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FEASIBILITY OF INTEGRATING DATA FROM MULTI-REGIONAL IO MODELS IN THE FLEMISH EE-IO MODEL

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The Policy Centre for Sustainable Materials Management brings together six renown knowledge institutes: KU Leuven, Universiteit Antwerpen, Universiteit Gent, Universiteit Hasselt, HUBrussel en VITO.

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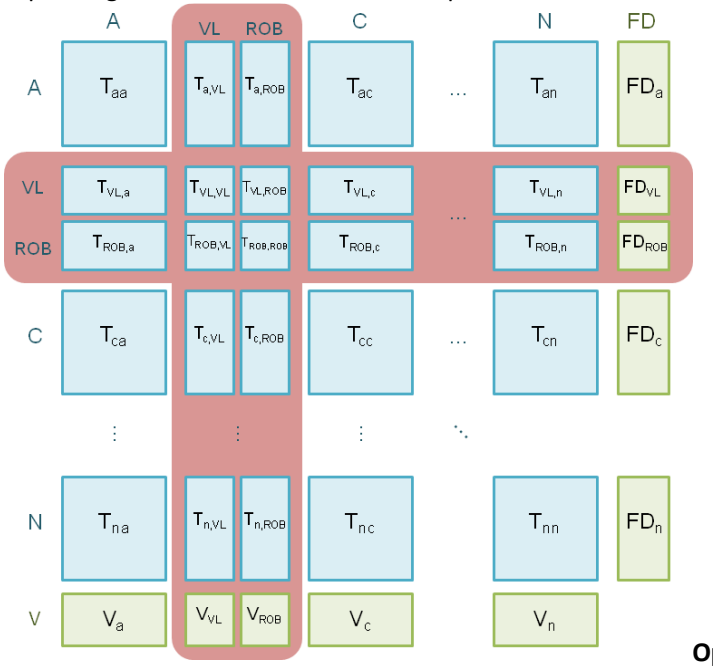
IO	Input Output
EE-IO	Environmentally Extended Input-Output
MRIO	Multiregional Input-Output
SUT	Supply and Use Table
IOT	Input Output Table
SIOT	Symmetric Input Output Table
EXIOPOL	A New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis
WIOD	World Input Output Database
EEBT	Emissions Embodied in Bilateral Trade
RoB	Rest of Belgium (Brussels + Wallonia)
RoW	Rest of World

Summary

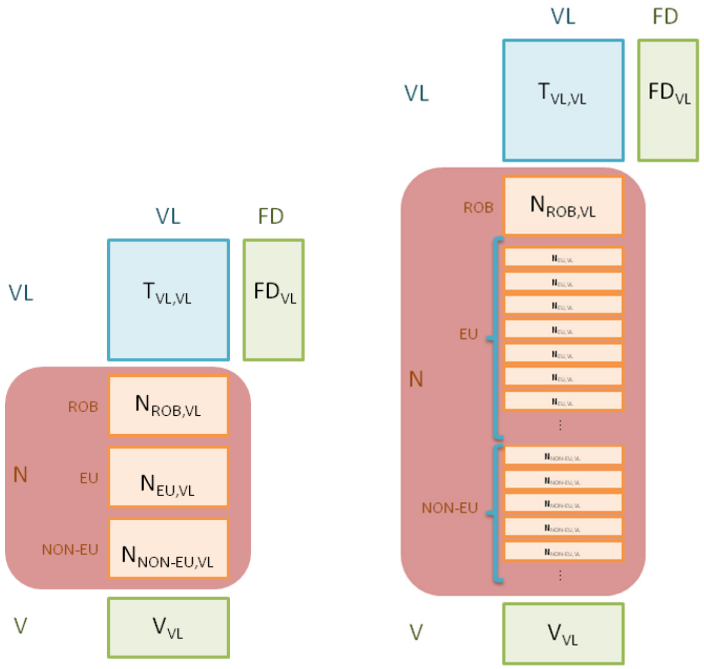
The Flemish environmentally extended input-output model in its current structure allows the inclusion of impacts that occur abroad due to consumption in Flanders. However, data used to calculate these 'imported impacts' are outdated and not always the most suitable for linking to the Flemish IO tables.
In recent years, several initiatives have been working on the development of multi-regional input-output models that cover (more or less) the entire world. The result of these actions is a number of MRIO models, all with different characteristics such as number of sectors/products, environmental parameters included and years. Some of these models are the following: the World Input Output Database (WIOD), the Exiobase project, EORA and GTAP.

This study will look into the possibilities to use one of the available MRIO models to update and refine the environmental import data in the Flemish IO model. To do this, different options for coupling the two models need to be considered as well as the different models available need to be compared and finally one selected.

When using the data from the MRIO models in the Flemish model, there are two main options that need to be considered: 1) integrating the Flemish IO model as such into the MRIO model creating a 'new' MRIO model (Belgium split up) or 2) use the environmental data from the MRIO model as a replacement of the environmental tables for import in the current model. The second option can be further subdivided into two alternatives: 2a) either the structure of three import regions can be kept as it is (Rest of Belgium, Europe and Rest of the World) or 2b) one can choose to further subdivide into important import regions for Flanders. The three options are shown in the figures below.



Option 1



Option 2a **Option 2b**

The most promising option for linking both the Flemish IO model and the MRIO model chosen, is option 2b, which links the environmental information from the MRIO model, while also further subdividing the regions where Flanders imports from. This thus means that the structure of the Flemish model remains as it is, but the environmental data for import (per euro) are taken from the MRIO model. This would give additional information compared to option 2a in that way that there is a further subdivision in import regions and thus more specific information on impacts abroad. The detail of the information (the visibility of the entire production chain abroad) is lost compared to option 1. Option 1 is however too elaborate to work out on the one hand and becomes too complex when having to use it (amount of data, complex relations between matrices, …).

When, from the different MRIO models one has to be selected most suited for using together with the Flemish tables, this will be highly dependent on the goal one has set for doing this. Since the different models have different characteristics and therefore different (dis)advantages, each of the models will have its best suited application. To determine the strengths and weaknesses of each of the models compared to the Flemish tables, different aspects should be taken into account: number of sectors that match, number of environmental pollutants included that match between the two models, match of the year(s) of the data, assumptions used in building the model, …. When analyzing these different aspects, it becomes clear that not one model clearly stands out. Exiobase for example matches most environmental pollutants and has more detailed sectors for agriculture, but data are outdated and don't match the years for which the Flemish model has tables. WIOD on the other hand has an exact match for 2003 and 2007, but has less pollutants included and doesn't have the detail on agriculture.

When deciding which model is the preferred one, the following questions need to be answered:

- Is it important that the data are from the same year as the Flemish model or not?
- Which environmental media need to be covered and to which extent?
- How much sector detail is needed (level of specificity in environmental data) for sectors abroad?

Of course, depending on the answers the costs and benefits of the exercise need to be compared to determine whether the effort is worthwhile.

1. The how and why of MRIO

1.1 Introduction

IO was developed already in 1936 by Leontief to study supply chains from an economic perspective. Since the seventies it started to be used also more for environmental assessments, which resulted in the development of environmentally-extended (EE) IO-tables. With the contemporary growing globalization also the interest for multi-regional IO-tables (MRIO) is growing.

Globalization is bringing more and more countries, rich and poor, into the world economy and subjecting them to increased competition. This process is changing how we trade and how we go about our everyday activities. (http://europa.eu/pol/comm/index_en.htm)

Consumption causes environmental impacts in two different ways. Direct environmental impacts result from consumption when consumers directly burn fossil fuels; for instance, from the petrol used for personal transportation or wood used for space heating. Significant environmental impacts also occur indirectly in the production of consumable goods. When production occurs in the same country as consumption, then government policy can be used to regulate environmental impacts. However, increasing competition from imported products has led to a large share of production occurring in a different country to consumption. Regulating the resulting pollution embodied in trade is becoming critical to stem global pollution levels. (Suh, 2010)

Consequently, during the past decades, production systems have become more and more spatially fragmented: different phases in the production chain are located in different locations. This is the case on the regional level, but also on a national and global level. Interregional and international trade flows have been growing very fast and reallocations of company divisions have been omnipresent. Globalization combined with an increasing human population and increased consumption means that our ecological impact is now falling more widely and more heavily across the planet. The lengthening and increased complexity of the supply chains across the entire world means that consumers are often located far away from the impacts they cause through their consumption patterns.

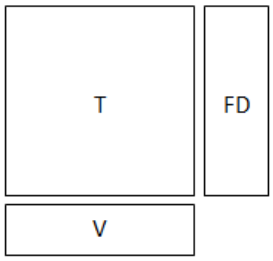
Regional economies are becoming both more competitive as more integrated at the same time, creating new challenges for policy analysts. In order to understand the new challenges to economic development and related environmental development, interregional models can assist in tracking changes.

To manage and reduce environmental impacts, it is necessary to get a clear picture of this trend as well as to measure it. Environmentally extended multiregional input-output analysis aims at doing so, by avoiding the assumption that imports are produced with the same technology as the domestic economy.
The development of multiregional input-output and computable general equilibrium models has revealed that projects generate different spatial distributive impacts depending on the nature of the project and the location of the initial place of the project. Interregional dependency will assume even greater importance in understanding the growth and development paths of economies.

As regions become both more competitive and interdependent over time, it will become even more critical to gain an understanding of (1) the nature and importance of external trade for a given region, (2) the geography of this trade – domestic versus international and the diversity of the trading partners in terms of demands and location - and (3) the sustainability and reliance of these trading relations. (Hewings, 2012)

1.2 Structure of MRIO tables[1]

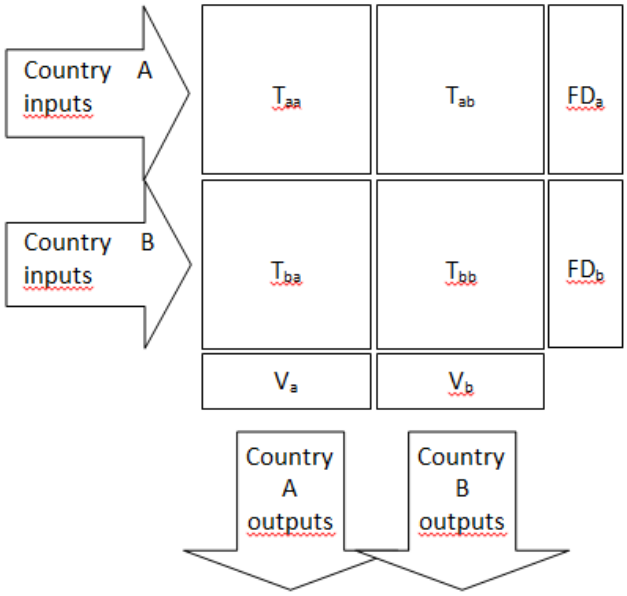
An IO matrix contains elements which are the sum of sales from one sector to another. Each row of the matrix represents the goods and services that are produced by one sector (sector output). The columns show the inputs each sector requires for its activity (sector input). This means that each column along a single row (one sector's output) are the various sectors which consume the products produced by the sector. Each element in the matrix thus presents the total value of transactions between sector A and sector B (bilateral flows). This transactions matrix (T) is the main block in the IO-table. In a single-country IO table, the rows and columns of the matrix represent the sectors in that economy. For the Flemish 2007 IO-table, 120 sectors are distinguished.



On the right of the transactions matrix, the block of columns in FD represent final consumption by households, government, inventory changes, investments and export. Below, there is a block of rows V for "primary inputs". These are compensation of employees, other taxes on production, other subsidies on production, consumption of fixed capital and net operating surplus.

In developing a multiregional IO table (MRIO), IO tables of countries are combined and the vectors of import and export in the IO tables are replaced by matrices with information on bilateral flows between countries. Noteworthy is that in a multi-region IO table (MRIO) the sectors represent each country's sectors. For example, if the table represents 40 countries, there will be 40 chemistry sectors, one for each country.

[1] Moran D., Geschke A., 2012



The transaction matrices (T_{ij}) detail the transactions between two sectors within a country (if i=j) or between countries (if i.≠j) e.g. from the viewpoint of country A T_{ab} describes the exports per industry from country A to country B and T_{ba} describes the imports per industry from country B to county A. T_{aa} describes the inter-industry flows in country A. Reading horizontally, T_{aa} defines all the outputs a sector in country A delivers to the sectors in country A, T_{ab} defines all the outputs a sector in country A exports to country B (per sector) and FD_a states the monetary flow the sector receives from its final customers. Reading vertically, T_{aa} defines all the inputs a sector needs from the sectors in country A, T_{ba} defines all the inputs a sector imports from country B (per sector) and V_a is the value added a sector in country A delivers (e.g. loans and wages). In conclusion, the first row states all the outputs the sectors in country A deliver and the first column states all the inputs the sectors in country A need.

An additional block of rows for nonmonetary inputs might be added to the IO table, containing for example labour hours, water usage or greenhouse gas emissions. The rows of this satellite indicator Q are as such treated as additional inputs to production. In IO analysis, pollution too is regarded as a necessary input to production, not a consequence.

MRIO analysis creates the opportunity to follow paths (production systems; supply chains) throughout the interregional economy, whether this concerns different parts of a country, different countries or different continents. For a world MRIO for example, you can trace the amount of emissions in China caused by the consumption of rice in Belgium.

1.3 Applications of (MR)IO

The ability of IO analysis to distinguish and link producers, supply chains and consumers makes it useful for developing sustainability policies. Especially MRIO is useful to distinguish and link producers, supply chains and consumers not only within the borders of a country, but also across borders all over the world. It is a perfect tool to clearly present and expose supply chains comprehensively and quantify the links between producers and consumers. Most environmental legislation today was designed to control the impact of production. However globalization raised the

importance of policy aimed at sustainable consumption. In order to take into account the shift of burdens, emission leakage, interregional dependency and so on, multiregional IO analysis gains more and more attention. Today, however, it is mainly the application towards policy in economic context that is well known, whereas applications in environmental context are still in a beginning phase.

2. Available MRIO models

In this chapter, the current state of MRIO development is briefly described. The different initiatives on the development of MRIO tables are highlighted, with a special focus on world input-output models such as Exiobase, WIOD and EORA. For matter of completeness, other initiatives in the field of MRIO are referred to as well.

2.1 Exiobase[2]

EXIOPOL (A New Environmental Accounting Framework Using Externality Data and Input-Output Tools for Policy Analysis) is an EU funded project that created a detailed, global, multiregional environmentally extended supply and use table.
The two main goals of the project were:

- To improve insights in external costs of environmental pressures and
- To overcome significant limitations in existing data sources in the field of Multiregional Environmentally Extended Supply and Use Tables (MR EE SUT) and Input Output Tables (IOT).

National Statistics Institutes make up SUT and IOT for single countries, with limited trade links. For European countries this is even an obligation. Sector or product detail are often not very high. Environmental extensions are typically lacking or are only very limited. Since harmonization in sector or product classification is limited and not commonly introduced and detailed trade data are missing, it is difficult to assess the extent to which a country induces environmental impacts via trade.

Trade-linked tables are also important for analyzing the effects of sustainability measures taken in Europe (or elsewhere) on the economic competitiveness. MR EE IO is the best suited for this type of studies, but often, the tables are too aggregated on a sector or regional level and/or focus on a narrow range of indicators for environmental impacts.

The EE IO work in EXIOPOL focuses on making a crucial advance in finding a solution to these problems, with emphasis on the environmental applications. EXIOPOL therefore wanted to realize the following:

- Harmonizing and detailing the SUT/IO tables of the EU27 and its main trade partners, differentiating in detail the sectors and products most relevant for environmental pressures and that have significant differences in impact intensities;
- Gathering a comprehensive set of environmental extensions per sector (emissions, resource use etc.), that would make it possible to calculate a broad range of indicators for environmental impacts;
- Linking the produced national EE SUT/IOT by means of international trade data, to an MR EE SUT;
- Embedding this data in a user-friendly, general purpose database system.

The project was set up by FEEM, Italy and TNO, Netherlands, with over 35 partners from all over Europe. EXIOPOL ran between March 2007 and October 2011, with a budget of almost 8 Mio Euro of which 5 Mio Euro was funded by the EU's 6th Framework Program.

[2] Tukker A., 2012

As a follow up to the EXIOPOL project the CREEA project will develop a similar database for the base year 2003.

The specific characteristics of the EXIOBASE (the output of EXIOPOL) are shown in the information sheet in Annex 1. EXIOBASE (base year 2000) is not for sale yet. Some free samples of Austria and a 3 region world model can be downloaded.

2.2 WIOD[3]

Policy makers and societies at large are facing more and more pressing trade-offs between socio-economic and environmental objectives. Increasing global integration through international trade and technological development is linked to a growing inequality between countries as well as between various classes within society. Increases in production induce growth in the use of non-renewable resources such as fossil fuels and generate higher levels of waste and emissions of environmental pollutants. These developments have a global character and any analysis of their causes and effects needs to recognize the dynamic interrelatedness of countries and industries.

The World Input Output Database (WIOD) project (which ran from May 1, 2009 to May 1, 2012) has developed new databases, accounting frameworks and models to increase our understanding of the above-mentioned phenomena. The core of the database is a set of harmonized supply and use tables, alongside with data on international trade in goods and services. These two sets of data have been integrated into sets of international (world) input-output tables, covering a period from 1995 to 2006. Taken together with extensive satellite accounts with environmental and socio-economic indicators, these industry-level data provide the necessary input to several types of models that can be used to evaluate policies aimed at striking a balance between the various policy objectives.

The World Input-Output Database project from the University of Groningen aimed at creating a time series of SUTs and SIOTs (Symmetric Input Output Tables) for a time series. The emphasis is on economic analysis; hence satellite accounts include value added generation, but also greenhouse gas emissions, pollutants and energy use.

The project was funded by the European Commission, Research Directorate General as part of the 7th Framework Programme, Theme 8: Socio-Economic Sciences and Humanities.

The specific characteristics of WIOD are shown in the information sheet in Annex 1.

2.3 Eora[4]

In order to underpin initiatives focused on consumer responsibility, a comprehensive and reliable multi-region input-output (MRIO) database on emissions and international trade is necessary (Tukker et al, 2009; Wiedmann et al, 2009). MRIO-based studies have recently been successful in bringing the issue of for example carbon emissions embodied in trade to attention.

Such an MRIO database should ideally cover the entire world at high sector detail, so that emissions-intensive industries or commodities can be singled out. However, previous multi-region studies have used either sector-disaggregated models for a limited number of countries, or sector-aggregated

[3] University of Groningen, 2010; http://www.wiod.org
[4] Lenzen et al, 2012

models for the world. The other MRIO initiatives (WIOD, EXIOPOL) have different purposes which is reflected in their choice of sector and country detail. Most initiatives do not provide for maximum sector disaggregation, but instead most initiatives opt for a breakdown into around 50 regions and 120 sectors common to all countries. Further differences relate to whether a continuous time series is generated or not, and how many valuation sheets exist.

The aim of the EORA project is to address a number of "shortcomings" and to go beyond existing ambitions for MRIO compilation. The goals are:

- Detail: disaggregation of countries and sectors to the maximum possible level;
- Dynamics: creation of a historical time series back to 1970;
- Flexibility: compilation of table sheets expressed in basic prices as well as margins and taxes, and in current and constant US$;
- Transparency: minimization of assumptions made during the compilation;
- Uncertainty: provision of standard deviation estimates for all MRIO elements;
- Reliability: provision of data for constraint violations;
- Timeliness: continuous updating of the entire database;
- Budget: implementation of the entire compilation and updating capability;
- Openness: public, free availability for research purposes.

The EORA project was funded by the Australian Research Council (ARC) under its Discovery Project DP0985522, and carried out at the University of Sydney in Australia.

The specific characteristics of EORA are shown in the information sheet in Annex 1.

2.4 GTAP database[5]

Several studies in the 1990's quantified the potential magnitude of flows of embodied carbon between countries and suggested that this may undermine the effectiveness of global climate policy through "carbon leakage". The concept of consumption-based accounting was suggested. Motivated by this work, the "uni-directional" MRIO centered on Norway was constructed to estimate the magnitude of carbon emissions embodied in international trade, estimate the consumption-based accounts, and to consider the potential policy implications. However, a global analysis was needed to evaluate the potential importance of carbon emissions embodied in trade for global climate policy.
When constructing the global MRIO, it was decided to use existing databases despite potential weaknesses. It was clear that the GTAP database had, by far, the most comprehensive and detailed database of IOTs and trade data and were already balanced and harmonized. A method called "emissions embodied in bilateral trade" (EEBT) was used to perform analyses of emissions embodied in trade. EEBT considers domestic emissions in each region to produce total exports.
Constructing a time-series of consistent MRIO's with GTAP was done using a "proxy" method. The GTAP database was available with energy volume data for the base years 1997, 2001 and 2004 and was extended to a time-series from 1990-2008 using GDP by expenditure data.

The GTAP-MRIO was originally developed at the Industrial Ecology Programme at the Norwegian University of Science and Technology in 2006-2007. Since 2008 the GTAP-MRIO has been further developed at CICERO (Glen Peters). GTAP has a lot of sectoral detail for agricultural commodities but limited detail for other sectors (see Annex 1).

[5] Peters et al, 2012

Although a lot of data are included in the GTAP, it is not actually a full MRIO table: GTAP does not yet include full trade matrices between all countries. It can however be converted to a full MRIO table without the need for additional balancing and it is the database with which most environmental MRIO analyses have been carried out so far, which is why it is mentioned here. It will not be looked at further in this report as an option for using it in combination with the Flemish IO-model. (Wiedmann, 2011)

2.5 Other

The **Asian International Input-Output Table (AIIOT)** by the Institute of Developing Economies IDE - JETRO comprises symmetric input-output tables of nine Asian countries plus USA. Currently 76 sectors are distinguished, extended with an employment matrix. Data refer to the years 1985 to 2005 in five-years intervals. The compilation of IO tables for BRIC countries is planned as well.

The OECD has been updating and maintaining the various country comparable economic databases. Since 1995, the harmonized IO tables in symmetric form have been developed at the OECD. The latest dataset includes tables for 46 countries (33 OECD and 13 non-OECD) for the tables for the mid-2000s. The latest **OECD Input-Output database** covers domestic and import transactions of 48 countries. The OECD dataset however is not considered a complete MRIO database, since full trade matrices between all countries (off-diagonal matrices) are not included.

3. The Flemish IO-MODEL and MRIO: how to integrate?

3.1 Introduction

3.1.1 Imports in the current Flemish IO-model[6]

Currently, the import/export data for Flanders are available for three regions, i.e. rest of Belgium, EU and the rest of the world, as shown in the figure below.

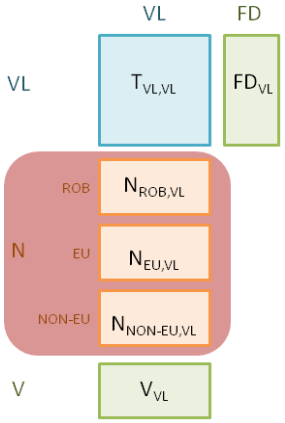


Figure 1: Structure of the Flemish EE-IO model
(T= matrix for intermediates, FD= final demand, N= import, V= value added)

In the current Flemish IO-model, the environmental extension tables for import represent the emissions of the sector from which products are imported and the emissions of the upstream production chain: the data represent the direct and indirect environmental impact of the sectors abroad. All data in the tables are represented per Euro of output, which allows the coupling with the monetary imports from the Flemish tables. Whereas the environmental data for Flanders are related to the input-output table, the environmental data for import are related to the use table.
To build the environmental extensions for import, the following aspects are important:

- Number of economic sectors and the types/grouping of sectors;
- Type of environmental data (pollutants);
- Homogeneous or heterogeneous table (one or more products per sector).

The impact of import to Flanders is split into three regions, as are the monetary use tables, i.e.:

- Import from Brussels and Wallonia;
- Import from Europe (EU-27) and;
- Import from the rest of the world (ROW).

[6] Vercalsteren et al, 2008

The data sources respectively used are the Flemish data (assumed that the environmental pressure of sectors is the same as in Flanders) and the EU-27 NAMEA 2000 database. The EU-27 NAMEA database at his turn uses the US Input-Output database (1998) for all imports from outside Europe.

The EU-27 NAMEA database contains a separate environmental extension table for the EU-27 and one for the import from ROW to the EU-27. These two tables were used as the basis for the extensions for EU and ROW in the Flemish model. Two points of attention need to be taken into account:

1. The more aggregated sector classification in EU-27 NAMEA (60 sectors) and;
2. Incomplete coverage of pollutants en other environmental indicators (mismatch).

Sector classification

The EU-27 NAMEA 2000 database uses a classification in 60 sectors while the Flemish model uses 117 or 122 sectors for 2003 and 2007 respectively. In order to make the link, a conversion between the two classifications is needed. For some sectors a one-to-one conversion was possible, but mostly a one-to-many conversion was the case. This means for example that for the sector in the NAMEA database "Rubber and plastic products, EU27", the environmental impact per euro is copied and used for the sectors "Rubber products" and "Plastic products" in the Flemish database.

Environmental indicators

As opposed to the Flemish IO-tables, the EU-27 NAMEA database doesn't contain data on energy and water use, and production of waste. It does however include data on emissions to air, water and soil. Unfortunately, the match between the pollutants included in the EU-27 NAMEA database and the Flemish tables isn't complete:

- Some pollutants that are included in the Flemish tables, are not available for imports (in the EU-27 NAMEA database);
- Some pollutants are available for import to Flanders, but then again not for the Flemish industries.

These differences of course determine the possibilities of the Flemish model (including imports) towards calculations and conclusions.

3.1.2 MRIO models as replacement for imports

There are two different options when looking at the possibility to link the Flemish IO model with the available MRIO models:

1) The Flemish model may be integrated as such in the MRIO model to create an adjusted/refined MRIO model, or;
2) One of the described MRIO models can be used instead of the EU and ROW data linked to the current Flemish model, to create a more accurate and recent impact of import and to create the possibility of much more detailed chain analyses.

Both options are described more in detail in the following paragraphs.

3.2 Option 1: integration of the Flemish model into the MRIO model

Independent of the MRIO model, it is an alternative to integrate the Flemish model in the MRIO model.

The figures below illustrate the impact of this approach. In a MRIO table Belgium is included as one row and column e.g. B indicated by the red area in the first figure. As option 1 aims to integrate Flanders into the model, Belgium would have to be split up into two regions: Flanders and rest of Belgium (ROB) as shown in the second figure. Theoretically the model is then able to show import and export data for Flanders (and ROB) to and from the other regions in the model and this on a sector level.

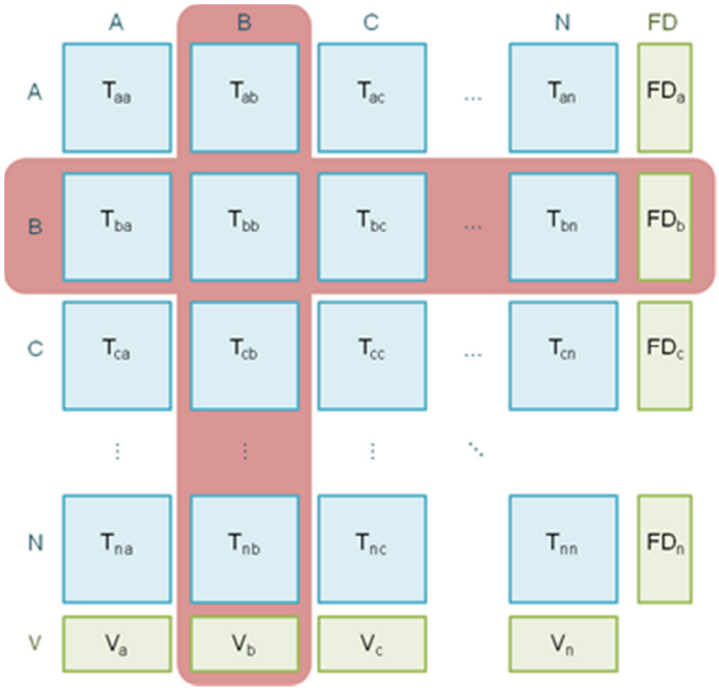


Figure 2: Schematic overview of the structure of a MRIO table, with Belgium as one country

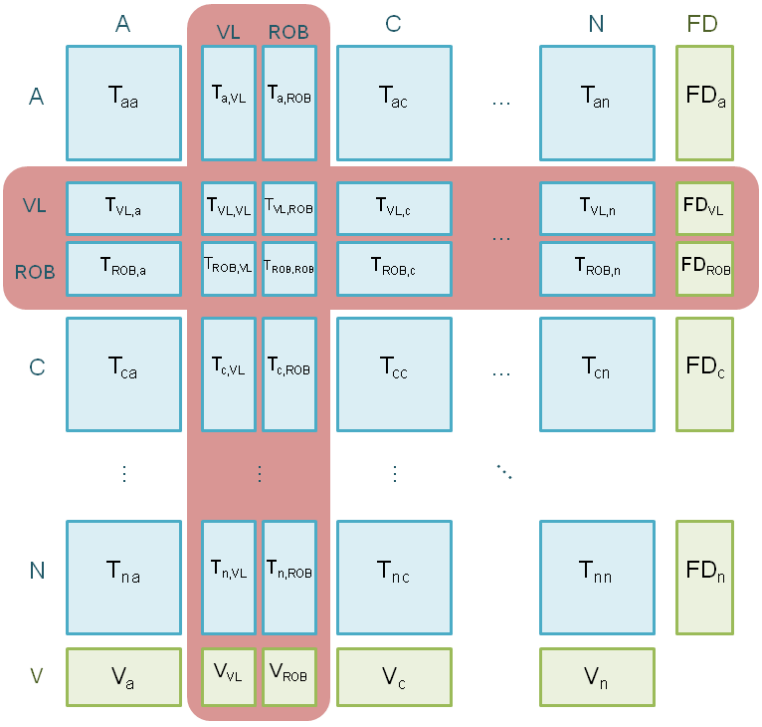


Figure 3: Schematic overview of the structure of a MRIO table, with Belgium subdivided in Flanders and the Rest of Belgium

There are however several points of attention when doing so:

- In official statistics, the Flemish tables do not occur: only the Belgian tables are reported and as such included in the MRIO models. If the Flemish model is to be integrated, this will require a **split** in **the Belgian table**: besides the data for Flanders, the data for the rest of Belgium would have to be available as well.
- Currently, the import/export data for Flanders are available for three regions, i.e. rest of Belgium, EU and the rest of the world. Integrating the Flemish tables would require a further **subdivision of the import/export data** to the different regions distinguished in the MRIO tables. For example the region EU in the current model should be further subdivided in the member states included in the MRIO tables.
- The imbalance over the entire MRIO table that would be created by integrating the Flemish model should of course be addressed: for a symmetric IOT, the sums of the columns should equal the sums of the rows. As this is already a tricky task for a single region model, it certainly is for an MRIO model.
- An important consequence when using an MRIO model is the extensive amount of data. Working with the model, making calculations etc., will become much more complicated and will certainly require a user-friendly platform.

In this option, the basis for the 'new' model would be the MRIO table, in which the Flemish IO-table would be integrated.

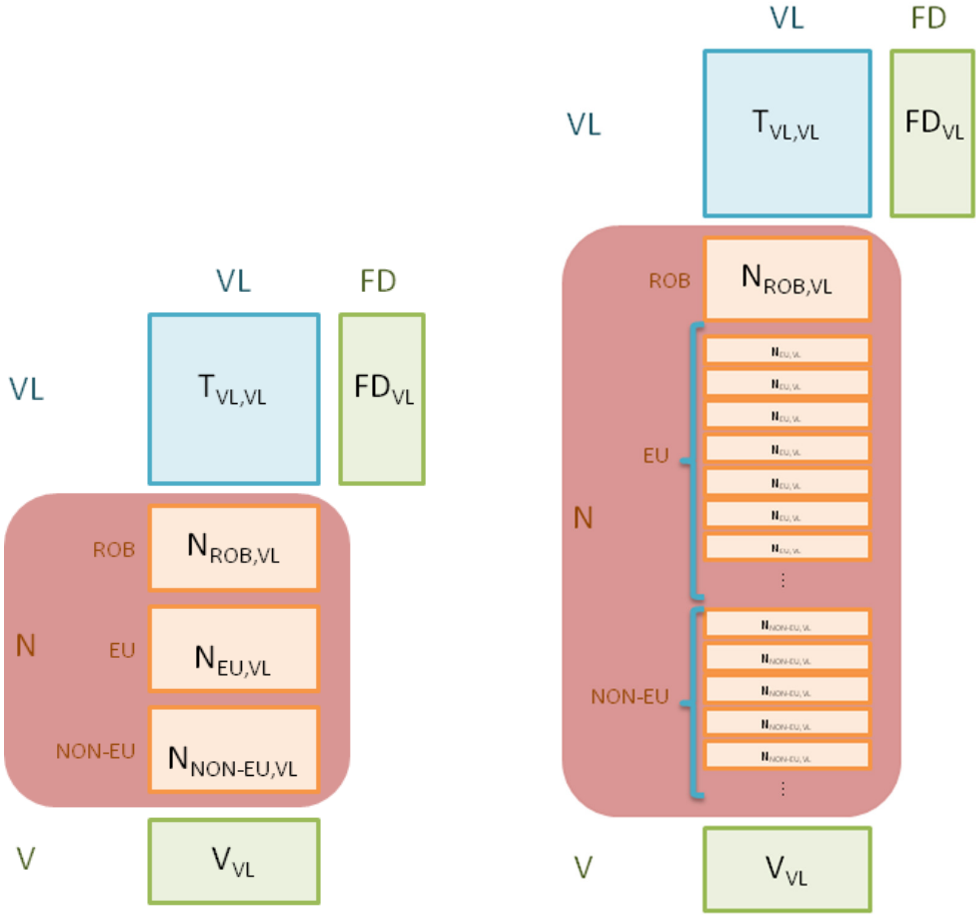
3.3 Option 2: using MRIO data for improving data quality for EU and ROW

For now, the data used to quantify the environmental impact embodied in imported products from EU and ROW, is based on data from the EU-27 NAMEA 2000 database. Since the Flemish data are available for both 2003 and 2007, more recent data for the environmental impact of imported products would be preferred.

Linking MRIO data to the Flemish model for what regards the data related to import in Flanders, could offer 2 benefits: i) more recent and accurate data related to environmental impact of imported products and ii) the possibility to further subdivide the import regions (now EU and ROW) into more specific countries/regions. These advantages make it clear that there are again two scenario's for linking the information from the MRIO tables to the Flemish model:

- Option 2a: linking the environmental information from the MRIO model, while maintaining the current structure of the Flemish IO-tables for import (ROB, EU, ROW);
- Option 2b: linking the environmental information from the MRIO model, while also further subdividing the regions where Flanders imports from and exports to).

The figure below shows the effect of these options in the structure of the IO-tables.



Option 2a ***Option 2b***

Figure 4: Schematic overview of the structure of the Flemish IO model for both options

Both options improve the quality and accuracy of data for imports, but the second option (2b) will give more details about imports compared to option 2a since the current model would be extended by import data of a list of regions. The level of detail for the division of import regions can vary, dependant on the availability of data in the MRIO model that is selected and dependant on the wishes of the users of the Flemish model. The import statistics of the European union can be divided for example into import statistics of different EU-countries and a rest fraction or into neighbouring countries, important international trade partners and a rest fraction.

As such a MRIO model can be used to improve the quality of the impacts of import in the Flemish IO-model. In order to do this, the environmental multipliers for each sector (for the entire supply chain) abroad should be calculated. This is again related to the preferred level of detail and ultimately based on the division into regions/countries as they are available in the MRIO model. This means of course, that the import regions in the Flemish model should be expanded, compared to the current situation where only 3 regions are distinguished (rest of Belgium, Europe and rest of the world). As such, the monetary use tables for import need to be further subdivided. This can be done using the relative distribution of import to Belgium in the MRIO models and then apply this distribution to the import data in the current model.

This option takes the Flemish IO-model as a basis, but focuses on the import flows in Flanders and allows to specify, elaborate and update the import flows and, related to that, the environmental impacts of imported products and goods.

4. Pro's and con's of integration

4.1 Opportunities and problems of the different options

Using option 1 would, as was mentioned previously, create the problem that i) Belgium should be split up into Flanders and Brussels+Wallonia, while ii) the balance of the MRIO table should be kept! This would be quite an extensive job. Also, when performing analyses for Flanders with this model, interpretation and manageability will become intricate. The balance between the added value of this alternative (benefits) and the costs for realization (efforts) must be looked at.

If we are interested in detailed monetary flows only related to Flanders, this option may give too much information (elaborated and confusing) and requires too much effort with an insufficient added value. If any questions on the details of import flows (the production chains abroad) are needed, one can just as well look at the situation for Belgium and get the answers directly out of the MRIO model as it is.

Using option 2a is easier from the monetary point of view: the Flemish model remains the same for what monetary flows are concerned. What is adjusted is the environmental impact related to imported goods. Currently, the multipliers (impact along supply chain/per euro import) are based on EU-27 NAMEA 2000. These could be updated and improved by using the information from the selected MRIO model. For this however, some manipulation of the available information is needed: combining the data for all countries into the two regions (EU and ROW).

Option 2b will still be easier to execute than option 1, but more complex than option 2a, since not only environmental multipliers for import need to be adjusted, also the monetary import and export flows need to be split up according to the regions/countries identified. An important point to discuss is therefore the level of detail of import regions: one can choose to use a continental approach (5 regions: Africa, Americas, Asia, Europe and Oceania) or a country approach (all countries separate) or a preferred combination of countries/regions can be made. It is clear that different options are possible when subdividing import regions.

For what the environmental data are concerned, these are available in the MRIO-models for each country, not grouped in regions. This would again mean that multipliers should be calculated by combining the data of different countries according to the preferred structure.

4.2 Comparison MRIO models with Flemish model

The Flemish model can be compared with the available MRIO models, in order to determine where possible problems might occur.

Table 1: Comparison between Flemish and different MRIO models

	Flemish IO model	EXIOBASE	WIOD	EORA
General characteristics				
rows x columns				
2003	117 x 117	/	35 x 35	20-500 x 20-500 depending on the country
2007	120 x 120	/	35 x 35	20-500 x 20-500 depending on the country
other year(s)		2000: 129x129	time series: 1995-2009	time series: 1990-2009
Environmental aspects				
emissions to air	70 pollutants	28/28 that match	8/8 that match	10/30 that match
emissions to water	13 pollutants	N-&P-load in manure and biomass	None ?	None ?
emissions to soil	N, P and 264 pesticides	N-&P-load in manure and biomass	None ?	None ?
water consumption	ground water, surface water, rain water, other water	Blue, green & total	Blue, green, grey & total	(to be made available soon)
energy consumption	energy carriers (24)	None ?	energy carriers (26) (good match)	None
waste	dangerous/not dangerous: for landfill, combustion, recycling, conditioning	not as an extension table (sectors)	None ?	None
material consumption	primary & secondary	185 materials, domestic &	24 materials: same categories,	None

	materials	unused extraction: same categories, much more detailed *!specific extraction sectors*	little more detail, quite a good match *! extraction sector = not subdivided*	
land use	/	15 land-use types	4 land-use types	(ecological footprint)

It is clear from the comparing table that for each MRIO model, there are similarities and differences with the Flemish model. Not one of the models is a complete match with the Flemish one, so the choice of model to use for import data will depend on the importance attached to the different characteristics.

Exiobase distinguishes a comparable set of sectors as the Flemish model. Both WIOD and Eora distinguish much less sectors (for Eora depending on the country). A less detailed level of sector detail leads to less specific (more average) environmental data for each sector/product. For example all food-processing sectors will have the same environmental impact per Euro, and as such also the environmental impact per Euro import in Flanders will be identical for all products of food-processing sectors. This might affect analyses that focus on food-related issues. Exiobase on the contrary distinguishes a lot of different agricultural sectors (10-20). The level of detail of the other sectors is less high. This advantage would be minimized when relating Exiobase to the Flemish model, since in our Flemish model only 3 agricultural sectors are included.

Making the link between the Flemish model and the data from other MRIO-models will depend on the structure of both models and the relationship between different sectors. Several situations exist:

- One-to-one link: the sectors in both models are the same and thus no additional manipulation of the environmental data per euro is needed;
- One-to-many link: there is only one sector in the MRIO model, which is representative for more than one sector in the Flemish model. This doesn't require any manipulation of the environmental data per euro for the sector in the MRIO model: the data will be used for the different sectors as included in the structure of the Flemish model;
- Many-to-one link or many-to-many link: There are several sectors distinguished in the MRIO model, while only one sector is included in the Flemish model. This would require a combination of the different environmental data per euro for the sectors into one number. For this, an indication of weighting between the different sectors is needed in order to have a weighted average impact per euro. This requires quite a lot of manipulation, especially when besides the sectors, this also requires the combination of different countries.

When comparing the set of pollutants included in the Flemish model with those included in the MRIO models, it is clear that for most impact categories the Flemish model has the most extensive set of pollutants available. For what regards emissions to air, Exiobase and Eora both have approximately 30 pollutants included. However the emissions to air included in Exiobase all match with the Flemish tables, while for Eora only the most important greenhouse gas emissions match. WIOD has data on 8 emissions to air, all of these also occur in the Flemish tables. For the other environmental pollutants, Exiobase has the most extensive set of pollutants available, much more than those included in WIOD

and EORA. Interesting is also that WIOD also includes information on energy carriers, like the Flemish tables, the other MRIO databases don't. For what materials are concerned, EORA includes no information, whereas both EXIOBASE as WIOD do. The level of detail is higher in EXIOBASE plus the extraction sectors are subdivided, where in WIOD the level of detail in materials (different materials) is less than EXIOBASE but more than the Flemish tables with the big difference that the extraction sectors are grouped as one.

A 3rd important parameter is the reference year the MRIO model relates to. Exiobase is only available for the year 2000, both WIOD and Eora have time-series available. A perfect match in reference year with the Flemish model is thus possible for WIOD and Eora, not for Exiobase. A short analysis of the WIOD data shows that monetary and environmental data change significantly between 2000 and 2010, so one can wonder whether reference year 2000 is still representative for 2003 and particularly 2007.

Exiobase might have the most pollutants in common with the Flemish model, but is much more outdated than WIOD for example. Therefore, it will be very dependent on what one considers to be most important (match in years or match in pollutants) whether one model is preferable compared to another. Overall, it is clear that the environmental data for import are always less elaborate than the available data for the Flemish sectors.

In the following chapters, the comparison is only made for the EXIOBASE table and the WIOD table. EORA is not further compared since in this model, the structure (number of sectors) will differ depending on the country. The EORA model doesn't use a uniform number of sectors/products. Instead, the number of sectors/products used in the statistics of each country is kept and correspondence tables are used between all countries.

5. Recommendations and conclusions

5.1 Recommendations

5.1.1 Method suitable for integrating information from MRIO in Flemish table

When looking at the different options for linking data from a MRIO model to the existing Flemish model, the preferred method seems to be option 2b. This means that the structure of the Flemish model remains as it is, but the environmental data for import (per euro) are taken from the MRIO models. The structure would still be as such that the imports are linked by taking the economic imports from the use tables and environmental multipliers per euro (so the total impact behind one euro of product imported) from the MRIO model. This of course requires some adjustments, of which the most relevant are:

- Conversion tables between the sectors in the Flemish model and the sectors in the MRIO model;
- Further subdivision of the import flows according to countries/regions defined.

Currently, the import and export to and from Flanders is grouped into three regions, i.e. the Rest Of Belgium (RoB), Europe (EU-27) and the Rest of the World (RoW). This can (preferably) be subdivided further, as to represent the most important import regions/countries separately and use the detailed impact data (per euro) as available in the MRIO models as much as possible.

A suggestion for this subdivision is worked out below, based on import data for Belgium from the National Bank of Belgium. These import data are analyzed to identify the countries from which the most value (€) is imported. The following tables show the top 20 countries from where Belgium imports most value, and this for both 2003 and 2007.

Table 2: Ranking of import countries according to imported value (€) for 2003 (NBB)

Country	% of imported value	Country	% of imported value
Germany	17,6%	China	1,5%
Netherlands	17,3%	Israel	1,3%
France	12,9%	Luxemburg	1,2%
United Kingdom	9,4%	Switzerland	1,1%
United States	4,7%	Russian Federation	1%
Italy	4,1%	Poland	1%
Spain	3%	Ireland	0,9%
Japan	2,3%	Austria	0,9%
Sweden	2,2%	Portugal	0,8%
India	2%	Turkey	0,7%
Total import 2003 (€) = 251 billion euro			

Table 3: Ranking of import countries according to imported value (€) for 2007 (NBB)

Country	% of imported value	Country	% of imported value
Netherlands	19,1%	Russian Federation	1,7%
Germany	16,8%	Japan	1,6%
France	11,4%	Poland	1,4%
United Kingdom	7,6%	Israel	1,3%
United States	4,1%	Luxemburg	1,2%
Italy	3,9%	Switzerland	1,1%
Spain	2,9%	Ireland	1%
Sweden	2,3%	Norway	1%
China	2,1%	Turkey	1%
India	2,1%	Czech Republic	0,9%
Total import 2007 (€) = 350 billion euro			

The color codes in the tables represent the geographic region to which each country belongs, based on the UN classification (orange = Europe, green = Northern America, blue = Asia)

A suggested structure for imports is (taken into account the detail in the MRIO models):

EU-27 (8)	**Rest of World (5)**
Netherlands (NL) Germany (DE) France (FR) United Kingdom (GB) Italy (IT) Spain (ES) Sweden (SE) Rest of EU-27 (RoEU)	United States (US) China (CN) India (IN) Japan (JP) Rest of World (RoW)

Of course, the Rest of Belgium (RoB, Brussels + Wallonia) remains as an import region as well, which in total leads to **14 import regions in the Flemish model**, thus 14 use tables for import.

5.1.2 MRIO model recommended to be used

As can be seen from Annex 2 and 3, there are several differences between the different MRIO models which make the choice for one or another not so straightforward. There are different aspects which need to be taken into consideration when selecting one model, for example:

- Year(s) for which data are available;
- Structure of the model, i.e. number of sectors/products;
- Environmental pollutants/impacts included;
- …

Taking these aspects into account, the choice really goes between the EXIOBASE and the WIOD model: the EORA model is structured in such a complicated way that linking the data with the Flemish model becomes a too intricate process, plus the environmental data included are not a good match with the Flemish model.

The two remaining models, EXIOBASE and WIOD, really differ on all aspects mentioned:

- EXIOBASE is only available for the year 2000, while WIOD is available for a time series from 1995 to 2009;
- EXIOBASE has a structure of 129x129 industries (thus more detailed), while WIOD only has a 35x35 industries structure;
- EXIOBASE has a match for 28 air emission pollutants and includes 185 materials, while WIOD only has a match for 10 air emission pollutants and includes 24 materials.

An important factor in the choice between these two models is the balance between the pro's and con's of each of the options. Whereas **EXIOBASE** has a detailed **structure** (more sectors are distinguished) which creates the advantage of more detailed environmental information, the fact that several of these details need to be aggregated to match the Flemish structure is problematic. It requires more data, more effort and several assumptions to make this possible, which will reduce the value of this detail. In Annex 3 the structure of the Flemish model and the EXIOBASE structure are compared. This shows that often a combination of sectors is needed. When this combination requires a **one-to-many link** (one sector abroad for many sectors in the Flemish model), this doesn't create problems. When however, the combination requires a **many-to-one link** (or many-to-many), the linking will become much more complex. The detail in the EXIOBASE model gives opportunities for some sectors, but will for a lot of other sectors go to waste since combination is needed.

When the impact caused abroad by Flemish economic activity is important, EXIOBASE is interesting, since it gives the opportunity to analyse impacts abroad in a quite detailed way (but with older data).

For **WIOD** the level of detail is less than that of the Flemish model, but this makes linking of the data much more straightforward. Using the WIOD model for environmental data per euro, is much easier compared to the EXIOBASE: there is only a one-to-one link or one-to-many link to be done, which is easy to do. Of course, the fact that there are only 35 sectors distinguished is important since it might create a significant loss of detail in the environmental data for some sectors (e.g. agriculture as one sector). This does reduce the 'specificity' of the environmental data: e.g. when agriculture is one sector compared to the subdivision in arable farming, horticulture and animal husbandry in the Flemish model.

When the main interest of analyses with the Flemish model focuses on the impact in Flanders, imports are taken into account to be complete but less precise in the assessment of environmental impacts. In this case WIOD is a valuable model to refer to. If the impact abroad is less specific, this of course is not ideal, but not problematic either when Flanders is the main focus.

When taking into account as well the fact that all efforts to link the high level of detail in the EXIOBASE to the Flemish model concern data of the year 2000, one can wonder whether this detail is really important enough when it is not representative for the situation in the year studied. Besides this, the fact that EXIOBASE is only available for 2000 also makes the availability of 2 years in the Flemish model less valuable: when making calculations with the model and EXIOBASE data for import

impacts, the differences between 2003 and 2007 related to import will only be based on monetary differences. The importance in difference of import data for 2003 and 2007 can be seen in tables 2 and 3. The total import has increased significantly, with almost 40%. The imports to Belgium from the Netherlands, for example, have increased with 53% in 2007, compared to 2003! It is clear that imports have significantly evolved over time. When we look at the evolution of for example CO_2-emissions (e.g. based on the WIOD model) for the entire economy in the Netherlands, between 2003 and 2007, the emissions per euro output of the industry decreased with 20%. Therefore it is clear that differentiated data for several years can really create added value in analysis results.

This shows that in case one values the 'up-to-date' import data more than the level of detail or amount of pollutants to analyze, WIOD is the most interesting choice. When one values the detail and amount of environmental information, EXIOBASE will probably be preferred.

5.1.3 Additional options for analysis through coupling

By coupling the environmental information in the WIOD/EXIOBASE model to the existing Flemish table according to option 2b, it will become possible to

- Get more detailed information (depending on choice in level of detail) on impacts abroad through Flemish consumption & production (differentiated impacts related to countries/regions distinguished);
- Get more up-to-date environmental information (2003 and 2007 available in WIOD);
- Calculate the impacts abroad better without complicating the model as it is (as it would when using the option to include the Flemish model in the MRIO);
- …

5.1.4 Estimation of costs

In this paragraph the costs are assessed related to the effective linking of the WIOD/EXIOBASE environmental data to the import in Flanders from the 14 regions as suggested. This estimation is only a rough indication based on the efforts and steps needed for creating the link.

The next steps are to be followed:

- Develop conversion table for linking the sectors in the MRIO table to the 118-120 sectors in the Flemish tables;
- Prepare the MRIO tables for the coupling: environmental data in MRIO tables are related to the total output of each sector and need to be recalculated per Euro output for each sector;
- Prepare Flemish use-tables for coupling: This is the most complex part, since the 3 import regions as defined in the current Flemish tables need to be further divided in 14 import regions (as suggested). One possibility is to use the ratio of the import value in Belgium from each defined country/region for sector X and the total import value in Belgium for sector X (from MRIO tables) as an allocation rule for subdividing the Flemish use-tables.
- Ideally the new 'import tables' are converted into a MatIDE and Simapro format, both software packages that are used for analyses with the Flemish IO-model.

A rough estimation of the mandays needed to perform the steps as described above: 50-80 working days, depending on the choice for linking to the WIOD resp. the EXIOBASE model and the number of reference years (2003 resp. 2007) to be elaborated.

5.2 Conclusion

Based on this feasibility study with regard to the added value and the linking of existing MRIO models for the Flemish IO-model, we come to the following suggestions and conclusions:

- The most promising option for linking both models is the option that links the environmental information from the MRIO model, while also further subdividing the regions where Flanders imports from. This means that the structure of the Flemish model remains as it is, but the environmental data for import (per euro) are taken from the MRIO model. The structure would still be as such that the imports are linked by taking the economic imports from the use tables and environmental multipliers per euro (so the total impact behind one euro of product imported) from the MRIO model. This of course requires some adjustments, of which the most relevant are:
    - Conversion tables between the sectors in the Flemish model and the sectors in the MRIO model;
    - Further subdivision of the import flows according to countries/regions defined.
- A suggested structure for dividing the import regions is (taken into account the detail in the MRIO models):

EU-27 (8)	**Rest of World (5)**
Netherlands (NL) Germany (DE) France (FR) United Kingdom (GB) Italy (IT) Spain (ES) Sweden (SE) Rest of EU-27 (RoEU)	United States (US) China (CN) India (IN) Japan (JP) Rest of World (RoW)

  Of course, the Rest of Belgium (RoB, Brussels + Wallonia) remains as an import region as well, which in total leads to 14 import regions in the Flemish model.
- As discussed in the previous chapters, it is impossible to select one of the available MRIO models to be used in combination with the Flemish tables. The choice will highly depend on the goal one has when starting the exercise. Therefore, some choices need to be made related to this goal in order to select the 'most suited' model. Important questions that need contemplation are:
    - Is it important that the data are from the same year as the Flemish model or not?
        - Yes → WIOD is preferred;
        - No → EXIOBASE can be used, but other aspects will have to point out whether the effort is worthwhile (current data are also not a match with the year of the Flemish tables);
    - Which environmental indicators need to be covered and to which extent?
        - As much pollutants as possible (air) as well as materials with much detail → EXIOBASE offers this;
        - The most important pollutants (air) (greenhouse gases) as well as materials, but on a general level (several materials, but only one extraction sector), plus energy carriers used → WIOD
    - How much sector detail is needed (level of specificity in environmental data) for sectors abroad?
        - High level of detail for some sectors, e.g. primary sectors → EXIOBASE
        - Less detail, more aggregated sectors → WIOD

Depending on the answers to the questions, a different choice in MRIO model can be made. Also, depending on the needs it remains necessary to consider whether the costs and benefits are balanced.

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Appendix 1 Cards for the different MRIO models

NAME:	Exiobase
	http://www.exiobase.eu/
Developed by:	FEEM, TNO + 35 partners
Financed by:	FP6
STRUCTURE MONETARY TABLES	
Available tables [SUT, IO, import, …]	Multi-regional Environmentally Extended Supply and Use / Input Output (MR EE SUT/IOT) database. It was developed by harmonizing and detailing SUT for a large number of countries, estimating emissions and resource extractions by industry, linking the country EE SUT via trade to an MR EE SUT, and producing an MR EE IOT from this.
Number of industries/products	Distinguishing 129 industry sectors and products by country
Reference year(s)	2000
Countries/regions?	Covering 43 countries (95% of the global economy) and the Rest of the World (combining the remaining 150+ countries)
Sources [statistics, RAS, …]	EU 27 based on Eurostat; 16 other countries based on SUT and IO. EU countries SUT not available: 'same country assumption' using macro-economic data. In case only IO: an artificial SUT was created assuming a perfectly diagonal supply table. If SUT table available in purchaser prices: converted to basic prices.
ENVIRONMENTAL DATA	
Sources [statistics, RAS, …]	**resource data** : SERI and Wuppertal Institute; **energy** : IEA database; **minerals** : USGS. Data are linked to the sector that de facto does the extraction. **Emissions**: **energy related emissions** : based IEA database, transformed to supply and use framework and converted into a residence perspective (IEA uses the territorial principle (particularly for transport fuels. IEA data needed to be mapped to the EXIOPOL classification based

	on physical and economic variables to estimate the use of IEA energy products by EXIOPOL sector. for non energy related emissions: similar activity variables were inventoried (amount of cows, pigs, chickens in a country) and emission factors were used to calculate the emissions. **Land use:** data from FAO **agricultural water use** computed with the LPJmL model, other water extraction a variety of data sources and assumptions are made
Available environmental parameters in extension tables [emissions to air, water, soil; use of water, energy, materials, …]	Covering 28 emissions to air, 15 land-use types (=resources), 185 materials (Domestic Extraction and Unused Domestic Extraction; N- and P- load of manure and biomass; water use (blue, green and total) by industry
DATA AVAILABILITY	
Publicly available	•Free versions A detailed EE SUT for one country, and an aggregated global MR EE SUT/IOT at the level of x world regions and y sectors/products •For purchase version The full, detailed MR EE SUT and a product x product and industry x industry MR EE IOT. Only available within a few months
Price	purchase version : A single membership costs EUR 1500 excluding VAT
Data format? [csv, excel, …]	Excel
OTHER	
Other (socio-economic) parameters available?	Taxes less subsidies on products purchased Other net taxes on production Compensation of employees : wages, salaries, & employers social contributions: Low-skilled, Medium-skilled, High-skilled Operating surplus : Consumption of fixed capital, Rents on land, Royalties on resources, Remaining net operating surplus Compensation of Employees : wages & salaries, employers social contributions Employed persons Employment hours : Low-skilled, Medium-skilled, High-skilled

NAME:	World Input Output Database (WIOD)
	http://www.wiod.org/
Developed by:	Univ. Groningen, IPTS
Financed by:	FP7, Theme 8 (socio economic sciences and humanities)
STRUCTURE MONETARY TABLES	
Available tables [SUT, IO, import, …]	World Tables · International Supply and Use table at current and previous year prices, with use split into domestic and import by country (35 industries by 59 products) · World input-output table at current prices and at previous year prices (35 industries by 35 industries) · Interregional Input-Output table for 6 regions (35 industries by 35 industries) National Tables · National supply and use tables at current and previous year prices (35 industries by 59 products) · National Input-Output tables in current prices (35 industries by 35 industries
Number of industries/products	USE table: - 36 columns intermediate cons. + final cons. HH, final cons. Non-profit, final cons. Government + gross fixed capital, changes in inventories, gross capital formation + exports (~similar to Flemish model) - 59 rows + rows for calculating c.i.f. to purchasers price + added value rows (~similar to Flemish model) **-> 35 industries X 35 industries (IOT)**
Reference year(s)	time series 1995-2009
Countries/regions?	EU-27 Canada, US, Brazil, Mexico, Turkey, Russia, China, India, Japan, South Korea, Taiwan, Indonesia, Australia >85% of world GDP

Sources [statistics, RAS, …]	public statistics (national accounts (time series), SUT (infrequent), international trade statistics (time series)) Harmonisation is applied (estimations) -> in between "official statistics" and "anything goes because we can RAS" approach
ENVIRONMENTAL DATA	
Sources [statistics, extrapolation, …]	"building on Exiopol project"
Available environmental parameters in extension tables [emissions to air, water, soil; use of water, energy, materials, …]	energy use emissions to air natural resources extraction (SERI database, based on FP5-Mosus, ~exiopol) land use (ResourceSTAT-FAO, ~Exiopol) water use (Exiopol: water blue (surface, ground), green (rain), total) emissions to water **Gross energy use by sector and energy commodity** **Emission relevant energy use by sector and energy commodity** **CO2 Emissions modelled by sector and energy commodity** **Emissions to air by sector and pollutant** **Land use, Materials use and Water use by type and sector**
DATA AVAILABILITY	
Publicly available	YES
Price	free downloadable (http://www.wiod.org/database/index.htm)
Data format? [csv, excel, …]	Excel
OTHER	
Other (socio-economic) parameters available?	"building on EU KLEMS project" for non-EU: country specific data or World KLEMS model?
Available parameters	Industry output, value added, at current and constant prices (35 industries) Capital stock, investment (35 industries) Wages and employment by skill type (low-, medium- and high-skilled) (35 industries)

NAME:	EORA
	www.worldmrio.com
Developed by:	University of Sidney
Financed by:	own research project
STRUCTURE MONETARY TABLES	
Available tables [SUT, IO, import, …]	EORA retains the technology assumption made by the providers of raw data. It combines a mix of supply-use (SUT), as well as industry-by-industry (IIOT) or commodity-by-commodity tables (CIOT), linked into one compound MRIO. This strategy was pursued in accordance with one of EORA's guiding principle-avoiding transformations of the original raw data as much as possible for the sake of transparency. SUT have advantages for analytical modelling, however S&U matrices are only available for a limited number of countries. For Belgium --> SUT. The remaining countries have to be represented by IOTs.
Number of industries/products	20-500 sectors, depending on the country --> no adjustments to make it all the same structure
Reference year(s)	Historical time series : 1990-2009
Countries/regions?	187 countries
Sources [statistics, RAS, …]	**Four main types** of data (in general): 1. IO tables and main aggregates data from national statistical offices; 2. IO compendia from EUROSTAT 2011, IDE-JETRO 2006 and OECD 2009; 3. the UN National Accounts Main Aggregates Databases (UNSD 2011a); 4. the UN National Accounts Official Data (UNSD 2011b); 5. the UN Comtrade international trade database (UN 2011); 6. the UN Servicetrade international trade database (UN 2009).
ENVIRONMENTAL DATA	
Sources [statistics, RAS, …]	Statistics
Available environmental parameters in extension tables [emissions to air, water, soil; use of water, energy, materials, …]	**35 types of environmental indicators** covering: 1) AIR POLLUTION: 23 GHG (with difference between fossil and biogenic CO2), air quality: CO, NOx, NMVOC, NH3, SO2, HC, HCFC141b, HCFC142b 2) water use 3) ecological footprint

	4) human appropriation of net primary productivity !!! Not all available yet, but will be made available soon pending the completion of analysis papers in progress
DATA AVAILABILITY	
Publicly available	YES, but not for for-profit projects
Price	*for free*
Data format? [csv, excel, …]	Excel
OTHER	
Other (socio-economic) parameters available?	/
Available parameters	MRIO analysis: structural path, footprint, tradeflow analysis, … reliability statistics (estimate of standard deviation) …

NAME:	**GTAP-MRIO**
Developed by:	Norwegian Univ. Of Science and Technology (Industrial Ecology Program) + Cicero
Financed by:	
STRUCTURE MONETARY TABLES	
Available tables [SUT, IO, import, …]	IOT
Number of industries/products	57 sectors
Reference year(s)	2004 & 2007
Countries/regions?	129 in GTAP8.0
Sources [statistics, RAS, …]	Economic & trade data based on the Global Trade Analysis Project (GTAP) database
ENVIRONMENTAL DATA	
Sources [statistics, extrapolation, …]	Environmental data based on the Global Trade analysis Project (GTAP) database For CO2: overwritten by national data (NAMEAs)
Available environmental parameters in extension tables [emissions to air, water, soil; use of water,	Energy volumes CO2 and non-CO2 emissions

energy, materials, …]	land use by agro-ecological zone
DATA AVAILABILITY	
Publicly available	yes
Price	*payment needed, but unknown*
Data format? [csv, excel, …]	?
OTHER	
Other (socio-economic) parameters available?	migration & remittances foreign income payments and receipts

Appendix 2 Comparison between air emissions and materials included in the different models

Flemish model - air emissions	Exiobase - air emissions	WIOD - air emissions	EORA - air emissions
Aromats			
Asbestos			
As	As		
Be			
Benzene			
Cd	Cd		
CH4	CH4	CH4	
Co			CF4
CO	CO	CO	CO2
CO2	CO2	CO2	CO2
Cr	Cr		
Cu	Cu		
Dioxins	Dioxins		
HFC134a			HFC134a
Formaldehyde			
Hg	Hg		
Mn			
N2O	N2O	N2O	N20
NH3	NH3	NH3	NH3
Ni	Ni		
NMVOS	NMVOC	NMVOC	NMVOC
NOx	NOx	NOX	NOx
PAK	PAH		
Pb	Pb		
PM10	PM10		
PM2,5	PM2.5		
Sb			
Se	Se		
SO2	SOx	SOX	SO2
Particulates	TSP		
Tl			
Toluene			
V			
VOS			
Zn	Zn		
Cl-			
H2S			

Flemish model - air emissions	Exiobase - air emissions	WIOD - air emissions	EORA - air emissions
PFK's			
SF6			SF6
Naftalene			
Phenanthrene			
Anthracene			
Fluoranthene			
Chrysene			
benzo(a)anthracene			
benzo(a)pyrene	Benzo(a)pyrene		
benzo(k)fluoranthene	Benzo(k)fluoranthene		
indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene		
benzo(g,h,i,)perylene			
benzo(e)pyrene			
benzo(j)fluoranthene			
benzo(b)fluoranthene	Benzo(b)fluoranthene		
dibenzo(a,h)anthracene			
acrylonitril			
1,2 dichloorethane			
Dichloormethane			
phenol			
styrene			
tetrachloormethane			
trichloorethene			
xylene-isomers			
Sulphur carbon			
tetrachloorethene			
pentachloorphenol			
hexachloorbenzene	HCB		
trichloorbenzene			
trichloorethane			
hexachloorcyclohexane			
trichloormethane			
monovinylchloride			
Total match	**27**	**8**	**10**

Flemish model - air emissions	Exiobase - air emissions	WIOD - air emissions	EORA - air emissions
No match	PCBs		C2F6 C3F8 C4F10 C5F12 C6F14 C7F16 cC4F8 HCFC141b HCFC142b HFC125 HFC143a HFC152a HFC227ea HFC23 HFC236fa HFC245fa HFC32 HFC365mfc HFC4310mee NF3

Flemish model – primary materials	Exiobase - primary materials	WIOD - primary materials	EORA - primary materials
Biomass used	Biomass used: Rice Wheat Other cereals Roots and tubers Sugar crops Pulses Nuts Oil crops Vegetables Fruits Fibres Other crops Crop res.-straw Other crop resid. Grazing	Biomass feed used Biomass animals used (partly) Biomass food used Biomass other used	/
Biomass unused	Biomass unused: Rice Wheat Other cereals Roots and tubers Sugar crops Pulses Nuts Oil crops Vegetables Fruits Fibres Other crops Crop res.-straw Other crop resid.	Biomass feed unused Biomass animals unused (partly) Biomass food unused Biomass other unused	/

Flemish model – primary materials	Exiobase - primary materials	WIOD - primary materials	EORA - primary materials
	Grazing		
Fish used	Biomass used animals-marine fish animals-inland water fish	Biomass animals used (partly)	/
Fish unused	Biomass unused animals-marine fish animals-inland water fish	Biomass animals unused (partly	/
Forestry used	Biomass used Wood timber Wood other	Biomass forestry used	/
Forestry unused	Biomass unused Wood timber Wood other	Biomass forestry unused	/
Minerals used	Non-metallic minerals used Chemical and fertilizer minerals Clays & kaolin Limestone, gypsum, chalk, dolomite Salt Slate Other industrial minerals Building stones Gravel and sand Other construction minerals	Minerals construction used Minerals industrial used	/
Minerals unused	Non-metallic minerals unused Chemical and fertilizer minerals Clays & kaolin Limestone, gypsum, chalk, dolomite Salt Slate Other industrial minerals Building stones Gravel and sand Other construction minerals	Minerals Construction unused Minerals industrial unused	/
Coal used	Fossil energy carriers used Hard coal Lignite/brown coal	Fossil coal used	/
Coal unused	Fossil energy carriers unused Hard coal Lignite/brown coal Peat(?)	Fossil coal unused	/
Oil-gas used	Fossil energy carriers used Crude oil Natural gas Natural gas liquids	Fossil oil used Fossil gas used	/
Oil-gas unused	Fossil energy carriers unused Crude oil Natural gas Natural gas liquids	Fossil oil unused Fossil gas unused	/

Flemish model – primary materials	Exiobase - primary materials	WIOD - primary materials	EORA - primary materials
Ores used	Metal ores used Iron ores Bauxite and aluminium Copper Lead Nickel Tin Uranium and thorium Zinc Precious metals Other metal ores	Minerals metals used	/
Ores unused	Metal ores unused Iron ores Bauxite and aluminium Copper Lead Nickel Tin Uranium and thorium Zinc Precious metals Other metal ores	Minerals metals unused	/

Appendix 3 Comparison between sectoral detail included in the different models

Making the link between the Flemish model and the data from the MRIO model will depend on the structure of the two models and the relationship between different sectors. Several situations may exist:

- One-to-one link: the sectors in both models are the same and thus no additional manipulation of the environmental data per euro is needed;
- One-to-many link: there is only one sector in the MRIO model, which is representative for more than one sector in the Flemish model. This doesn't require any manipulation of the environmental data per euro for the sector in the MRIO model: the data will be used for the different sectors as included in the structure of the Flemish model;
- Many-to-one link or many-to-many link: There are several sectors distinguished in the MRIO model, while only one sector is included in the Flemish model. This would require a combination of the different environmental data per euro for the sectors into one number. For this, an indication of weighting between the different sectors is needed in order to have a weighted average impact per euro. This requires quite a lot of manipulation, especially when besides the sectors, this also requires the combination of different countries.

In the table, the relationships are indicated in colors as follows:

- One-to-one: blank
- One-to-many: green
- Many-to-one or many-to-many: red

A comparison is only made for the EXIOBASE table and the WIOD table. EORA is not further compared since in this model, the structure (number of sectors) will differ depending on the country. The EORA model doesn't use a uniform number of sectors/products. Instead, the number of sectors/products used in the statistics of each country is kept and correspondence tables are used between all countries.

Comparison between the structure of the Flemish IO model and the EXIOBASE

Flemish IO-model (2007) 122 x 122	EXIOBASE (2000) 129 x 129
Arable farming	-Cultivation of paddy rice -Cultivation of wheat -Cultivation of cereal grains -Cultivation of oil seeds -Cultivation of sugar cane, sugar beet -Cultivation of plant-based fibers -Cultivation of crops***
Horticulture	-Cultivation of vegetables, fruit, nuts -Cultivation of crops***
Animal husbandry	-Cattle farming -Pigs farming -Poultry farming -Meat animals -Animal products -Raw milk -Wool, silk-worm cocoons
Forestry	Forestry, logging and related service activities
Fishing, fishery	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing
Mining of coal, browncoal, peat	Mining of coal and lignite; extraction of peat
Extraction of petroleum, natural gas and related services	-Extraction of crude petroleum and services… -Extraction of natural gas and services…. -Extraction, liquefaction, and regasification of other petroleum and gaseous materials
Mining of uranium and thorium ores	Mining of uranium and thorium ores
Mining of metal ores	-Mining of iron ores -Mining of copper ores & concentrates -Mining of nickel ores & concentrates -Mining of aluminium ores & concentrates -Mining of precious metal ores & concentrates -Mining of lead, zinc, tin ores & concentrates -Mining of other non-ferrous metal ores & concentrates
Extraction of minerals	-Quarrying of stone -Quarrying of sand and clay -Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying
Processing of meat and production of meat products	-Processing of meat cattle -Processing of meat pigs -Processing of meat poultry -Production of meat products
Processing and conservation of fish and fish products	Manufacture of fish products
Production of vegetable and animal oils and fats	Processing vegetable oils & fats
Dairy industry	Processing of dairy products
Processing and conservation of fruits and vegetables	Processing of food products? (processed rice?~milling and starch)
Milling and starch production	
Bread, baked goods, cookies, …	
Production of sugar, chocolate and sugar products	Sugar refining
Production of drinks	Manufacture of beverages
Production of tobacco products	Manufacture of tobacco products
Processing, spinning of textile fibers, weaving of textile	Manufacture of textiles

Flemish IO-model (2007) 122 x 122	EXIOBASE (2000) 129 x 129
Manufacturing of textile products (confection)	
Manufacturing of clothing, fur industry	Manufacture of wearing apparel; dressing and dyeing of fur
Leather industry and manufacturing of shoes	Tanning and dressing of leather, manufacture of luggage, handbags, saddler, harness and footwear
Wood industry and manufacturing of wooden, straw, cork products	Manufacture of wood and of products of wood, cork, except furniture; articles of straw
Paper and cardboard industry	Manufacture of pulp, paper and paper products
Publishing	Publishing, printing and reproduction of recorded media
Printing and related services	
Production of cokes, refined petroleum products	-Manufacture of coke oven products -Manufacture of motor spirits -Manufacture of kerosene -Manufacture of gas oils -Manufacture of fuel oils -Manufacture of petroleum gases and other (except natural gas) -Manufacture of other petroleum products -Processing of nuclear fuel
Production of chemical basic products	Manufacture of chemicals and chemical products
Production of pesticides, of chemical products for agriculture; of paint, varnish, ink	
Pharmaceutical industry	
Production of soap, detergents, perfume and cosmetics	
Production of other chemical products	
Production of synthetic and artificial fibers	
Rubber industry	Manufacture of rubber and plastic products
Production of plastic products	
Production of glass and glass products	Manufacture of glass and glass products
Production of ceramic products, cement, chalk, plaster	-Manufacture of ceramic goods -Manufacture of cement, lime and plaster
Manufacturing of concrete, chalk and plaster products, (natural) stone	-Manufacture of bricks, tiles and construction products, in baked clay -Manufacture of other non-metallic mineral products
Production of iron and steel, ferro-alloys and pipes	-Manufacture of basic iron and steel and of ferro-alloys and first products thereof -Precious metal production -Aluminium production -Lead, zinc and tin production -Copper production -Other non-ferrous metal production -Casting of metals
First processing of steal, production of non-ferro metals, moulding of metals	
Surface treatment of metals	Manufacture of metal products, except machinery and equipment
Manufacturing of metal constructions, metal recipients, radiators, kettles for central heating, ...; forging, pressing, ...	
Production of scissors, knives, cutlery, tools and other metal products	
Production of motors and mechanical drivers, excl. Engines for air transport, cars and other motorised vehicles	Manufacture of machinery and equipment
Production of machines for general use	

Flemish IO-model (2007) 122 x 122	EXIOBASE (2000) 129 x 129
Production of machines for agriculture and forestry, and tools	
Production of household appliances	
Production of office machines and computers	Manufacture of office machinery and apparatus
Production of electromotors, electric generators and transformators, switch and supply machinery, isolated wiring, ...	Manufacture of electrical machinery and apparatus
Production of accumulators and electric batteries, electric lamps and lighting equipment, ...	
Production of audio-, video- and tele-communication equipment	Manufacture of radio, television, communication equipment and apparatus
Production of medical equipment, precision and optical instruments and watches	Manufacture of medical, precision and optical instruments, watches and clocks
Manufacturing and assembling of cars	Manufacture of motor vehicles, trailers and semi-trailers
Manufacturing of bodywork, trailers and caravans, car parts	
Building and reparing of ships, production of rolling material for rail and tramway, air and space shuttles	Manufacture of other transport equipment
Manufacturing of motorcycles, cycles, ...	
Manufacturing of furniture	Manufacture of furniture; Manufacturing
Treating of gems and manufacturing of jewellery	
Manufacturing of music instruments, sports articles, games, toys, ...	
Recuperation	-Recycling of metal waste and scrap -Recycling of non-metal waste and scrap
Production and distribution of electricity, gas, steam and hot water	-Production of electricity by coal -Production of electricity by gas -Production of electricity by nuclear -Production of electricity by hydro -Production of electricity by wind -Production of electricity nec, incL biomass and waste -Transmission of electricity -Distribution and trade of electricity -Manufacture of gas; distribution of gaseous fuels through mains -Steam and hot water supply
Collection, treatment and distribution of water	Collection, purification and distribution of water
Preparation of a (building) site	Construction
General construction and civil technical work, roofing and building of roof constructions	
Installation of rails, roads, airports, sports accommodation, ...	
Building installation	
Finishing of buildings, rental of machines for building sector	
Car dealer, maintenance and repairing of cars, ...	Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motor cycles parts and accessoiries
Retail fuels (gas stations)	Retail sale of automotive fuel
Wholesale	Wholesale trade and commission trade, except of motor vehicles and motorcycles
Retail	Retail trade, except of…
Hotels and other	Hotels and restaurants

Flemish IO-model (2007) 122 x 122	EXIOBASE (2000) 129 x 129
Restaurants, catering, bars, canteens, ...	
Transport by rail, transport over land following a schedule, taxis, other...	-Transport by railways -other land transport
Freight transport, transport through piping	-Other land transport -Transport via pipelines
Marine aviation	Sea and coastal water transport
Inland navigation	Inland water transport
Aviation	Air transport
Travelling agencies and tour operators	Supporting and auxiliary transport activities; activities of travel agencies
Freight handling, storage, ... (market)	
Transport related services (non-market)	
Post, telecommunication	Post and telecommunications
Financial institutions	Financial intermediation, except insurance and pension funding
Insurance	Insurance and pension funding
Services related to financial institutions	Activities auxiliary to financial intermediation
Real estate	Real estate activities
Car and other transportation renting, leasing	Renting of machinery and equipment without operator and of personal and household goods
Renting of machines and equipment,	
IT and related services	Computer and related activities
Detective and development work (market)	Research and development
Detective and development work (non-market)	
Legal aid, accountants, tax consultants, ...	Other business activities
Consultant companies (management)	
Technical advice, architects, engineers, ...	
Advertising	
Recruitment	
Investigation and security activities, industrial cleaning and various business services	
Public administration	Public administarion and defence; compulsory social security
Social security	
Education (market)	Education
Public education	
Education (other non-market)	
Health services	Health and social work
Veterinary services	
Public services (market)	
Public services (non-market)	
Waste and waste water collection, treatment (market)	-collection and treatment of sewage -collection of waste -incineration of waste -landfill of waste -sanitation, remediation and similar activities
Waste and waste water collection, treatment (non-market)	
Diverse associations (market)	Activities of membership organisations
Diverse associations (non-market)	
Film, video, radio and television (market)	Recreational, cultural and sporting activities
Film, video, radio and television (non-market)	
Other activities in the amusement business (market)	
Other activities in the amusement business (non-market)	
Press agencies and other cultural activities (market)	
Other cultural activities (non-market)	

Flemish IO-model (2007) 122 x 122	EXIOBASE (2000) 129 x 129
Sport and other recreation (market)	
Sports (non-market)	
Other services	Other service activities
Private households with employees	Private households with employed persons

It is clear from this comparison between the structure of the Flemish model and the EXIOBASE structure, that for a lot of sectors a combination of sectors is needed. When this combination requires a **one-to-many link** (one sector abroad for many sectors in the Flemish model), this doesn't create problems. When however, the combination requires a **many-to-one link** (or many-to-many), the linking will become much more complex. The detail in the EXIOBASE model thus gives opportunities for some sectors, but will for a lot of other sectors go to waste since combination is needed.

Comparison between the structure of the Flemish IO model and the WIOD

Flemish IO-model (2007) 122 x 122	WIOD (2007) 35 x 35
Arable farming	Agriculture, hunting, forestry and fishing
Horticulture	
Animal husbandry	
Forestry	
Fishing, fishery	
Mining of coal, browncoal, peat	Mining and quarrying
Extraction of petroleum, natural gas and related services	
Mining of uranium and thorium ores	
Mining of metal ores	
Extraction of minerals	
Processing of meat and production of meat products	Food, beverages and tobacco
Processing and conservation of fish and fish products	
Production of vegetable and animal oils and fats	
Dairy industry	
Processing and conservation of fruits and vegetables	
Milling and starch production	
Bread, baked goods, cookies, …	
Production of sugar, chocolate and sugar products	
Production of drinks	
Production of tobacco products	
Processing, spinning of textile fibers, weaving of textile	Textiles and Textile products
Manufacturing of textile products (confection)	
Manufacturing of clothing, fur industry	
Leather industry and manufacturing of shoes	Leather, leather and Footwear
Wood industry and manufacturing of wooden, straw, cork products	Wood and products of wood and cork
Paper and cardboard industry	Pulp, paper, printing and publishing
Publishing	
Printing and related services	
Production of cokes, refined petroleum products	Coke, refined petroleum and nuclear fuel
Production of chemical basic products	Chemicals and chemical products
Production of pesticides, of chemical products for agriculture; of paint, varnish, ink	
Pharmaceutical industry	
Production of soap, detergents, perfume and cosmetics	
Production of other chemical products	
Production of synthetic and artificial fibers	
Rubber industry	Rubber and plastics
Production of plastic products	
Production of glass and glass products	Other non-metallic mineral
Production of ceramic products, cement, chalk, plaster	
Manufacturing of concrete, chalk and plaster products, (natural) stone	
Production of iron and steel, ferro-alloys and pipes	Basic metals and fabricated metal
First processing of steal, production of non-ferro metals, moulding of metals	

Flemish IO-model (2007) 122 x 122	WIOD (2007) 35 x 35
Surface treatment of metals	Basic metals and fabricated metal
Manufacturing of metal constructions, metal recipients, radiators, kettles for central heating, ...; forging, pressing, ...	
Production of scissors, knives, cutlery, tools and other metal products	
Production of motors and mechanical drivers, excl. Engines for air transport, cars and other motorised vehicles	Machinery
Production of machines for general use	
Production of machines for agriculture and forestry, and tools	
Production of household appliances	
Production of office machines and computers	Electrical and optical equipment
Production of electromotors, electric generators and transformators, switch and supply machinery, isolated wiring, ...	
Production of accumulators and electric batteries, electric lamps and lighting equipment, ...	
Production of audio-, video- and tele-communication equipment	
Production of medical equipment, precision and optical instruments and watches	
Manufacturing and assembling of cars	Transport equipment
Manufacturing of bodywork, trailers and caravans, car parts	
Building and reparing of ships, production of rolling material for rail and tramway, air and space shuttles	
Manufacturing of motorcycles, cycles, ...	
Manufacturing of furniture	Manufacturing; Recycling
Treating of gems and manufacturing of jewellery	
Manufacturing of music instruments, sports articles, games, toys, ...	
Recuperation	
Production and distribution of electricity, gas, steam and hot water	Electricity, gas and water supply
Collection, treatment and distribution of water	
Preparation of a (building) site	Construction
General construction and civil technical work, roofing and building of roof constructions	
Installation of rails, roads, airports, sports accommodation, ...	
Building installation	
Finishing of buildings, rental of machines for building sector	
Car dealer, maintenance and repairing of cars, ...	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel
Retail fuels (gas stations)	
Wholesale	Wholesale trade and commission trade, except of motor vehicles and motorcycles
Retail	Retail trade, except of motor vehicles and motorcycles; repair of household goods
Hotels and other	Hotels & restaurants
Restaurants, catering, bars, canteens, ...	
Transport by rail, transport over land following a	Inland transport

Flemish IO-model (2007) 122 x 122	WIOD (2007) 35 x 35
schedule, taxis, other...	
Freight transport, transport through piping	
Marine aviation	Water transport
Inland water navigation	
Aviation	Air transport
Travelling agencies and tour operators	Other supporting and auxiliary transport activities; activities of travel agencies
Freight handling, storage, ... (market)	
Transport related services (non-market)	
Post, telecommunication	Post and telecommunications
Financial institutions	Financial intermediation
Insurance	
Services related to financial institutions	
Real estate	Real estate activities
Car and other transportation renting, leasing	Renting of M&Eq and other business activities
Renting of machines and equipment,	
IT and related services	
Detective and development work (market)	
Detective and development work (non-market)	
Legal aid, accountants, tax consultants, ...	
Consultant companies (management)	
Technical advice, architects, engineers, ...	
Advertising	
Recruitment	
Investigation and security activities, industrial cleaning and various business services	
Public administration	Public administration and defence; compulsory social security
Social security	
Education (market)	Education
Public education	
Education (other non-market)	
Health services	Health and social work
Veterinary services	
Public services (market)	
Public services (non-market)	
Waste and waste water collection, treatment (market)	Other community, social and personal services
Waste and waste water collection, treatment (non-market)	
Diverse associations (market)	
Diverse associations (non-market)	
Film, video, radio and television (market)	
Film, video, radio and television (non-market)	
Other activities in the amusement business (market)	
Other activities in the amusement business (non-market)	
Press agencies and other cultural activities (market)	
Other cultural activities (non-market)	
Sport and other recreation (market)	
Sports (non-market)	
Other services	
Private households with employees	Private households with employed persons

Using the WIOD model for environmental data per euro, is much easier compared to the EXIOBASE: there is only a one-to-one link or one-to-many link to be done, which is easy to do. Of course, the fact that there are only 35 sectors distinguished is important since it might create a significant loss of detail in the environmental data for some sectors (e.g. agriculture as one sector).