FUEL COMBUSTION (2016 EDITION)

CO2 Emissions from Fuel Combustion (2016 edition)

Expires 15 April 2018

This data service contains annual time series of CO2 emissions from fossil fuel combustion, a major source of anthropogenic greenhouse gas emissions.

Expanded Product Description

New (September 2016): A final version of this online data service has just been released.

The *CO2 Emissions From Fuel Combustion* annual data service contains time series of CO_2 emissions from fossil fuel combustion, a major source of anthropogenic greenhouse gas emissions. Data are included for 34 OECD countries and for more than 100 non-OECD countries and regions.

Two databases are included: **2016 OECD** and **2016 World**.

The **2016 OECD edition** (preliminary edition) includes OECD data from 1960 to 2014. Emissions were calculated using the IEA energy databases and the default methods and emissions factors from the 2006 *IPCC Guidelines for National Greenhouse Gas Inventories*. This is in contrast to previous editions of this publication which were based on Revised 1996 *IPCC Guidelines for National Greenhouse Gas Inventories*. Estimates of total CO_2 emissions from fuel combustion may differ from those previously published due to revisions to underlying energy data submitted by countries, and also due to differences between the two sets of methodologies. For further information on the impact of these methodological changes, see the associated online documentation file.

The **2016 World edition** includes OECD and non-OECD countries and regions, with data from 1971 to 2014. Emissions were calculated using the IEA energy databases and the default methods and emissions factors from the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Summary data for 1990, 2000, 2005 and 2010 for other greenhouse gases (CH_4, N_2O, HFCs, PFCs and SF_6) as well as for CO_2 from non-energy related sources and gas flaring (counted as a fugitive emission) are also available.

Please note that the CO_2 emission factors from electricity generation are in a separate file and will be sent separately by e-mail after purchase. Also note that these emission factors cannot be downloaded using a data card.

Please note that your use of IEA data is subject to the Terms and Conditions found on the IEA's website here: http://www.iea.org/t&c/termsandconditions/. **In particular, external dissemination of any IEA data, including within software or other tools, requires specific permission and may be subject to an additional licence fee.** Please contact us at stats@iea.org if you have any questions on the terms.

Note on multi-user licences: Apart from the *Global Licences*, subscriptions are for a single legal entity.

Click here for our terms and conditions.

Appendix 2. Sectoral classification in WIOD 2013 version

	Text
AtB	Agriculture, Hunting, Forestry and Fishing
C	Mining and Quarrying
15t16	Food, Beverages and Tobacco
17t18	Textiles and Textile Products
19	Leather, Leather and Footwear
20	Wood and Products of Wood and Cork
21t22	Pulp, Paper, Paper , Printing and Publishing
23	Coke, Refined Petroleum and Nuclear Fuel
24	Chemicals and Chemical Products
25	Rubber and Plastics
26	Other Non-Metallic Mineral
27t28	Basic Metals and Fabricated Metal
29	Machinery, Nec
30t33	Electrical and Optical Equipment
34t35	Transport Equipment
36t37	Manufacturing, Nec; Recycling
E	Electricity, Gas and Water Supply
F	Construction
50	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles
52	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods
H	Hotels and Restaurants
60	Inland Transport
61	Water Transport
62	Air Transport
63	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies
64	Post and Telecommunications
J	Financial Intermediation
70	Real Estate Activities
71t74	Renting of M&Eq and Other Business Activities
L	Public Admin and Defence; Compulsory Social Security
M	Education
N	Health and Social Work
O	Other Community, Social and Personal Services
P	Private Households with Employed Persons

Appendix 3. Difference between Wiod and the Danish IOT for 2011

2011	Danish Input-output								WIOD							
	Input	C	NPISH	G	I	L	E	Output	Input	C	NPISH	G	I	L	E	Output
AtB	10.084	629	0	62	-17	296	3.918	14.971	7.665	2.925	0	144	-23	33	5.025	15.768
C	5.797	26	0	0	64	-294	6.313	11.907	7.050	82	0	0	91	115	6.920	14.259
15t16	6.248	5.005	0	1	121	166	14.537	26.078	4.763	1.221	0	11	12	23	18.754	24.784
17t18	407	145	0	4	45	40	1.007	1.648	10	2	0	0	1	10	1.327	1.351
19	17	6	0	0	2	2	42	69	1	0	0	0	0	5	41	47
20	1.346	59	0	0	56	4	620	2.085	842	195	0	0	83	9	766	1.894
21t22	5.857	154	0	13	61	-45	1.101	7.141	3.805	1.352	0	10	62	-30	1.567	6.766
23	1.431	1.124	0	0	0	921	3.551	7.028	1.374	793	0	0	1	18	4.026	6.212
24	2.339	261	0	171	1.757	-43	13.340	17.825	1.290	326	0	135	28	53	13.148	14.981
25	1.591	77	0	0	113	-11	2.028	3.798	626	16	0	2	60	12	3.117	3.833
26	2.673	98	0	0	12	-1	872	3.655	1.603	256	0	0	60	18	1.075	3.011
27t28	6.165	41	0	0	149	135	3.215	9.705	3.528	231	0	0	147	51	5.656	9.613
29	7.344	62	0	0	3.115	2	12.616	23.140	1.379	193	0	2	584	82	15.280	17.519
30t33	4.497	763	0	119	1.853	184	9.103	16.519	2.948	278	0	2	385	93	13.255	16.961
34t35	595	30	0	4	188	34	1.558	2.410	10	1	0	0	1	43	2.135	2.191
36t37	3.383	2.287	0	0	7	8	75	5.761	667	15	0	0	15	43	3.947	4.688
E	5.091	4.788	0	0	90	23	1.368	11.360	4.874	5.549	0	0	30	19	2.430	12.903
F	10.923	762	0	1.216	23.230	0	1.922	38.052	10.277	601	0	1.090	22.681	0	321	34.970
50	2.167	4.353	0	10	894	28	480	7.931	3.413	3.743	0	53	574	21	49	7.853
51	14.429	6.700	0	206	2.260	80	18.611	42.285	19.228	11.430	0	420	4.593	167	4.859	40.697
52	2.235	14.137	0	286	572	154	12	17.397	9.283	6.301	0	203	2.178	80	15	18.059
H	2.795	6.969	0	0	11	0	277	10.053	3.712	6.223	0	0	4	0	155	10.094
60	8.292	2.653	0	61	41	0	2.506	13.554	9.116	1.009	0	35	5	0	3.742	13.908
61	2.504	291	0	36	23	0	31.228	34.083	5	2	0	0	1	0	32.767	32.775
62	1.019	60	0	0	16	0	2.711	3.806	3	0	0	0	1	0	3.093	3.097
63	5.265	412	0	555	59	0	2.006	8.296	7.144	605	0	16	17	0	2.442	10.224
64	4.811	2.791	0	0	323	0	718	8.644	8.891	2.739	0	0	148	0	1.484	13.262
J	16.452	10.900	0	29	1.015	2	1.297	29.695	14.820	11.534	0	48	167	0	1.323	27.893
70	10.780	31.807	0	80	961	0	4	43.633	11.594	31.682	0	0	2.153	0	148	45.578
71t74	37.682	5.489	0	3.496	5.040	3	6.899	58.610	44.463	2.270	0	846	5.441	13	8.111	61.143
L	2.532	505	0	22.491	293	0	301	26.123	3.649	473	0	23.750	55	0	266	28.194
M	1.628	1.326	1.930	18.328	2.400	0	130	25.743	869	1.576	0	22.059	25	0	54	24.583
N	996	5.632	722	38.989	326	0	74	46.739	1.329	5.852	567	40.226	7	0	72	48.052
O	10.735	5.370	2.785	3.480	1.502	167	1.497	25.536	9.002	6.452	2.096	3.143	320	39	1.747	22.799
P	0	272	0	600	0	0	0	872	0	266	0	150	0	0	0	417
AtB	1.415	718	0	0	0	29	509	2.671	2.480	745	0	35	1	0		3.261
C	3.921	14	0	0	0	-121	45	3.860	2.076	43	0	1	3	0		2.123
15t16	5.540	3.790	0	16	0	141	2.280	11.768	2.942	8.111	0	18	3	0		11.074
17t18	952	2.029	0	7	70	101	4.091	7.249	378	1.065	0	13	66	0		1.523
19	40	85	0	0	3	4	170	302	38	292	0	1	3	0		334
20	1.610	232	0	0	16	16	153	2.028	1.280	41	0	1	6	0		1.327
21t22	1.670	237	0	96	30	-19	690	2.705	2.131	463	0	60	39	0		2.693
23	3.139	983	0	0	0	993	1.608	6.723	10.400	5.665	0	34	4	0		16.103
24	6.605	1.142	0	522	141	79	2.181	10.669	6.765	2.089	0	920	40	0		9.813
25	2.775	132	0	1	33	-21	721	3.640	2.456	574	0	5	26	0		3.061
26	1.176	102	0	0	29	10	266	1.583	1.148	132	0	2	9	0		1.290
27t28	5.401	158	0	0	334	115	1.760	7.767	7.349	314	0	9	244	0		7.917
29	5.475	209	0	0	2.040	89	2.836	10.650	4.454	963	0	15	2.941	0		8.373
30t33	6.733	3.057	0	107	2.788	307	4.934	17.926	5.826	2.291	0	118	2.274	0		10.510
34t35	1.822	2.320	0	46	1.324	288	3.505	9.306	1.145	2.342	0	35	1.860	0		5.383
36t37	30	6	0	0	0	0	29	65	690	1.397	0	17	529	0		2.633
E	456	138	0	0	0	20	438	1.053	551	103	0	1	12	0		667
F	1.527	1	0	0	244	0	0	1.772	299	49	0	33	26	0		406
50	148	153	0	0	0	0	0	301	215	35	0	1	6	0		257
51	2.495	0	0	0	0	1	44	2.540	2.384	450	0	17	78	0		2.929
52	10	0	0	0	0	2	5	17	278	96	0	3	14	0		391
H	127	0	0	0	0	0	0	127	29	38	0	0	0	0		68
60	2.071	42	0	0	0	0	0	2.114	2.975	554	0	23	2	0		3.555
61	39	4	0	0	0	0	1.550	1.594	1.660	134	0	1	0	0		1.795
62	1.708	128	0	0	0	0	135	1.970	1.186	63	0	1	1	0		1.251
63	28.302	26	0	0	0	0	0	28.328	18.473	2.311	0	66	2	0		20.852
64	652	326	0	0	60	0	12	1.050	2.816	408	0	13	10	0		3.247
J	1.040	306	0	2	0	1	0	1.350	1.881	308	0	2	4	0		2.196
70	0	0	0	0	0	0	0	0	40	4	0	0	1	0		45
71t74	6.065	240	0	0	1.607	2	157	8.071	7.368	437	0	156	836	0		8.797
L	8	3	0	0	0	0	0	11	747	95	0	12	2	0		856
M	75	84	0	0	0	0	0	159	84	4	0	35	2	0		126
N	49	44	0	21	0	0	0	115	41	8	0	15	2	0		67
O	1.449	98	0	0	58	14	19	1.638	1.457	262	3	82	6	0		1.809
P	0	0	0	0	0	0	0	0	2	0	0	0	0	0		2
Total interm. cons.	294.639	132.793	5.437	91.056	55.361	3.908	174.076	757.271	293.275	138.078	2.668	94.091	48.964	917	159.118	737.112
taxes less subs. on prod.	12.497	26.710	0	412	7.072	43	-136	46.598	19.548	18.876	6	781	7.563	95	0	46.869
Cif/ fob adj. on exports	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dir. Purch. abroad by res.	3.200	6.958	0	0	0	0	0	10.158	0	7.341	0	0	0	0	0	7.341
Purch. dom. ter. by non-res.	0	-7.031	0	0	0	0	7.031	0	0	-6.939	0	0	0	0	0	-6.939
Value added at basic prices	294.630	0	0	0	0	0	0	294.630	285.269	0	0	0	0	0	0	285.269
International transp. marg.	0	0	0	0	0	0	0	0	2.286	1.183	0	39	481	0	0	3.989
Output at basic prices	604.965	159.430	5.437	91.468	62.433	3.951	180.971		600.378	158.540	2.674	94.911	57.008	1.012	159.118	