one planet economy network

Multiregional Input-Output Database

OPEN:EU Technical Document

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TECHNICAL DOCUMENT

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1. Introduction

Multiregional input-output analysis (MRIO) is increasingly used to analyse the environmental implications of consumption, be it for greenhouse gas emissions, land use, and water use. Input-output tables display the interconnection between different sectors of production and allow for a tracing of the production and consumption in an economy. Traditionally, input-output tables are constructed for national economies; however, production is increasingly global. Already in 2001, 22% of global CO2 emissions were associated with the production for goods traded internationally. Hence, multi-regional input-output tables – including the trade between different countries –have become attractive for representing the global aspects of our consumption (Andrew et al. 2009; Druckman and Jackson 2009; Lenzen et al. 2010; Wiedmann 2009a, 2009b; Wiedmann et al. 2010; Wilting and Vringer 2009; Hertwich and Peters 2009; Weber and Matthews 2008; Peters 2008).

The unique feature of a MRIO is that it allows the tracing of the production of a "typical product" of economic sectors, quantifying the contributions to the value of the product from different economic sectors in various countries represented in the model. It hence offers a description of the global supply chains of products consumed. If the specific use of land, energy, and water, and emissions of the industry sectors in each country are known, the total land, carbon and water footprints of the products can be quantified.

In the OPEN:EU project, a MRIO is used to assess the environmental footprints of products, supplemented by more specific accounting methods for the production of agricultural products which are particularly important for land and water use. This report is written to document the MRIO modeling methods used in the OPEN:EU project. It also provides a short discussion of the choice of a particular data set (GTAP vs. EXIOPOL) and some comments on the GTAP7 model. It is targeted at scientists who would like to understand the underlying methods and data considerations used to construct the footprint analysis for OPEN:EU. It also serves as introduction and documentation for those who will maintain and update the EUREPA tool that will be build in the project.

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. Due to increased globalization of production networks, there is increasing interest in the effects of trade on the environment (c.f. Jayadevappa and Chhatre, 2000; Copeland and Taylor, 2003).

With the increased interest in trade and the environment research activity is focusing on methods of accurately calculating the pollution embodied in traded products. Early studies in this area assumed that imports were produced with the same technology as the domestic economy (e.g. Wyckoff and Roop, 1994; Lenzen, 1998; Kondo et al., 1998; Battjes et al., 1998; Machado et al., 2001), however, using this assumption large errors may result when the countries have diverging technology and energy mixes (Lenzen et al., 2004; Peters and

Hertwich, 2006a,c)[1]. This stimulated research in the use of multi-regional input-output (MRIO) models. While MRIO models have been applied to regional economics since the 1950's (Miller and Blair, 1985), applications to environmental problems has only recently emerged (Chung and Rhee, 2001; Ahmad and Wyckoff, 2003; Lenzen et al., 2004; Nijdam et al., 2005; Peters and Hertwich, 2006a,b; Guan and Hubacek, 2006; Wiedmann, T. 2009b). These studies are finding large portions of pollution embodied in trade. For instance, Ahmad and Wyckoff, 2003 found that the emissions embodied in trade was on average 14% in OECD countries and over 50% in some OECD countries; they included data covering 80% of global emissions and use "conservative" assumptions to obtain a lower bound. Further, Ahmad and Wyckoff, 2003 found that "emissions embodied in international trade are important, growing, and likely to continue to grow".

Full multi-region models endogenously combine domestic technical coefficient matrices with import matrices from multiple countries or regions into one large coefficient matrix, thus capturing trade supply chains between all trading partners as well as feedback effects. The latter are changes in production in one region that result from changes in intermediate demand in another region, which are in turn brought about by demand changes in the first region.

In this report we discuss the theory behind MRIO models for applications in footprint calculations (Section 2) and discuss common modeling assumptions (Section 3). MRIO models require a considerable amount of data and we discuss many of the practical data issues that are encountered in MRIO modeling (Section 4). In Section 5 we briefly review important applications of MRIO in environmental policy making. In Section 6 we finally discuss the potential for increased use of MRIO models to indicate the type of policy questions the OPEN:EU model could be used to answer (section 6).

[1] Similar conclusions are found in the economic literature on factors (labor and capital) embodied in trade (Hakura, 2001).

2. Multi-regional Input-Output Analysis (MRIO)

Using IOA the total output of the domestic economy is given by[2]

$$x = Ax + y \qquad (1)$$

where *A* is the total inter-industry requirements and *y* is the total net demand on the economy,

$$y = y^d + y^{ex} - m \qquad (2)$$

where y^d are the products produced and consumed domestically, y^{ex} are the products produced domestically, but consumed in foreign regions (exports), and m are the products consumed domestically for both final and intermediate consumption, but produced in foreign regions (total imports). In this form, (1) is not suitable for applying arbitrary demands since imports are embedded in both *A* and *y* (Dietzenbacher et al., 2005).

It is possible to separate the domestic and imported components in *A* and *y* to obtain

$$x = (A^d + A^{im})x + y^d + y^{ex} + y^{im} - m \qquad (3)$$

where A^d is the industry requirements of domestically produced products per unit output, A^{im} is the industry requirements of imported products per unit output, and y^{im} is the final demand of imports (United Nations, 1999). A balance must hold for the total imports,

$$m = A^{im}x + y^{im} \qquad (4)$$

and thus (1) can be reduced to domestic activity only,

$$x = A^d x + y^d + y^{ex} = A^d x + y^t \qquad (5)$$

Using the linearity assumption of IOA, it follows that the output of the domestic economy for an arbitrary demand is

$$x^* = (I - A^d)^{-1} y^* \qquad (6)$$

where y^* could represent household demand, government demand, a unit demand on a particular sector, and so on. Given the domestic output, the requirement of imports by industry to produce y^* are given by $A^{im}x^*$. This import may instigate a series of feedbacks through trade flows and is discussed further below.

Using the direct multiplier for environmental impacts[3] per unit output, F, the environmental impacts embodied in domestic consumption are,

$$f^* = F(I - A^d)^{-1} y^* \qquad (7)$$

This equation does not include the environmental impacts that may occur in foreign regions due to imports.

Particularly for environmental impacts with global implications, such as global warming, it is important to calculate the global environmental impacts for production and consumption. Imports are generally produced in countries with different production technologies and energy mixes compared to the domestic economy. This suggests that a multi-regional model is required to correctly evaluate the pollution embodied in traded products. When trade is

[2] This section and selected parts of this document are based on Peters and Hertwich, 2009.

[3] The same equation applies for the standard economic factors of production such as labor and capital.

allowed between two or more countries trade feedbacks may occur so that production in one country, may require some of its own production via feedback loops (see Figure 1a). This type of interaction can be analyzed using MRIO.

***Table 1*. The notation used for the MRIO model.**

Name	Description
x_i	Output of region i.
y_{ii}	Final demand for goods produced and consumed in i.
y_{ij}	Final demand from region i to region j.
$y_i^{ex} = \sum_{j=1, j\neq i}^{m} y_{ij}$	Total final demand exports from region i.
A_{ii}	Interindustry requirements on domestic production in region i.
A_{ij}	Interindustry requirements from region i to j.
$A_i = \sum_i A_{ij}$	Total interindustry requirements in region i.
$m_{ij} = A_{ij} x_j + y_{ij}$	Total trade from region i to region j.
F_i	Direct factor requirements in region i.

An MRIO model extends the standard IO matrix to a larger system where each industry in each country has a separate row and column. If there are m regions then the extended IO matrix becomes[4]

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_m \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & A_{13} & \cdots & A_{1m} \\ A_{21} & A_{22} & A_{23} & \cdots & A_{2m} \\ A_{31} & A_{32} & A_{33} & \cdots & A_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_{m1} & A_{m2} & A_{m3} & \cdots & A_{mm} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_m \end{pmatrix} + \begin{pmatrix} y_{11} + y_1^{ex} \\ y_{21} \\ y_{31} \\ \vdots \\ y_{m1} \end{pmatrix} \tag{8}$$

The notation is described in Table 1. We have simplified the system by centering the model on the domestic economy, $i = 1$. Due to symmetry, any region can be considered as the domestic economy by re-labeling it as region 1. The block matrices of the extended IO table represent the global technology. The diagonal block matrices represent domestic interindustry requirements and the off-diagonal elements represent the interindustry requirements of traded products.

For some it may be easier to understand the MRIO model with separate equations. The output in the domestic economy is

$$x_1 = A_{11} x_1 + y_{11} + \underbrace{\sum_{j \neq 1} \left(A_{1j} x_j + y_{1j} \right)}_{\text{exports}} \qquad \text{for } i = 1 \tag{9}$$

where the export terms are all exports from region 1 to interindustry and final demand in all other regions. The outputs in the other regions are,

[4] Peters and Hertwich, 2004 build the MRIO equations from a 2-region system and is useful for those that may require a more detailed description of how the equations are derived.

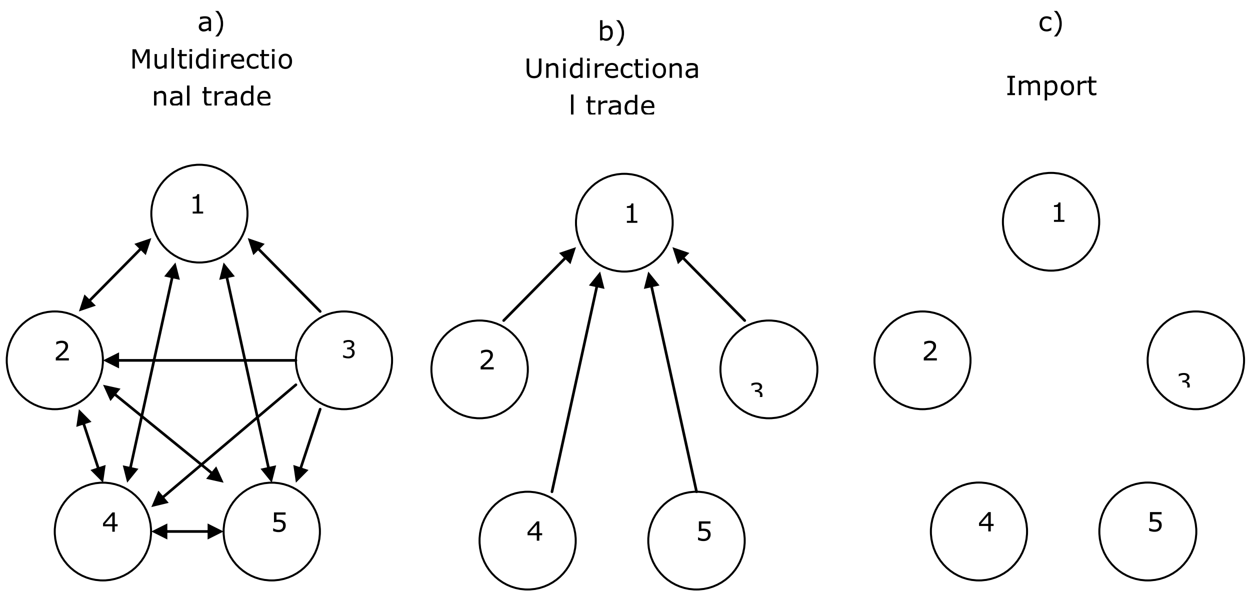
$$x_i = A_{ii}x_i + \underbrace{\sum_{j \neq i} A_{ij}x_j + y_{i1}}_{\text{exports}} \qquad \text{for all } i \neq 1 \qquad (10)$$

Since region 1 is treated as the domestic economy, the final demands y_{i1} are imports to region 1.

For a given consumption bundle, y_{i1}, in region 1 the environmental impacts occurring in each region to produce y_{i1} are given by $F_i x_i$ and the global environmental impact are,

$$f = \sum_i F_i x_i \qquad (11)$$

where F_i are the direct pollution intensities in region i.



*Figure***Error! No text of specified style in document.**-*1.* A schematic representation of the three trade scenarios for a five region model (adapted from Lenzen et al., 2004).

3. Common assumptions in MRIO

To perform an MRIO study requires a considerable amount of data, much of which is not directly available. Consequently, most current applications of environmental MRIO have applied some approximations to (8). In this section we discuss various approximations and simplifications that have been used in environmental MRIO. The following is largely based on Ahmad and Wyckoff, 2003; Lenzen et al., 2004; Peters and Hertwich, 2004; Nijdam et al., 2005; Peters and Hertwich, 2006a,b. Practical issues associated with data availability and handling are discussed in Section 4.

Uni-directional trade

If it is assumed that the domestic economy trades with all regions, but the other regions do not trade amongst each other (see Figure 1b), then the data requirements are greatly reduced without introducing large errors. Lenzen et al., 2004 found these effects to be around 1-4% (see their Table 7) and these terms are often assumed to be negligible in other regional models (Round, 2001).

Mathematically, the uni-directional trade assumption reduces (8) to,

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_m \end{pmatrix} = \begin{pmatrix} A_{11} & 0 & 0 & \cdots & 0 \\ A_{21} & A_{22} & 0 & \cdots & 0 \\ A_{31} & 0 & A_{33} & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_{m1} & 0 & 0 & \cdots & A_{mm} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \\ x_m \end{pmatrix} + \begin{pmatrix} y_{11} + y_1^{ex} \\ y_{21} \\ y_{31} \\ \vdots \\ y_{m1} \end{pmatrix} \quad (12)$$

Since this assumption reduces many of the feedback loops, the equation can be solved directly to obtain,

$$x_1 = (I - A_{11})^{-1}\left(y_{11} + y_1^{ex}\right) \quad (13)$$

for the domestic economy and the output in the other regions are

$$x_i = (I - A_{ii})^{-1} M_i \qquad \text{for} i > 1 \quad (14)$$

where

$$M_i = A_{i1}x_1 + y_{i1} \quad (15)$$

The exports term y_1^{ex} now includes both exports to final demand and exports to industry. This approach has been applied by Nijdam et al., 2005; Peters and Hertwich, 2006a,b, and (Weber and Matthews 2008).

If only analyzing the total final demand on an economy, the uni-directional trade assumption does not require A_{ij}. If the total final demand is used, then (15) gives the total imports into the domestic economy and so M_i can be obtained directly from IO or trade data.

The assumption of uni-directional trade gives two options for the diagonal terms of the foreign regions. If $A_{ii}, i > 1$ is placed on the diagonal, then multi-directional trade is totally neglected.

Alternatively, if $A_i, i > 1$ is placed on the diagonal, then multi-directional trade is included, but with the assumption that imports are produced with domestic technology (see Section 3.2). However, the country that is allocated the emissions for the production of the imports will be incorrect. Due to data availability, countries may only supply A_i in which case it is implicitly assumed that multi-directional trade is included using domestic technology.

Import assumption

A common assumption is that imports are produced with domestic production technology (Figure 1c). The import assumption has also been called "autonomous regions" by Lenzen et al., 2004 and "mirrored economy" by Strømman and Gauteplass, 2004. The assumption greatly reduces data requirements, but may lead to large errors. Lenzen et al., 2004 found the error between the import assumption and multi-directional trade for Danish CO_2 emissions to be 20-50% depending on the final demand. Peters and Hertwich, 2006a found the difference between the import assumption and uni-directional trade for Norwegian household consumption to be a factor of 2.7 for CO_2, 9.7 for SO_2, and 1.5 for NO_x. Most IO studies of environmental issues apply the import assumption and so it is likely that many of these studies incorrectly calculate the emissions associated with the production of imports.

One way to apply the import assumption is to assume $A_{ii} = A_{11}$, $A_{ij} = A_{i1}$, and $F_i = F_1$ and then substitute into (8). Simplification then results in,

$$x_i = (I - A_1)^{-1} y_i \qquad (16)$$

where y_i is the final demand placed on each region (Peters and Hertwich, 2004). This equation gives the emissions in each region, including imports to industry, but it assumes they have the same production technology as the domestic economy and allocates the embodied emissions to the domestic economy. The correct allocation can be obtained by using (8), but with substitution of $A_{ii} = A_{11}$ and $A_{ij} = A_{i1}$.

Others

Some approaches have been slightly different to what is outlined above. Ahmad and Wyckoff, 2003 do not use the matrix based approach we have described above, but use an iterative procedure which approximates the matrix solution. Lenzen et al., 2004 replace each of the block matrices with a make and use block which displays additional structure, but applies an industry-technology assumption on solution. Methods not using IOA to estimate pollution embodied in trade often neglect indirect emissions in the production chain and are consequently not considered in this article.

4. Practical issues

A significant amount of data from a variety of sources is required to perform an MRIO study. As a consequence several practical issues arise in the data manipulation phase. This section briefly discusses the main areas of concern. Lenzen et al., 2004 also give a detailed discussion of some of these issues.

Grouping of like regions

Two approaches have been used in the past to fill in for missing IO data. A first approach is to allocate the countries without IO data the IO data of a "representative" country. Ahmad and Wyckoff, 2003 used the United States of America and Lenzen et al., 2004 used Australia as the representative country. Another approach is to collect IO data for the most significant trading partners and then allocate the minor trading partners to one of the major trading partners to make larger aggregated regions with fixed technology. This approach was applied by Peters and Hertwich 2006a,b and the allocation was performed based on energy use per capita, CO_2 emissions per capita, and gross domestic product per capita. If the major trading partners represent a diverse range of economies, then the second approach is likely to give a better approximation. In both approaches, it is also possible to adjust emission coefficients if the data is available; for example, when allocating emissions data between countries Ahmad and Wyckoff, 2003 adjusted the emission coefficient for electricity production based on other reliable data sources (also see Battjes et al., 1998).

Using trade shares to estimate A_{ij}

Data on A_{ij} and y_{ij} is generally not directly available; however, many countries construct $A_i^{im} = \sum_{j \neq i} A_{ij}$ and $y_i^{im} = \sum_{j \neq i} y_{ij}$. Using A_i^{im} together with trade flow data it is possible to estimate the share of trade flows to final demand and industry in each region using

$$A_{ij} = \hat{s}_{ij} A_i^{im} \qquad (17)$$

and

$$y_{ij} = \hat{s}_{ij} y_i^{im} \qquad (18)$$

where

$$\left\{s_{ij}\right\}_k = \frac{\left\{m_{ij}\right\}_k}{\left\{\sum_i m_{ij}\right\}_k} \qquad (19)$$

where $\left\{m_{ij}\right\}_k$ is the total imports of product *k* from region *i* to *j*. It is important to consider the trade shares in individual sectors and not the average of all sectors. More details on using trade shares to estimate A_{ij} can be found in Lenzen et al., 2004.

Exchange rates

In an MRIO model, exchange rates are needed to link the data from different regions to a common currency. There has been considerable debate in the climate change literature about the use of Purchasing Power Parities (PPP) or Market Exchange Rates (MER) in currency conversation (Castles and Henderson, 2003; Grübler et al., 2004; Nordhaus, 2005). The MER is calculated based on traded products, while the PPP is calculated based on a bundle of consumed products; both traded and non-traded. The PPP rates give a better measure of income levels across different countries. Much of the debate about PPP and MER has been based on the comparison of income levels and not a comparison of traded products. Since MRIO models focus on traded products we suggest the use of MERs to obtain a common currency. It is possible to avoid the exchange rate problems by using physical units for key sectors; however, data in physical units requires additional data issues, particularly availability.

Inflation

The data covering a variety of regions is likely to come from various time periods. Adjustments for inflation are required to make the data consistent for a given base year. The easiest approach is to use the Consumer Price Index (CPI) in each country to adjust for inflation. However, the CPI is likely to introduce other errors. The CPI is an aggregated index, while price changes are likely to be different in each of the IO sectors. Further, the CPI also varies depending on the base year used and the method of indexing applied. These issues are difficult to resolve and the errors will be greater for a large CPI and when there is a big difference in base years.

Product or industry classifications

It is possible to perform IOA using a product classification or an industry classification. Through the make and use system it is possible to transfer between the two using the make matrix. The emissions data is usually in an industry classification and the final demand, depending on the application, will be either an industry or product classification. Consequently, for some studies there will be a need to map between the industry and product classifications. Given that the emissions data is always in an industry classification and IO tables are often only supplied in an industry classification we suggest using industry classifications as this requires less data manipulations. This would imply mapping the final demands in a product classification into the industry classification using the make matrix.

Re-classifying data

The IO data from different regions is often in different classification systems. To perform the analysis requires mapping the data, at some stage, to a consistent classification. For some classifications it is possible to obtain correspondence tables, otherwise, the correspondence tables need to be constructed by referring to the different classification descriptions. Often, the classification systems do not have a direct correspondence between sectors and while the classification definitions can be used as a guide, re-classification will nearly always introduce errors of unknown size.

Another issue is that some data is collected based on entirely different conceptual framework. For example, IO data in an industry classification is based on industries being the smallest unit, while consumer expenditure survey data is collected on the basis of products and functions being the smallest unit (the classification of individual consumption by purpose (COICOP) is a good example). Mapping between products or functions and industries is difficult implying that several assumption and approximations are required. In some cases checks can be applied. For example, when mapping consumer expenditure data to an industry classification, it is possible to ensure that a rough balance is obtained at the sector level between the mapped expenditure data and the household expenditure from the IO tables.

Aggregation

In the MRIO setting, Lenzen et al., 2004 show the importance of aggregation errors with the broad conclusion that the data should be in the highest detail available. Thus, a global MRIO with 10-sector aggregation, for example, may produce unreliable results. The required sector detail depends on the use of the model.

Valuation

IO data is often available in three levels of valuation; basic, producer, or purchaser (retail) prices. The different valuations differ in the trade and transport margins, and taxes and subsidies; producer = basic + taxes - subsidies, purchaser = producer + margins. Typically margins and taxes are applied at different rates in different sectors and on different products. Even across the same product, margins and taxes can differ for a variety of reasons such as, different mark-ups, different modes of transport, different levels of taxation, bulk discounts, different recording principles, and so on (United Nations, 1999). For these reasons it is more homogenous to work in basic prices as they are more representative of the production value of a product compared to the market value.

Unfortunately, not all IO data is available in basic prices. Estimation can be used to adjust the IO data to the required valuation, but without the detailed data in each sector, the possibility for introducing large errors is considerable. Due to data availability, it is likely to be easier to convert the final demand to a new valuation compared to the IO data. In practice, if data is not available in the necessary valuation, it may be best to report the valuation of the data and emphasis that it will either under- or over-estimate the environmental impacts depending on the valuation used.

An addition problem arises in the valuation of trade data. Exports are usually presented as free on board (fob) and imports as cost, insurance, freight (cif). For consistency, the imports need to be converted to basic prices. Lenzen et al., 2004 use economy wide fob/cif ratios and then balance the resulting MRIO table using a RAS technique.

Marginal technology

It can be argued that the regional technology differences are not relevant in some studies. Instead, any expanded production will occur with marginal technology (Weidema et al., 1999; Ekvall and Weidema, 2004). If modeling past flows, then the technology used in production is required. In the modeling of future scenarios it is important to consider the likely technology mix and emissions coefficients in the future; in this case, marginal technologies may be preferred. A possible alternative is to consider the energy embodied in trade as the energy intensities are less dependent on the fuel mix (Peters and Hertwich, 2005a).

Errors

Errors can enter into the calculations in many ways. The IO data and factor use intensities always have an error associated with them (e.g., Rypdal and Zhang, 2000; Lenzen, 2001; Yamakawa and Peters 2009, Lenzen et al. 2010). Errors also arise in the adjustments for currency conversions, inflation, different sector classifications, aggregation, and so on. The magnitude of these errors is often difficult to estimate, but the errors still need to be considered (Morgan and Henrion, 1990). Ideally, some sort of error analysis should be performed or the potential magnitude of uncertainties discussed.

5. Evaluation of available MRIO data sources

General data availability

To perform a detailed MRIO study IO data is essentially required for every country. This data is generally available for most OECD countries, but for relatively few non-OECD countries. Most EU countries submit data to Eurostat in a consistent format. The USA, Canada, and Australia regularly compile IO data but using different classifications. The data availability in non-OECD countries is sparse and often for major non-OECD countries only. Some data projects have attempted to build large IO databases for global models.

Emissions data is often available for countries that supply IO data, but in many cases the data needs separate construction. Energy data can be used to construct some air emissions data (e.g., Ahmad and Wyckoff, 2003; Dimaranan and McDougall, 2006) alternatively, additional data work may be required (e.g., Suh, 2005; Guan and Hubacek, 2006). Care needs to be taken with energy and environmental data from some sources as they may have a different system boundary to the IO data (Gravgård Pedersen and de Haan, 2006; Peters and Hertwich, 2006c). Energy and emissions data are often constructed according to "national territory", while IO data are constructed according to "resident institutional units". Resident institutional units may operate and pollute outside national territory, but are still a part of the domestic economy. The main differences between the two definitions are for international transportation and tourist activities. For Denmark in 2001 the differences between the two definitions were 23% for CO_2, 93% for SO_2 and 72% for NO_x (Gravgård Pedersen and de Haan, 2006). For Norway in 2000 the difference was 25% for CO_2 (Peters and Hertwich, 2006c).

Trade data is available from several sources, but generally trade data has missing data and mismatches. This requires addition processing and cross-checking for consistency (e.g., Dimaranan and McDougall, 2006). Import and export data often do not match due to different pricing conventions and errors in reporting. If traded goods between two countries go through a third country then allocation problems often arise.

MRIO data choice in OPEN:EU

For the OPEN:EU project, we have considered two principal data sources for MRIO data: The Global Trade, Assistance, and Production project (GTAP) and the EXIOPOL project (A new environmental accounting framework using externality data).

Table 2 provides an overview over important characteristics of the two data sources.

For GTAP, we consider both release 6 and release 7. GTAP7 provides data for 113 world regions in 57 sector detail (Narayanan G. and Walmsley, 2008). It has the most extensive regional coverage. It is a well-recognized database that has been used extensively for trade analysis, agricultural economics and tariff issues, and recently also for carbon footprint analysis (Hertwich & Peters, 2009). While the GTAP database is extensive and has a more recent reference year, it must be noted that the actual data utilized is often from earlier years and has only been adjusted to the activity in the reference year. The data for individual regions is usually submitted by users of the data and consequently data is sometimes not updated with new versions of the database. The database has a strong emphasis on food and agriculture. This is a particularly useful feature for the OPEN: EU project as both Ecological and Water Footprint of calculations are mainly based on data for agricultural products. More agricultural sectors in the IO model allow for a more accurate allocation of bioproducts. The increase in regional coverage from version 6 to 7 is also welcome. It should be noted that in version 7.1, a harmonized set of EU27 input-output data was introduced based on the work of the EC Joint Research Center in Seville (IPTS), which provides for an improved data situation for EU countries.

The rationale of the EXIOPOL project is to provide an MRIO database specifically for environmental analysis, with more detail on the environmentally relevant sectors (agriculture, energy, materials) and environmental extensions describing the energy, material and land use, as well as emissions of greenhouse gases and air pollutants and some other pollutants to cover important contributions to environmental impact indicators as used in life-cycle assessment (Tukker et al. 2009). In addition, the manipulation of the input-output tables should not be as extensive as in GTAP, preserving to some degree the underlying IO tables published for the individual countries. Disadvantages with EXIOPOL are that fewer countries are covered, that the reference year 2000 is earlier than that for GTAP7 (2004) and that the database has not yet been used as extensively and hence has not yet the international recognition that GTAP has. Furthermore, the use of GTAP data will facilitate comparisons with results (for the carbon footprint) from previous studies and other research groups.

Based on these considerations, we originally suggested the use of the EXIOPOL database for OPEN:EU. However, the completion of the database has suffered some setbacks and had to be delayed. The database is hence not yet ready at a time we need to proceed with the OPEN:EU project. For this reason, we have reconsidered our earlier recommendation and now implement the GTAP7 database. In principle, the work in WP1 and WP2 has been structured in a manner that would allow the implementation of the EXIOPOL database in the same scripts and with the same footprint data as the GTAP database. Whether this remains feasible within the time horizon and effort reserved for this project remains to be seen. As mentioned above, there is a trade-off in advantages of using one database over the other and it is important to note that using GTAP instead of EXIOPOL does not have any effect on the ability of the OPEN:EU project to deliver all of its aims.

In the appendix, the sectors and countries represented in GTAP7 are described.

Table 2. **Overview of the characteristics of global MRIO datasets considered for OPEN:EU**

	GTAP6	**GTAP7**	**EXIOPOL**
Published	2006	2008	Winter 2010/11
Base year	2001	2004	2000
No. of countries	87	113	EU27+16 (1)
No. of sectors	57	57	128
Environmental extensions	GHG	GHG	GHGs, air pollution, land use, material extraction
Environmental detail	agricultural sectors		agriculture, energy + material sectors presented

(1) US, Japan, China, Canada, South Korea, Brazil, India, Mexico, Russia, Australia, Switzerland, Turkey, Taiwan, Norway, Indonesia and South Africa.

6. Example applications and policy implications

Generally, there are three scales of interest in consumption related issues; national, regional, and local (Munksgaard et al., 2005). In the context of this article we will consider two scales; total demand (national and global) and arbitrary demand (regional and local). Most applications of MRIO have been to address global issues of pollution embodied in trade and the carbon footprint of nations. Only recently have MRIO studies considered arbitrary demands. In this section, we outline the main applications of MRIO in the field of industrial ecology. We do not consider studies that have modeled similar questions, but using single region models with the import assumption.

Trans-boundary pollution

The main motivation for the studies by Chung and Rhee, 2001; Ahmad and Wyckoff, 2003; Lenzen et al., 2004; Peters and Hertwich, 2006c was to evaluate pollution embodied in trade at the national level and to determine the different environmental impacts of consumption versus production and its implications to global climate change policy (Kondo et al., 1998; Munksgaard and Pedersen, 2001; Bastianoni et al., 2004). These studies generally found a large portion of CO_2 emissions embodied in trade. The most comprehensive early study, Ahmad and Wyckoff, 2003, found that the CO_2 emissions embodied in imports in some OECD countries was over 50% and on average 14% of OECD CO_2 emissions were embodied in imports. However, the authors used conservative assumption such as not including services trade, excluding process emissions, and intentionally making assumptions that led to a lower bound. It is likely that these numbers are larger in reality. Lenzen et al., 2004 found that 66% of Danish domestic CO_2 emissions in 1997 were embodied in imports, which is considerably greater than the value of 36% found by Ahmad and Wyckoff, 2003. Peters and Hertwich, 2006c found that 67% of Norwegian domestic CO_2 emissions in 2000 were embodied in imports, which is similar to the value of 54% found by Ahmad and Wyckoff, 2003 for 1997. The reason for the differences are unknown, but may be since Ahmad and Wyckoff, 2003 used different assumptions and data set. Chung and Rhee, 2001 used an MRIO for trade between Japan and Korea, but they did not consider the pollution embodied in imports from outside of Japan and Korea. Their study has a regional focus for trade between Japan and Korea, but not on the global implications.

More recently, Peters and Hertwich (2008) and Davis and Caldeira (2010) have analysed the CO2 emissions embodied in international trade based on the GTAP 6 and GTAP7 databases, respectively. They found that high-density OECD countries had higher emissions embodied in imports than exports, while for raw materials exporters like Russia, Canada, Australia, Finland, Norway and South Africa, the situation was the reverse. Emerging economies specializing in manufacturing, like China and India also had higher emissions embodied in exports and imports.

Guan and Hubacek, 2006 consider virtual water flows[5] between south and north China using an MRIO model. They found that the water scarce north exports large quantities of virtual water to the relatively water abundant south. Guan and Hubacek, 2006 go on to show that this contradicts the standard theory of comparative advantage; often referred to as the "Leontief paradox". This highlights the wider applications of MRIO models to any factor of production embodied in trade (also see Hakura, 2001).

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[5] Guan and Hubacek, 2006 refer to embedded water content as "virtual water".

Arbitrary demands

The studies by Nijdam et al., 2005; Peters and Hertwich, 2005b; 2006a focus on the implication of imports for household environmental impacts (HEI). Both use MRIO models with uni-directional trade only, Nijdam et al., 2005 consider nine environmental indicators for Dutch household consumption, while Peters and Hertwich, 2005b; 2006a consider CO_2, SO_2, and NO_x emissions for different Norwegian final demands. Both studies found that large fractions of HEI are embodied in imports directly to households and imports to domestic industries as inputs to produce domestic household demand. Except for traffic noise (Dutch study) and NO_x (Norwegian study) over 50% of the measured global HEI were embodied in imports; greenhouse gases were around 50% in both cases. In many cases the environmental impacts from developing countries was most significant, particularly considering the smaller share of imports coming from those regions. Both studies reinforced the overall importance of mobility and food in HEI (c.f. Hertwich, 2005), but found increased importance of consumable items due to imports. The Norwegian study found that for food, business services, clothing, chemicals, furniture, cars, agriculture, textiles, and most manufactured goods the majority of emissions occurred in foreign regions.

The study by Peters and Hertwich, 2006b considered the importance of imports for the global CO_2, SO_2, and NO_x emissions of Norwegian household, government, and exported final demands. The article considered the final demands from a consumption perspective, production perspective, and used structural path analysis to analyze the trade linkages between consumption and production. The main empirical conclusion from this study was that a large portion of CO_2, SO_2, and NO_x emissions of the Norwegian economy can be traced back to electricity production, primarily by coal, and other energy intensive industries in developing countries. Further, the different methods of analysis were found to be relevant for different policy applications. The article highlights, for global pollutants in particular, that policy needs to address the environmental implications of imports.

Priority setting for nations and regions

Input-output studies have recently also been used to set priorities for environmental policy and in particular policies directed towards products, production and consumption. These studies aim at getting a deeper insight on the contribution to overall environmental impacts of different consumption areas and products. For example, the EIRPO (Environmental impacts of products) study has been very influential in shaping EU product policy (Tukker 2006). A prioritization of consumption categories and materials has recently also been performed for UNEP, 2010. Hertwich and Peters (2009) focused specifically on the carbon footprint of the 87 regions included in GTAP6 and provided an analysis of how the importance of consumption categories depends on the region and income level of countries.

These studies identify housing (including the construction and furnishing of buildings and the energy use for heating, cooling and appliances), food, mobility, and the consumption of manufactured goods as major drivers of environmental impacts. Impacts increase uniformly with increasing levels of wealth.

Similar studies can also be of interest at the sub-national level, covering entire regions or towns (Turner et al. 2007; Flynn et al. 2006) or only the activities of regional or local authorities (Larsen and Hertwich 2010).

In this context, MRIO models are used both to have a common basis for comparing countries and to correctly model the global production networks that supply the goods consumed in modern consumer economies. It is foreseen that this type of application is of specific interest for the OPEN:EU project.

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8. References

Ahmad, Nadim and Wyckoff, Andrew (2003). Carbon dioxide emissions embodied in international trade of goods. DSTI/DOC(2003)15, Organisation for Economic Co-operation and Development (OECD).

Andrew, R., G. P. Peters, and J. Lennox. 2009. Approximation and regional aggregation in multi-regional input-output analysis for national carbon footprint accounting. *Economic Systems Research* 21(3): 311-335.

Bastianoni, Simone, Pulselli, Federico Maria, and Tiezzi, Enzo (2004). The problem of assigning responsibility for greenhouse gas emissions. *Ecological Economics*, 49:253–257.

Battjes, J.J., Noorman, K.J., and Biesiot, W. (1998). Assessing the energy intensities of imports. *Energy Economics*, 20:67–83.

Castles, Ian and Henderson, David (2003). Economics, emissions scenarios and the work of the IPCC. *Energy and Environment*, 14(4):415– 435.

Chung, Hyun-Sik and Rhee, Hae-Chun (2001). Carbon dioxide emissions of Korea and Japan and its transmission via international trade. *International Economic Journal*, 15(4):117–136.

Clift, Roland and Wright, Lucy (2000). Relationships between environmental impacts and added value along the supply chain. *Technological Forecasting and Social Change*, 65:281–295.

Copeland, Brain R. and Taylor, M. Scott (2003). *Trade and The Environment*: *Theory and Evidence*. Princeton University Press.

Davis, S. J. and K. Caldeira. 2010. Consumption-based accounting of CO2 emissions. *Proceedings of the National Academy of Sciences* 107(12): 5687-5692

Dietzenbacher, Erik, Albina, Vito, and Kühtz, Silvana (2005). The fallacy of using US-type input-output tables. In *15th International Input-Output Conference*, Beijing, China.

Dimaranan, Betina V. and McDougall, Robert A., editors (Forthcoming, 2006). *Global Trade, Assistance, and Production: The GTAP 6 Data Base*. Center for Global Trade Analysis, Purdue University.

Druckman, A. and T. Jackson. 2009. The carbon footprint of UK households 1990-2004: A socio-economically disaggregated, quasi-multi-regional input-output model. *Ecological Economics* 68(7): 2066-2077.

Ekvall, Tomas and Weidema, Bo P. (2004). System boundaries and input data in consequential life cycle inventory analysis. *International Journal of Life Cycle Assessment*, 9(3):161–171.

Flynn, A., T. Wiedrnann, J. Barrett, and A. Collins. 2006. The environmental impacts of consumption at a subnational level - The ecological footprint of Cardiff. *Journal of Industrial Ecology* 10(3): 9-24.

Gravgård Pedersen, Ole and de Haan, Mark (2006). The system of environmental and economic accounts–2003 and the economic relevance of physical flow accounting. *Journal of Industrial Ecology*, 10(1-2):19–42

Grübler, Arnulf, Nakicenovic, Nebojsa, Alcamo, Joe, Davis, Ged, Fenhann, Joergen, Hare, Bill, Mori, Shunsuke, Pepper, Bill, Pitcher, Hugh, Riahi, Keywan, Rogner, Hans-Holger, Rovere, Emilo Lebre La, Sankovski, Alexei, Schlesinger, Michael, Shukla, R.P., Swart, Rob, Victor, Nadejda, and Jung, Tae Yong (2004). Emissions scenarios: A final response. *Energy and Environment*, 15(1):11–24.

Guan, Dabo and Hubacek, Klaus (Forthcoming, 2006). Assessment of regional trade and virtual water flows in China. *Ecological Economics*.

Hakura, Dalia S. (2001). Why does HOV fail? The role of technology differences within the EC. *Journal of International Economics*, 54.

Hertwich, Edgar G. (2005). Lifecycle approaches to sustainable consumption: A critical review. *Environmental Science and Technology*, 39(13):4673–4684.

Hertwich, E. G. and G. P. Peters. 2009. Carbon Footprint of Nations: A Global, Trade-Linked Analysis. Environmental Science & Technology 43(16): 6414-6420.

Jayadevappa, Ravishankar and Chhatre, Sumedha (2000). International trade and environmental quality: a survey. *Ecological Economics*, 32:175– 194.

Kondo, Y., Moriguchi, Y., and Shimizu, H. (1998). CO_2 emissions in Japan: Influences of imports and exports. *Applied Energy*, 59(2-3):163– 174.

Lenzen, Manfred (1998). Primary energy and greenhouse gases embodied in Australian final consumption: An input-output analysis. *Energy Policy*, 26:495–506.

Lenzen, Manfred (2001). A generalized input-output multiplier calculus for Australia. *Economic Systems Research*, 13(1):65–92.

Lenzen, Manfred (2003). Environmentally important paths, linkages and key sectors in the Australian economy. *Structural Change and Economic Dynamics*, 10(6):545–572.

Lenzen, Manfred, Pade, Lise-Lotte, and Munksgaard, Jesper (2004). CO_2 multipliers in multi-region input-output models. *Economic Systems Research*, 16(4):391–412.

Lenzen, M., R. Wood, and T. Wiedmann. 2010. Uncertainty analysis for multi-region input-output models - a case study of the UK's carbon footprint. *Economic Systems Research* 22(1): 43-63.

Machado, Giovani, Schaeffer, Roberto, and Worrell, Ernst (2001). Energy and carbon embodied in the international trade of Brazil: an input-output approach. *Ecological Economics*, 39:409–424.

Miller, R. and Blair, P.D. (1985). *Input-output analysis*: *Foundations and extensions*. Englewood Cliffs, NJ, Prentice-Hall.

Morgan, M.G. and Henrion, Max (1990). *Uncertainty: A guide to dealing with uncertainty in quantitative risk and policy analysis*. Cambridge University Press.

Munksgaard, Jesper and Pedersen, Klaus Alsted (2001). CO_2 accounts for open economies: Producer or consumer responsibility? *Energy Policy*, 29:327–334.

Munksgaard, Jesper, Wier, Mette, Lenzen, Manfred, and Dey, Christopher (2005). Using input-output analysis to measure the environmental pressure of consumption at different spatial levels. *Journal of Industrial Ecology*, 9(1-2):169–186.

Narayanan G., B. and T. L. Walmsley, eds. 2008. *Global Trade, Assistance, and Production: The GTAP 7 Data Base*. Lafayette: Center for Global Trade Analysis, Purdue University.

Nijdam, D.S., Wilting, H. C., Goedkoop, M. J., and Madsen, J. (2005). Environmental load from Dutch private consumption: How much pollution is exported? *Journal of Industrial Ecology*, 9(1-2):147–168.

Nordhaus, William (2005). Alternative measures of output in global economic-environmental models: Purchasing power parity or market exchange rates. Prepared for meeting of IPCC expert meeting on emissions scenarios.

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

Peters, Glen P. and Hertwich, Edgar G. (2004). Production factors and pollution embodied in trade: Theoretical development. Working Paper 5/2004, Industrial Ecology Programme, Norwegian University of Science and Technology.

Peters, Glen P. and Hertwich, Edgar G. (2005a). Energy and pollution embodied in trade: The case of Norway. In Kjelstrup, Signe, Hustad, Johan E., Gundersen, Truls, Røsjorde, Audun, and Tsatsaronis, George, editors, *Shaping our future energy systems: Proceedings of the 18th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems (ECOS 2005)*, pages 93–100. Tapir Academic Press, Trondheim, Norway.

Peters, Glen P. and Hertwich, Edgar G. (2005b). The global dimensions of Norwegian household consumption. In *10th European Roundtable on Sustainable Consumption and Production*, Antwerp, Belgium.

Peters, Glen P. and Hertwich, Edgar G. (2006a). The importance of imports for household environmental impacts. *Journal of Industrial Ecology*, 10(2):89-110.

Peters, Glen P. and Hertwich, Edgar G. (2006b). Structural analysis of international trade: Environmental impacts of Norway. *Economic Systems Research*, 18(2): 155-181.

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

Peters, G. P. and E. G. Hertwich. 2009. The application of multi-regional input-output analysis to industrial ecology: Evaluating trans-boundary environmental impacts. In *Handbook of Input-Output Analysis for Industrial Ecology*, edited by S. Suh. Dordrecht, NL: Springer.

Round, Jeffery I. (2001). Feedback effects in interregional input-output models: What have we learned? In Lahr, Michael L. and Dietzenbacher, Erik, editors, *Input-output analysis: Frontiers and extensions*, pages 54–70. Palgrave Publishers Ltd.

Rypdal, Kristin and Zhang, Li-Chun (2000). Uncertainties in the Norwegian greenhouse gas emission inventory. Reports 2000/13, Statistics Norway.

Strømman, A.H. and Gauteplass, A.A. (2004). Domestic fractions of emissions in linked economies. Working Paper no. 4/2004, Industrial Ecology Programme, Norwegian University of Science and Technology, Trondheim, Norway.

Suh, Sangwon (2005). Developing a sectorial environmental database for input-output analysis: the comprehensive environmental data archive of the US. *Economic Systems Research*, 17(4):449–469.

Suh, Sangwon, Lenzen, Manfred, Treloar, Graham J., Hondo, Hiroki, Horvath, Arpad, Huppes, Gjalt, Jolliet, Olivier, Klann, Uwe, Krewitt, Wolfram, Moriguchi, Yuichi, Munksgaard, Jesper, and Norris, Gregory (2004). System boundary selection in life-cycle inventories using hybrid approaches. *Environmental Science and Technology*, 38(3):657– 664.

Tukker, A., G. Huppes, J. Guniee, R. Heijungs, A. de Koning, L. van Oers, S. Suh, T. Geerken, M. Van Holderbeke, B. Jansen, P. Nielsen, P. Eder, and L. Delgado. 2006. *Environmental Impact of Products (EIPRO)*. EUR22284EN. Seville: EC Joint Research Centre - IPTS.

Tukker, A., E. Poliakov, R. Heijungs, T. Hawkins, F. Neuwahl, J. M. Rueda-Cantuche, S. Giljum, S. Moll, J. Oosterhaven, and M. Bouwmeester. 2009. Towards a global multi-regional environmentally extended input-output database. *Ecological Economics* 68(7): 1928-1937.

Turner, K., M. Lenzen, T. Wiedmann, and J. Barrett. 2007. Examining the global environmental impact of regional consumption activities - Part 1: A technical note on combining input-output and ecological footprint analysis. *Ecological Economics* 62(1): 37-44.

UNEP. 2010. *Environmental impacts of consumption and production: priority products and materials*. Edited by E. G. Hertwich, et al. Paris: International Panel for Sustainable Resource Management.

United Nations (1999). *Handbook of input-output table compilation and analysis. Studies in Methods Series F, No 74. Handbook of National Accounting*. United Nations.

Weber, C. L. and H. S. Matthews. 2008. Quantifying the global and distributional aspects of American household carbon footprint. *Ecological Economics* 66(2-3): 379-391.

Weidema, B.P., Frees, N., and Nielsen, A.-M. (1999). Marginal production technologies for life cycle inventories. *International Journal of Life Cycle Assessment*, 4(1):48–56.

Wiedmann, T. 2009a. A first empirical comparison of energy Footprints embodied in trade - MRIO versus PLUM. *Ecological Economics* 68(7): 1975-1990.

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

Wiedmann, T., R. Wood, J. C. Minx, M. Lenzen, D. B. Guan, and R. Harris. 2010. A carbon footprint time series of the uk - results from a multi-region input-output model. *Economic Systems Research* 22(1): 19-42.

Wilting, H. C. and K. Vringer. 2009. Carbon and land use accounting from a producer's and a consumer's perspective - an empirical examination covering the world. *Economic Systems Research* 21(3): 291-310

Wyckoff, Andrew W. and Roop, Joseph M. (1994). The embodiment of carbon in imports of manufactured products: Implications for international agreements on greenhouse gas emissions. *Energy Policy*, 22:187–194.

Yamakawa, A. and G. P. Peters. 2009. Using time-series to measure uncertainty in environmental input-output analysis. *Economic Systems Research* 21(4): 337-362.

9. Appendix: GTAP7 Country and sector detail

Region or country name:

1	Australia
2	New Zealand
3	Rest of Oceania
4	China
5	Hong Kong
6	Japan
7	Korea
8	Taiwan
9	Rest of East Asia
10	Cambodia
11	Indonesia
12	Lao People's Democratic Republic
13	Myanmar
14	Malaysia
15	Philippines
16	Singapore
17	Thailand
18	Vietnam
19	Rest of Southeast Asia
20	Bangladesh
21	India
22	Pakistan
23	Sri Lanka
24	Rest of South Asia
25	Canada
26	United States of America
27	Mexico
28	Rest of North America
29	Argentina
30	Bolivia
31	Brazil
32	Chile
33	Colombia
34	Ecuador
35	Paraguay
36	Peru
37	Uruguay
38	Venezuela
39	Rest of South America
40	Costa Rica
41	Guatemala
42	Nicaragua
43	Panama
44	Rest of Central America
45	Caribbean
46	Austria
47	Belgium
48	Cyprus
49	Czech Republic
50	Denmark
51	Estonia
52	Finland
53	France
54	Germany
55	Greece
56	Hungary
57	Ireland
58	Italy
59	Latvia
60	Lithuania
61	Luxembourg
62	Malta
63	Netherlands
64	Poland
65	Portugal
66	Slovakia
67	Slovenia
68	Spain
69	Sweden
70	United Kingdom
71	Switzerland
72	Norway
73	Rest of EFTA
74	Albania
75	Bulgaria
76	Belarus
77	Croatia
78	Romania
79	Russian Federation
80	Ukraine
81	Rest of Eastern Europe
82	Rest of Europe
83	Kazakhstan
84	Kyrgyzstan
85	Rest of Former Soviet Union
86	Armenia
87	Azerbaijan
88	Georgia
89	Iran, Islamic Republic of
90	Turkey
91	Rest of Western Asia
92	Egypt
93	Morocco
94	Tunisia
95	Rest of North Africa
96	Nigeria
97	Senegal
98	Rest of Western Africa
99	Rest of Central Africa
100	Rest of South Central Africa
101	Ethiopia
102	Madagascar
103	Malawi
104	Mauritius
105	Mozambique
106	Tanzania
107	Uganda
108	Zambia
109	Zimbabwe
110	Rest of Eastern Africa
111	Botswana
112	South Africa
113	Rest of South African Customs Union

Industries, final consumption category

Paddy rice
Wheat
Cereal grains nec
Vegetables, fruit, nuts
Oil seeds
Sugar cane, sugar beet
Plant-based fibers
Crops nec
Bovine cattle, sheep and goats, horses
Animal products nec
Raw milk
Wool, silk-worm cocoons
Forestry
Fishing
Coal
Oil
Gas
Minerals nec
Bovine meat products
Meat products nec
Vegetable oils and fats
Dairy products
Processed rice
Sugar
Food products nec
Beverages and tobacco products
Textiles
Wearing apparel
Leather products
Wood products
Paper products, publishing
Petroleum, coal products
Chemical, rubber, plastic products
Mineral products nec
Ferrous metals
Metals nec
Metal products
Motor vehicles and parts
Transport equipment nec
Electronic equipment
Machinery and equipment nec
Manufactures nec
Electricity
Gas manufacture, distribution
Water
Construction
Trade
Transport nec
Water transport
Air transport
Communication
Financial services nec
Insurance
Business services nec
Recreational and other services
Public Administration, Defense, Education, Health
Dwellings
Household consumption
Government consumption
Capital consumption

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