**World Input-Output Database (WIOD):**

**Construction, Challenges and Applications**

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**NB The results in this paper are preliminary and should not be quoted**

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**Abstract**

This paper describes the construction and contents of a new database to analyze the effects of globalization on socio-economic and environmental trends at the industry, country and global level. This database called WIOD (World Input-Output Database) is constructed by linking national supply and use tables with statistics on international trade. In this way it is feasible to estimate e.g. the use of Chinese paint in German cars bought by Japanese consumers. This international input-output table is firmly grounded in national accounts statistics and complemented with additional socio-economic accounts on the use of various types of labour (by skill level) and capital (ICT and non-ICT assets). It also includes various environmental indicators such as energy use and greenhouse-gas emission. The database will include the major economies in the world covering about 90% of world GDP and provide time series from 1995 onwards. We discuss the methods and datasources used in construction. In addition we give illustrative applications in the area of outsourcing and its impact on global trends in trade and emissions of greenhouse gases. The database is currently being constructed by a consortium of eleven research institutes in the WIOD-project (www.wiod.net) and the paper reports on the first phase of this project.

**1.** **Introduction**

The ongoing process of globalisation puts new challenges to the study of economic growth and development around the world. As finance, people, goods and services increasingly flow from one country to another, international interdependencies strongly impact on the development space of individual countries. Changing patterns of world trade drive income distributions across and within regions, and shift environmental burdens of production and consumption. This is manifest in the mushrooming of global production networks in which various stages of the production process take place at distant geographical areas. Intermediate goods and services are heavily traded across borders, driven by the opportunities offered by advances in information and communication technologies. A hard-disk drive manufactured in Thailand typically consists of inputs sourced from over fifteen different countries. A car in Spain is assembled out of imports from all around the world. This globalisation process provides new opportunities for a global division of labour and production, increasing employment opportunities and growth. On the other hand, shifting trade and production patterns might have adverse effects on local and global distributions of income and natural resources. For example, the pollution haven hypothesis maintains that rich countries are able to contain the environmental pressure of domestic production only by relocating pollution-intensive industries. This would lead to an increasing divergence between the actual use of resources in local production and the use of resources implicit in local consumption.

Globalisation also puts new demands on statistical information for research and policy analysis. A thorough analysis of globalisation and its effects on the economy and environment relies heavily on extensive monitoring of international trade. Existing international trade statistics provide information on the value of goods and services traded, but convey little about the value added in production by the exporting country. The latter though is crucial for an analysis of e.g. income, employment and environmental effects of local production. This type of information however is currently not being collected in statistical systems and researchers have to rely on datasets constructed outside the international statistical systems. Various alternative datasets have been built in the past of which the GTAP database is the most widely known and used. However, all these databases provide only one or a limited amount of benchmark years and do not offer an analysis of developments over time. In this paper we present a new database called the World Input-Output Database (WIOD) that aims to fill this gap. The WIOD will provide a time-series of world input-output tables from 1995 onwards. National input-output tables of forty major countries in the world are linked through international trade statistics. A world input-output table allows one to study say the use of Chinese chemicals in German automobiles bought by Japanese consumers over time. Moreover, the WIOD contains additional satellite accounts. A socio-economic account provides detailed information on the use of various types of labour (distinguished by educational attainment level) and capital (including ICT and non-ICT) in production. The environmental accounts provide information on energy use, greenhouse-gas emissions and other air pollutants of production and final consumption. By standardising concepts and classifications, WIOD opens up a new range of feasible studies on the effects of globalisation. As the WIOD will be made available to the public for free in due time, we hope to enable and stimulate new research in this area.

The remainder of the paper is organised as follows. In section 2 we outline the conceptual framework of a world input-output table. Methods of construction and datasources used are discussed in Section 3. Section 4 introduces datasources for the world input-output table and the socio-economic and environmental satellite accounts. In Section 5 we provide two preliminary applications of the WIOD: one on international trade in value added and another on consumption-based accounting of greenhouse-gas emissions. Section 6 concludes.

**2. World Input-Output Table (WIOT): Concepts**

In this section we outline the basic concepts of a world input-output table (WIOT). A natural starting point to investigate the increasing interdependence of countries is the use of international trade statistics. Export and import statistics are routinely produced by national statistical institutes (NSIs) on the basis of custom declarations and firm surveys. The compilation of this data is internationally harmonised and comparable statistics are frequently published by the European Union, the OECD and the United Nations. Exports and imports as a share of GDP are steadily increasing in most countries in the world and this measure is often used to indicate the increasing international integration of national economies. A significant share of this international exchange is trade in intermediate products.[[1]](#footnote-1) Rather than goods destined for final consumption, these goods are further used in the production process of the importing country, a phenomenon also known as global production networks. Separate stages of the production process now take place at different geographical locations rather than being concentrated in a particular country. For example, whereas in the past the production of personal computers took mainly place within the U.S., now the separate phases of component production, assembly, testing and packaging are scattered around the world. There is much evidence about the rise of these networks in the past decades but this consists mostly of single product studies based on firm-level cases (Kaplinsky 2000, Gereffi 1999; Sturgeon, van Biesebroeck and Gereffi 2008).

A major bottleneck in the study of global production networks and their socio-economic and environmental effects is the lack of information on cross-country inter-industry linkages. International trade statistics indicate the value of export of say disk-drives from Malaysia to Japan. But they do not convey any information about the value of the product that is actually created in the exporting country. The only information given in the trade statistics is the description of the product following international product classifications such as the Harmonised System (HS). When the components of the disk-drive, such as optical devices, semi-conductors and plastics, are imported by Malaysia, rather than produced domestically, the export value of the disk-drive will be a weak indicator of the value added created in the Malaysian economy. It may range anywhere between virtually zero, in case Malaysia is merely re-exporting finished disk-drives from another country, to the full value in case all stages of production took place within the Malaysian economy. As a result, the increasing importance of global production networks diminishes the usefulness of international trade statistics for country-level analysis. It may lead to reliance on misleading indicators such as the share of high-tech products in total exports. This is a popular indicator of the strength of a national economy and innovation system. But this indicator can be high even for a country that is only involved in the last stages of production such as assembly, testing and packaging that require little skills or technical capabilities.

Clearly what is needed for this type of analysis is information not only on the flow of products between countries, but on the flows of products between industries within and across countries. This type of information is contained in a so-called international, or world, input-output table. To outline the framework of such a table we start with the discussion of a national input-output (IO) table.

In Figure 1 the schematic outline for a national input-out table (IOT) is presented. [[2]](#footnote-2) For ease of discussion we assume that each industry produces only one (unique) product. The rows in the upper parts indicate the use of products, being for intermediate or final use. Each product can be an intermediate in the production of other products (intermediate use). Final use includes domestic use (private or government consumption and investment) and exports. The final element in each row indicates the total use of each product. The industry columns in the IOT contain information on the supply of each product. A product can be imported or domestically produced. The column indicates the values of all intermediate, labour and capital inputs used in production. The vector of input shares in output is often referred to as the technology for domestic production. The compensation for labour and capital services together make up value added which indicates the value added by the use of domestic labour and capital services to the value of the intermediate inputs. Total supply of the product in the economy is determined by domestic output plus imports. An important accounting identity in the IOT is that total supply equals total use for each product, such that all flows in the economic system are accounted for. National IOTs can be linked together into a world input-output table.

**[Figure 1 about here]**

Basically, a world input-output table (WIOT) is a combination of national IOTs in which the use of products is broken down according to their origin. Each product is produced either by a domestic industry or by a foreign industry. In contrast to the national IOT, this information is made explicit in the WIOT. For a country A, flows of products both for intermediate and final use are split into domestically produced or imported. In addition, the WIOT shows for imports in which foreign *industry* the product was produced. This is illustrated by the schematic outline for a WIOT in Figure 2.

**[Figure 2 about here]**

Figure 2 illustrates the simple case of three regions: countries A and B, and the rest of the world. In WIOD we will distinguish 40 countries and the rest of the World, but the basic outline remains the same. For each country the use rows are split into two separate rows, one for domestic origin and one for foreign origin. In contrast to the national IOT for country A it is now clear from which foreign industry the imports originate, and how the exports of country A are being used by the rest of the world, that is, by which industry or final end user. This combination of national and international flows of products provides a powerful tool for analysis of global production chains and their effects on employment, value added and investment patterns and on shifts in environmental pressures. While national IO tables are routinely produced by NSIs, WIOTs are not as they require a high level of harmonisation of statistical practices across countries. In the following sections we outline our efforts in constructing a WIOT.

**3. World Input-Output Table (WIOT): Construction and sources**

In this section we outline the construction of the WIOT and discuss the underlying data sources. As building blocks we will use national supply and use tables (SUTs) that are the core statistical sources from which NSIs derive national input-output tables. In short, we derive time series of national SUTs and link these across countries through detailed international trade statistics to create so-called international SUTs. These international SUTs are used to construct the symmetric world input-output table which is product or industry based, depending on the set of alternative assumptions used. In Section 3.1 we provide an overview, while in section 3.2 we delve into methodologies and data sources used. For an elaborate discussion of construction methods, practical implementation and detailed sources, see Erumban et al. (2010, forthcoming).

**3.1 Brief overview of WIOT construction**

The construction of our WIOT has two distinct characteristics when compared to e.g. the methods used by GTAP, OECD and IDE-JETRO. First, we rely on national supply and use tables (SUTs) rather than input-output tables as our basic building blocks. Second, to ensure meaningful analysis over time, we start from output and final consumption series given in the national accounts and benchmark national SUTs to these time-consistent series. SUTs are a more natural starting point for this type of analysis as they provide information on both products and (using and producing) industries. A supply table provides information on products produced by each domestic industry and a use table indicates the use of each product by an industry or final user. The linking with international trade data, that is product based, and socio-economic and environmental data, that is mainly industry-based, can be naturally made in a SUT framework. In contrast, an input-output table is exclusively of the product or industry type. Often it is constructed on the basis of an underlying SUT, requiring additional assumptions.

In Figure 3 a schematic representation of a national SUT is given. Compared to an IOT, the SUT contains additional information on the domestic origin of products. In addition to the imports, the supply columns in the left-hand side of the table indicate the value of each product produced by domestic industries. The upper rows of the SUT indicate the use of each product. Note that a SUT is not necessarily square with the number of industries equal to the number of products, as it does not require that each industry produces one unique product only.

A SUT must obey two basic accounting identities: for each product total supply must equal total use, and for each industry the total value of inputs (including intermediate products, labour and capital) must equal total output value.

Supply of products can either be from domestic production or from imports. Let *S* denote supply and *M* imports, subscripts *i* and *j* denote products and industries and superscripts *D* and *M* denote domestically produced and imported products respectively. Then total supply for each product i is given by the summation of domestic supply and imports:

 (1)

Total use (*U*) is given be the summation of final domestic use (*F*), exports (*E*) and intermediate use (*I*) such that

 (2)

The identity of supply and use is then given by

 (3)

The second accounting identity can be written as follows

 (4)

This identity indicates that for each industry the total value of output (at left hand side) is equal to the total value of inputs (right hand side). The latter is given by the sum of value added (VA) and intermediate use of products.

**[Figure 3 about here]**

In the first step of our construction process we benchmark the national SUTs to time-series of industrial output and final use from national account statistics. Typically, SUTs are only available for a limited set of years (e.g. every 5 year) [[3]](#footnote-3) and once released by the national statistical institute revisions are rare. This compromises the consistency and comparability of these tables over time as statistical systems develop, new methodologies and accounting rules are used, classification schemes change and new data becomes available. These revisions can be substantial especially at a detailed industry level. By benchmarking the SUTs on consistent time series from the National Accounting System (NAS), tables can be linked over time in a meaningful way. In the next section we provide further information about the extrapolation and linking procedures.

In a second step, the national SUTs are combined with information from international trade statistics to construct what we call international SUTs. Basically, a split is made between use of products that were domestically produced and those that were imported, such that

 (5)

where  indicates re-exports. This breakdown must be made in such a way that total domestic supply equals use of domestic production for each product:

 (6)

and total imports equal total use of imported products

 (7)

The outline of an international SUT is given in Figure 4.

**[Figure 4 about here]**

So far we have only considered imports without any geographical breakdown. To study international production linkages however, the country of origin of imports is important as well. Let *k* denote the country from which imports are originating, then an additional breakdown of imports is needed such that

 (8)

The international SUTs for each country are combined into a world input-output table, as given in Figure 2. This transformation step requires additional assumptions that are spelled out in more detail below.

**3.2 Implementation and sources**

In this section we outline the various steps taken in the construction process of the WIOT. These steps are summarised in Figure 5 that illustrates the basic data sources used and the various transformations applied. Four phases can be distinguished:

A. Raw data collection and harmonisation

B. Construction of time-series of SUTs

C. Construction of import use table and breakdown by country of origin

D. Construction of WIOT

**[Figure 6 about here]**

*A. Raw data collection and harmonisation*

Three types of data are being used in the process, namely national accounts statistics (NAS), supply-use tables (SUTs) and international trade statistics (ITS). Importantly, this data must be publicly available such that users of the WIOT are able to trace the steps made in the construction process. Moreover, official published data is more reliable as checking and validation procedures at NSIs are more thorough than for data that is ad-hoc generated for specific research purposes. The data is being harmonised in terms of industry- and product-classifications both across time and across countries. The WIOD classification list has 59 products and 35 industries based on the CPA and NACE rev 1 (ISIC rev 2) classifications. The product and industry lists are given in Appendix Tables 1 and 2. This level of detail has been chosen on the basis of initial data-availability exploration and ensures a maximum of detail without the need for additional information that is not generated in the system of national accounts. The 35-industry list is identical to the list used in the EUKLEMS database with additional breakdown of the transport sector as these industries are important in linking trade across countries and in the transformation to alternative price concepts (from purchasers’ to basic prices, see below).[[4]](#footnote-4) Hence WIOD can be easily linked to additional variables on investment, labour and productivity in the EU KLEMS database (see [www.euklems.net](http://www.euklems.net), O’Mahony and Timmer, 2009). The product list is based on the level of detail typically found in SUTs produced by European NSIs, following Eurostat regulations and is more detailed than the industry list. It is well-known that non-survey methods to split up a use table into imported and domestic, such as used in WIOD (see below), are best applied at a high level of product detail.

To arrive at a common classification, correspondence tables have been made for each national SUT bridging the level of detail and classifications in the country to the WIOD classification. This involved aggregation and sometimes disaggregation based on additional detailed data. While for most European countries this was relatively straightforward, tables for non-EU countries proved more difficult. National SUTs were also checked for consistency and adjusted to common concepts (e.g. regarding the treatment of FISIM and purchases abroad). Undisclosed cells due to confidentiality concerns were imputed based on additional information. The adjustments and harmonisation are described in more detail on a country-by-country basis in Erumban et al. (2010).

*B. Construction of time-series of SUTs*

As discussed above, national SUTs are only infrequently available and are often not harmonised over time. Therefore they are benchmarked on consistent time-series from the NAS in a second step. From the NAS data time series on gross output and value added by industry, total imports and total exports and final use by use category are taken. This data is used to generate time series of SUTs using the so-called SUT-RAS method (Temurshoev and Timmer 2009). This method is akin to the well-known bi-proportional updating method for input-output tables known as the RAS-technique. This technique has been adapted for updating SUTs.

Timeseries of SUTs are derived for two price concepts: basic prices and purchasers’ prices. Basic price tables reflect the costs of all elements inherent in production borne by the producer, whereas purchasers’ price tables reflect the amount paid by the purchaser. The difference between the two is the trade and transportation margins and net taxes. Both price concepts have their use for analysis depending on the type of research question. Supply tables are always at basic price and often have additional information on margins and net taxes by product. The use table is typically at a purchasers’ price basis and hence needs to be transformed to a basic price table. The difference between the two tables is given in the so-called valuation matrices (Eurostat 2008, Chapter 6). These matrices are typically not available from public data sources and hence need to be estimated. In WIOD we distinguish 4 types of margins: automotive trade, wholesale trade, retail trade and transport margins. The distribution of each margin type varies widely over the purchasing users and we use this information to improve our estimates of basic price tables, see Erumban et al. (2010) for more detail.

*C. Breakdown of import and domestic production in Use table*

The next step is a breakdown of the use table into domestic and imported origin. As margins are only generated by the domestic industries, a breakdown of the use table at basic price is made. Ideally one would like to have additional information based on firm surveys that inventory the origin of products used, but this type of information is hard to elicit and only rarely available. We use a non-survey imputation method that relies on a classification of detailed products in the ITS into three use categories. Our basic data is import flows of all countries covered in WIOD from all partners in the world at the HS6-digit product level taken from the UN COMTRADE database. Based on the detailed product description at the HS 6-digit level products are allocated to three use categories: intermediates, final consumption, and investment.[[5]](#footnote-5). This resembles the well-known correspondence between the about 5,000 products listed in HS 6 and the Broad Economic Categories (BEC) as made available from the United Nations Statistics Division. These Broad Economic Categories can then be aggregated to the broader use categories mentioned above. For the WIOD this correspondence has been partly revised to better fit the purpose of linking the trade data to the SUTs (see Stehrer et al. 2010, for details).

For services trade no standardised database on bilateral flows exists. These have been collected from various sources (including OECD, Eurostat, IMF and WTO), checked for consistence and integrated into a bilateral service trade database. As services trade is taken from the balance of payments statistics it is originally reported at BoP codes. For building the shares a mapping to WIOD products has been applied. For these service categories there does not exist a breakdown into the use categories mentioned above; thus we either used available information from existing import use or symmetric import IO tables; for countries where no information was available we applied shares taken from other countries. (see Stehrer et al., 2010, for details)

Based on our use-category classification we allocate imports across use categories in the following way. First, we used the share of use category *l* (intermediates, final consumption or investment) to split up total imports as provided in the supply tables for each product *i*. The resulting numbers for intermediates are allocated over using industries by proportionality assumption. Similarly, final consumption is allocated over the consumption categories (final consumption expenditure by households, final consumption expenditure by non-profit organisations and final consumption expenditure by government). Investment was allocated to column gross fixed capital formation. [[6]](#footnote-6) This yields the import use table. Finally, each cell of the import use table is split up to the country of origin where country import shares might differ across use categories, but not within these categories.

Note that here are discrepancies between the import values recorded in the National Accounts on the one hand, and in international trade statistics on the other. Some of them are due to conceptual differences, and others due to classification and data collection procedures (see extensive discussion in Guo, Web and Yamano 2009). As we rely on NAS as our benchmark we apply shares from the trade statistics to the NAS series. Thus, to be consistent with the imports as provided in the SUTs we use only shares derived from the ITS rather than the actual values.

Formally, let  indicate the share of use categories l (intermediate, final consumption or investment) in imports of product *i* by a particular country from country *k* defined as

 such that  (9)

where  is the total value from all 6-digit products that are classified by use category *l* and WIOD product group *i* imported from country *k*, and the total value of WIOD product group *i* imported by a country. These shares are derived from the bilateral international trade statistics and applied to the total imports of product *i* as given in the SUT timeseries to derive imported use categories. is the amount of product group *i* imported from country *k* and used as intermediate by industry *j*. It is given by:

 (10)

where such that is the share of intermediates of product *i* used by industry *j*.

Similarly, let f denote the final use categories (final consumption by households, by non-profit organisations and by government). Then the amount of product group *i* imported from country *k* and used as final use category *f*, , is given by:

 (11)

The amount of product group *i* imported from country *k* and used as investment,, is given by:

 (12)

Finally, we derive the use of domestically produced products as the residual by subtracting the imports from total use as follows:

 (13)

Note that our approach differs from the standard proportionality method popular in the literature and applied e.g. by GTAP. In those cases, a common import proportion is used for all cells in a use row, irrespective the user. This common proportion is simply calculated as the share of imports in total supply of a product. We find that import proportions differ widely across use categories and importantly, within each use category they differ also by country of origin. Our detailed bilateral approach ensures that this type of information is reflected in the international SUTs and consequently the WIOT.

*D. Construction of WIOT*

As a final step, international SUTs are transformed into a world input-output table. IO tables are symmetric and can be of the product-by-product type, describing the amount of products needed to produce a particular good or service, or of the industry-by-industry type, describing the flow of goods and services from one industry to another. In case each product is only produced by one industry, the two types of tables will be the same. But the larger the share of secondary production, the larger the difference will be. The choice for between the two depends on the type of research questions. Many foreseen applications of the WIOT, such as those described in the next sections, will rely heavily on industry-type tables as the additional data, such as employment or investment, is often only available on an industry basis. Moreover, the industry-type table retains best the links with national account statistics.

An IOT is a construct on the basis of a SUT at basic prices based on additional assumptions concerning technology. We use the so-called “fixed product-sales structure” assumption stating that each product has its own specific sales structure irrespective of the industry where it is produced. Sales structure here refers to the proportions of the output of the product in which it is sold to the respective intermediate and final users. This assumption is most widely used, not only because it is more realistic than its alternatives, but also because it requires a relative simple mechanical procedure. Furthermore, it does not generate any negatives in the IOT that would require manual rebalancing. Application of manual ad-hoc procedures would greatly reduce the tractability of our methods. Chapter 11 in the Eurostat handbook (Eurostat, 2008) provides a useful and extensive discussion of the transformation of SUTs into IOTs, including a mathematical treatment.

In a first step the international SUTs for all countries are combined into a world SUT. Basically, the national tables are stacked and reordered to resemble a standard supply-use table. The framework for the world SUT is given in Figure 7. Subsequently, using the fixed product-sales structure, the world SUT is transformed into the WIOT given in Figure 2. To ensure consistency between bilateral flows of imports and exports, exports are defined as mirror flows from imports. More specifically, imports of product *i* of say country A from country B are assumed to be equal to the exports of this product from B to A.

**[Figure 6 about here]**

The full WIOT will contain data for forty countries covered in the WIOD. Including the biggest countries in the world, this set covers more than 85 per cent of world GDP. Nevertheless to complete the WIOT and make it suitable for various modelling purposes, we also added a region called the Rest of the World (RoW) that proxies for all other countries in the world. The RoW needs to be modelled due to a lack of detailed data on input-output structures. Imports from RoW are given as as share of imports from RoW from trade data applied to the imports in the supply table. Hence, exports from the RoW are simply the imports by our set of countries not originating from the set of WIOD countries. Exports to RoW from the set of WIOD countries or, equivalently, imports by the ROW are defined residually to ensure that exports from all countries (incl. RoW) equal the imports by all countries (incl. RoW). Production and consumption in the ROW will be modelled based on totals for industry output and final use categories from the UN National Accounts, assuming an input-output structure equal to that of an average developing country. Also, at a later stage we will add in a separate oil-producing region that will be useful in particular in environmental applications.

**4. Basic data sources**

*Sources for WIOT*

As described in the previous section, the construction of the WIOT requires three types of data: national SUTs, National Accounts time series on industry output and final use, and bilateral international trade data in goods and services. In Table 1 we provide an overview of the SUTs used in WIOD. For some countries full time-series of SUTs are available, but for most countries only some or even one year is available. This is indicated in the table. In some cases SUTs for a particular year were available, but have not been used as they contained too many errors or inconsistencies to be useful. Also, for some non-EU countries SUTs are not available, but only IOTs. For these countries a transformation from IOT to SUT has been made by assuming a diagonal supply table at the product and industry level of the original national table which is often more detailed than the WIOD list. Table 1 provides details about the size of the original SUTs and IOTs and their price concept. The tables have been sourced from publicly available data from National Statistical Institutes and for many EU countries from the Eurostat input-output database.[[7]](#footnote-7)

SUTs might be available for various years, but that does not imply that they are also comparable over time as revisions might have taken place in the National Accounts, while the historical SUTs have not been revised. Therefore to link the SUTs over time, National Accounts statistics are used. Data for 1995-2007 was collected for the following series: total exports, total imports, gross output at basic prices by 35 industries, total use of intermediates by 35 industries, final expenditure at purchasers’ prices (private and government consumption and investment), and total changes in inventories. This data is available from National Statistical Institutes and OECD and UN National Accounts statistics. National SUTs are in national currencies and need to be put on a common basis for the WIOT. This can be done by using official exchange rates from IMF, or by so-called Purchasing Power Parities (PPPs) that correct for price differences across countries. Currently, only exchange rates are being used, but in a later stage PPP-conversion will also be made.

Bilateral international trade data in goods is collected from the UN COMTRADE database (which can be downloaded for example via the World Integrated Trade Solutions (WITS) webpage at http://wits.worldbank.org/witsweb/). This data base contains bilateral exports and imports by commodity and partner country at the 6-digit product level (Harmonised System, HS). Calculations used for the construction of the international USE tables are based on import values. Alternatively, we could have relied on export flow data. However, it is well-known that official bilateral import and export trade flows are not fully consistent due to reporting errors, etc. and hence this choice would make a difference. Following most other studies, we choose to use imports flows as these are generally seen as more reliable than export flows. Data at the 6-digit level often contains confidential flows which only appear in the higher aggregates. These confidential are allocated over the respective categories (see Stehrer, et al., 2010, for details). Statistics for trade in goods are well-developed, in contrast to trade in services. Although services trade is taking an increasing share of global trade flows, statistics are only rough and hard to reconcile across the various sources. Therefore trade in services data have first been collected from a number of sources (OECD, WTO, Eurostat, IMF) and based on these a consistent database has been developed. One particular challenge is to allocate the statistics based on Balance of Payments codes to the various products in the WIOD list which has been managed by setting up a correspondence between BoP codes and WIOD product list and applying the respective shares for the country of origin. The split between use categories was based on existing information from import SUTs and imports IOTs as described above. The approach taken in constructing the bilateral trade data for WIOD is more extensively described in Stehrer et al. (2010). In addition to a WIOT, the WIOD also includes socio-economic and environmental satellite accounts. In Figure 7 the conceptual framework of the extended national SUT is given. Value added is broken down into the compensation for the production factors labour and capital.[[8]](#footnote-8) In addition statistics on energy use, greenhouse-gas and other air emissions, and resource use by industry and final users are collected.

**[Figure 7 about here]**

*Socio-economic accounts*

The socio-economic accounts contain data on detailed labour and capital inputs for all 35 industries. This includes data on hours worked and compensation for three labour types (low-, medium- and high-skilled labour) and data on capital stocks and compensation for 8 asset types: 3 ICT assets (software, computer and telecommunication equipment) and 5 non-ICT assets (residential buildings, non-residential structures, transport equipment, other non-ICT machinery and equipment, and other assets). Labour service input is based on series of hours worked and wages of various types of labour. These series are not part of the core set of national accounts statistics reported by NSIs; typically only total hours worked and wages by industry are available from the National Accounts. For these series additional material has been collected from employment and labour force statistics. For each country covered, a choice was made of the best statistical source for consistent wage and employment data at the industry level. In most countries this was the labour force survey (LFS). , In most cases this needed to be combined with an earnings surveys as wages are often not included in the LFS. In other instances, an establishment survey, or social-security database was used. Care has been taken to arrive at series which are time consistent, as most employment surveys are not designed to track developments over time, and breaks in methodology or coverage frequently occur. Labour compensation of self-employed is not registered in the National Accounts, which as emphasised by Krueger (1999) leads to an understatement of labour’s share. We make an imputation by assuming that the compensation per hour of self-employed is equal to the compensation per hour of employees. This is especially important for industries which have a large share of self-employed workers, such as agriculture, trade, business and personal services. Also, we assume the same labour characteristics for self-employed as for employees when information on the former is missing. These assumptions are made at the industry level.

For the breakdown of value added, compensation for each capital asset is needed. Capital input series by industry are generally not available from the National Accounts. At best, capital stocks are estimated for aggregate investment without distinguishing various asset types. Instead, we rely on the concept of capital services. Capital compensation is given by multiplying stocks with rental prices. The rental price of each asset consists of a nominal rate of return, depreciation and capital gains (Jorgenson and Yip, 1991).[[9]](#footnote-9) The nominal rate of return is determined ex-post as it is assumed that the total value of capital services for each industry equals capital compensation. Capital compensation is derived as gross value added minus labour compensation. This procedure yields an internal nominal rate of return that exhausts capital income and is consistent with constant returns to scale. The nominal rate of return is the same for all assets in an industry, but is allowed to vary across industries.

For each individual asset, stocks have been estimated on the basis of investment series using the perpetual inventory method (PIM) with geometric depreciation profiles. Depreciation rates differ by asset and industry, but have been assumed identical across countries. The basic investment series by industry and asset have been derived from capital flow matrices and benchmarked to the aggregate investment series from the National Accounts. Although the ESA provides a classification of capital assets, it is not always detailed enough to back out investment in information and communication equipment. Additional information has been collected to obtain investment series for these assets, or assumptions concerning hardware-software ratios have been employed. When the deflator for computers did not contain an adjustment for quality change, a harmonised deflator based on the United States deflator has been used as suggested by Schreyer (2002). The EU KLEMS database provides this data for a large set of OECD countries (see [www.euklems.net](http://www.euklems.net)). O’Mahony and Timmer (2009) provide a more detailed description of the methods used. For non-OECD countries additional data has been collected and prepared following the same harmonisation and construction procedures as used in the EU KLEMS database. Erumban, Gouma, de Vries and Timmer (2011) provide additional detail on the data and methods used for non-OECD countries.

*Environmental accounts [[10]](#footnote-10)*

The core of the environmental database consists of energy and air emission accounts. Energy-related air emissions are estimated using energy accounts and technology-specific emission factors. A large part of the air emissions resulting in the impact categories covered in WIOD (global warming, acidification and tropospheric ozone formation) are originated from gases emitted in energy-use processes. These emissions are complemented with non-energy related (process) emissions where appropriate, using inventory data from reports to the United Nations Framework Convention on Climate Change UNFCCC and CLRTAP (Convention on Long Range Transboundary Air Pollution).

Energy accounts are compiled using extended energy balances from the International Energy Agency (IEA) as a starting point. Additional information was used to bridge between territory and residence principles (adjusting for bunkering and international transport, tourism, defence, embassies) and to allocate IEA accounts to the target classification and accounting concepts consistent with WIOT (e.g. distribution of transport activities and auto-produced electricity among industries). The very first step in deriving energy accounts from international energy balances, as provided by IEA, is to establish a correspondence-key linking energy balance items and NACE entries plus households. Some of the energy balance items can be directly linked to the production of certain NACE entities, but in some cases the energy balance item is related to more than one industry. For instance, the energy balance item “road transport” needs to be distributed over all industries plus households. Likewise, the energy balance item “commerce and public services” needs to be distributed over a number of services. Losses are also a relevant part of the energy accounts and an important element in the assessment of energy efficiency. All losses are recorded and allocated to the supplying industry.

Air emissions are estimated from energy accounts. The general approach implies the use of activity data and emission factors, following the general formula: E = AR× EF. The emission (E) is obtained by multiplying a certain triggering activity (AR: activity rate), e.g. production of the metal industry as measured by output value, by a certain emission factor (EF). Such factors embed the concept of a linear relationship between the activity data and the actual emissions. Several technical guidance documents provide such emission factors, in particular those prepared for the compilation of national emission inventories under international conventions such as United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Long-Range Transboundary Air Pollution (CLRTAP). Additionally, two very important secondary sources of information for emission factors are used: the results of the FP6 project EXIOPOL (<http://www.feem-project.net/exiopol/>) and the Emission Database for Global Atmospheric Research (EDGAR) information system (<http://www.pbl.nl/en/themasites/edgar/> index.html). Activity data will concern the use of energy, broken down into energy commodities and sectors as reported in IEA statistics.

Air emission data not related to energy consumption (e.g. CH4 emissions) will be collected from inventories to complement the energy-based emissions. The substances included in the database comprise the air emissions linked directly to the three environmental impact categories covered, namely:

* Greenhouse gas emissions to air (CO2, N2O, CH4, HFCs, PFCs, SF6), needed to derive Global Warming Potentials
* Emissions of CFCs, Halons, Methyl Bromide CH3Br, and HCFCs , needed to derive Ozone Depletion Potentials, and
* Emissions of acidifying substances to air (NOx, SOx, NH3), needed to derive Acidification Potentials

More detailed information on the construction of the environmental accounts can be found in Villaneuva, Genty and Neuwahl (2010).

**5. Applications of the WIOD database**

This section describes two applications of the WIOD database. In Section 5.1, the world input-output table is combined with socio-economic accounts to measure the factor content of trade and analyse the development of global value chains. In Section 5.2, the world input-output table is combined with environmental accounts to measure greenhouse gas emissions as a result of production and consumption.

**5.1 Global value chains and the factor content of trade**

Trade has become increasingly fragmented, with production at different stages performed across multiple countries. At each stage in the production process, value is added to a product. The case study of the Apple iPod offers an illustrative example of fragmentation in production (Dedrick et al. 2008). The iPod is assembled in China and sold at the factory gate for $144, which is reflected in export statistics from China. However, the export of the iPod from China includes about $100 in imported Japanese value added (e.g. the hard drive, display, and battery), and $15 of imported U.S. value added (e.g. the processor, controller, and memory). Actually, China only adds $4 in value added. In addition, the production factors used in the various stages of production differ across countries. For example, the production of the processor in the U.S. requires mostly skilled labur, while assembly of the iPod components in China is performed mainly by low-skilled workers. So, while the international trade statistics suggest $144 of high-tech exports from China for each exported iPod, the value actually added in China is only small and contains barely skills. An analysis of global value chains would reveal such information as it indicates for a product the value added by certain production factors in various countries. This requires accounting for trade in intermediate inputs as will be done in this section.

Literature on the factor content of trade is booming. For example, authors use the GTAP database to test the Heckscher-Ohlin-Vanek predictions of comparative advantage (e.g. Reimer (2006); Johnson (2008); Trefler and Zhu (2010)). Other authors aim to measure the factor content of trade for specific countries (e.g. Feenstra and Hong (2007) for China, see also de Backer and Yamano (2007))[[11]](#footnote-11). Our application contributes to this literature in the way that it uses a time-series input-output database. Previous studies examined the factor content for a particular moment in time. The time-series perspective in WIOD allows us to examine changes in the factor content due to increasing fragmentation and globalization, changes in specialization patterns and technological changes. In addition, the socio-economic accounts allow a richer characterization of the production factors used by industries in creating value added. Previous studies distinguished capital and labor at best. However, as the iPod example illustrates, more detail in labor is needed as well. Assembly activities or production of high-tech intermediate inputs require very different skills. Taking these skills into account provide a richer description of the factor content of trade.

*Data*

Two datasets are considered, namely the world input-output table and the socio-economic accounts as described in the previous section. The current provisional world input-output tables for the years 1995 and 2006 are used. The lay-out of this table is shown in Figure 2 for two countries plus RoW. The world input-output table and the socio-economic accounts distinguish 35 industries (so the first 35 rows refer to the first country). Values are in USD using exchange rates for conversion of local currencies. At a later stage relative prices (PPPs) will be used instead. Production factors in the socio-economic accounts are measured as value shares in gross output. Implicitly we assume that the relative prices of outputs and inputs obey the Law of one price and are equal to the exchange rate. In the next version of this paper, by using industry-level deflators, the tables will be put in previous year prices and production factors will be measured in volumes.

*Method*

The approach follows the standard approach in the input-output literature and traces the amount of factor inputs needed to produce a certain amount of final demand (see e.g. Miller and Blair, 2009). Variations of this approach is also used in the bourgeoning literature on trade in value added (e.g. Reimer 2006). The key element in this approach is that not only direct, but also indirect contributions are taken into account. This is done by focusing on the flow of goods and services from producing sectors to final users. This flow can either be direct or indirect as illustrated in Figure 8. Suppose the German economy consists of final consumers and production sectors (chemical manufacturing and other industries). The chemical sector produces goods that are demanded by consumers, e.g. paints (flow 1 in Figure 8). Similarly, foreign consumers demand German chemicals and they are served by exports (flow 2). Part of the chemical production will also be used by other sectors, e.g. paint by car manufacturers and pharmaceuticals by the health sector as intermediate inputs, both domestically (flow 3) or by foreign sectors through exports (flow 6). These sectors also deliver to final demand and hence the German chemical sector contributes also indirectly to final demand, either domestic demand (flow 3 followed by 4 or 6 followed by 7) or foreign demand (3 followed by 5 or 6 followed by 8). Production can be even more round-about when German chemicals are used by other sectors to produce intermediates, e.g. German paint used for German sparks that are subsequently used in Japanese car sold to French consumers (e.g. flow 3 followed by 9 and 8), and so forth.

The effect of round-about production is that the labour and capital services used in the production of German chemicals will not only be “embodied’ in final products of this sector, but also indirectly in final products of other sectors (both domestic and foreign). Similarly, the final output of the German chemical sector does not only contain labour and capital services directly employed in the sector itself, but also from other domestic and foreign sectors through the use of intermediate inputs. The size of these indirect effects depends on the interdependencies of production of the various production sectors. Global value chain analysis tries to provide a decomposition of these flows and trace the various stages of production, identified by industry and country, in which value is added by the deployment of labour and capital inputs.

**[insert figure 8 about here]**

More formally, let N be the number of products, C the number of countries and F the factors of production. We define matrix **F** as the direct factor inputs per unit of *gross output* with dimension FC x NC. This matrix considers country and industry-specific direct factor inputs. An element in this matrix indicates the share in the value of gross output of a production factor used directly by the country to produce a given product, for example the value of ICT-capital used in the Australian agricultural sector to produce one dollar of output. The elements are direct factor inputs in the industry, because they do not account for production factors embodied in intermediate inputs used by this industry. In addition, let **A** be the world input-output matrix with intermediate input coefficients of dimension (NC x NC). The matrix **A** describes how a given product in a country is produced with different combinations of intermediate products, both domestically produced and imported from other countries. In turn, intermediate inputs are produced as well, requiring capital and labor and other intermediate inputs. These intermediate also need to be produced, and so forth. Summing all inputs yields total production that is – directly and indirectly – required to produce for final demand. This is represented by the so-called Leontief inverse. Define **(I-A)-**1 as the Leontief inverse of the world IO table (NC x NC) with **I** an (NC x NC) identity matrix. Then factor inputs required per unit of *final demand* are given by

 (14)

where **B** is the matrix of factor inputs per unit of final demand (FC x NC). Note that **B** includes both direct and indirect factor inputs, and contains coefficients. The *amounts* of factor inputs that can be attributed to observed levels of final demand can be found by using the expression

 (15)

in which **D** is an (NC x NC) diagonal matrix with final demand levels and **K** is the (FC x NC) matrix of amounts of factor inputs attributed to each of the NC final demand levels. A typical element in K indicates the amount of a production factor from country *k*, embodied in final output produced in a particular industry in country *z*. For various applications we are also interested in amounts of factors associated with specific subgroups of final demand, such as final demand for world electronics, final demand for Dutch products or final domestic demand in Germany. In these cases we modify **D** by setting all values to zero, except for the final demand flows of interest.

*Global value chains*

A global value chain (GVC) indicates the value added by various production factors around the world in the production of a particular set of final goods. This has led to increased insight in the various ways in which GVC have evolved across the globe in the past decades. So far, GVC analysis has mainly been made for particular products and industries as described in the introduction. The more macro implications of these shifts are yet not well studied. For the first time, the WIOD offers the opportunity to provide an analysis at the sector and aggregate level.

Global value chain decompositions can be made for any set of products. For example, a breakdown of final output of the German education sector would show that almost all of the value of output is created by German labor and capital, as only a very limited amount of imported intermediates are being used. In contrast, production that relies heavily on the use of imported intermediates would show up as a case where the added value of domestic production factors is relatively minor and a sizeable share of output value is created by foreign production factors, as in the iPod example discussed above. Below we will provide a GVC analysis of the automotive industry (ISIC rev2 industry 34 and 35: transport equipment manufacturing).

Figure 9 provides a breakdown of the value added chain of final output from the German automotive industry. Between 1995 and 2006 large changes have taken place in this value chain.[[12]](#footnote-12) The total value of final output is determined by the amount spend by consumers, including domestic and foreign demand (e.g. expenditure on cars produced in Germany).[[13]](#footnote-13) It does not include the output value of products that are not for final consumption but used elsewhere in the production process (e.g. car parts that are sent to Czech Republic for further processing). Hence final output is less than the output sales from the industry.

**[Figure 9 about here]**

Germany captures a large part of this value chain first through direct deployment of labour and capital inputs in the automotive industry. But German labour and capital used elsewhere in the economy are also embodied through intermediate deliveries (e.g. through the use of paint produced in the German chemical industry).[[14]](#footnote-14) Similarly, foreign factor inputs are also embodied through the use of (imported) intermediates. Clearly, the German automotive industry is sourcing an increasing amount of intermediate inputs that embody factor inputs from elsewhere, in particular the EU and the rest of the world. The German share in the value chain declined from 74 to 62 per cent.

Our socio-economic accounts allow a decomposition of the value added into five production factors: low-, medium- and high-skilled labour, and ICT and non-ICT capital. Figure 10 provides the decomposition of the value added by German and non-German factors of production in the final output of the German automotive industry. Most notable is the decline in the share of medium-skilled German labour between 1995 and 2006. This has been ‘substituted’ for by the increasing use of capital, medium- and high-skilled labour outside Germany. This can be both a price effect (declining relative wages for medium-skilled workers) and a quantity effect (declining number of workers) as we analyze current values of output. In a later stage of the project we will separate the two effects.

Figure 11 provides a similar decomposition for other countries: China, Japan and the US, for the year 2006. Some striking differences in the value chains can be observed. For example, the German automotive industry relies heavily on foreign factor inputs, while in Japan more than 90 per cent is generated within the domestic economy. Also the greater use of capital in Japan is clear. High-skilled workers play a big role in the US relative to the other countries, while the Chinese automotive industry relies heavily on low-skilled workers.

**[Figure 10 about here]**

**[Figure 11 about here]**

As our WIOT contains data in a common currency, one can aggregate across all countries and provide a GVC analysis for the global automotive industry. Figure 12 clearly illustrates the increasing share captured by China between 1995 and 2006, partly at the expense of the Japanese and US shares. Finally, in Figure 13 it is shown that the global automotive industry became more dependent in the use of capital and high-skilled labour, while the share of low-skilled and especially medium-skilled workers declined. This is mainly due to rapid increase Chinese automotive production based on low-skilled workers and outsourcing of Germany and the US of parts of the production process to other countries, mainly involving low-skilled activities or activities that have been skilled-down.

**[Figure 12 about here]**

**[Figure 13 about here]**

Similar analyses can be made for other industries. As an example Figures 14 and 15 analyse the GVC for textile manufacturing (ISIC 17-19 textile, wearing apparel and footwear manufacturing). In this industry the “making-room-for-China” effect is clearly visible as its share in global value added increased dramatically. Also the share of the rest of the world increased, while production factors in Japan, the EU and the US were withdrawn. Perhaps surprisingly, China and the ROW not only increased the value added by employing more low-skilled workers, but also by increased provision of capital services.

**[Figure 14 about here]**

**[Figure 15 about here]**

An interesting way of looking at the development of GVCs is from a distributional point of view. Basically, the GVC decompositions can be interpreted as income distributions. An increasing share of global expenditure on textiles is received as income by low-skilled workers in China and elsewhere in the global economy. On the other hand, workers in the textile and other manufacturing sectors in the OECD are capturing a diminishing share of these expenditures. Possibly, a mirror movement to the trends in manufacturing can be found in GVCs of services industries of the OECD. Traditionally OECD countries captured large parts of the value in these sectors. It might be that China and other emerging economies are also increasing their shares in services GVCs, but if expenditure on services is outpacing that of manufacturing, OECD countries will still benefit. But it might have specific consequences for various labour groups in OECD economies. The interaction between income distributions within the OECD (in particular the wage premium of high-skilled workers) and across the OECD and other countries will be analysed in future research.

As a final note it should be stressed that the country dimension in the GVC analysis is based on location of production and not on ownership of production factors. It provides the share captured by capital and labour employed in a particular country, but is silent on ownership. In the case of labour income, this is relative straightforward as for most countries cross-border labour migration is relatively minor. Hence labour income paid out in a particular industry mostly benefits the workers of the country in which production takes place. This is less clear for capital income. For example, many Chinese textile factories are owned by non-Chinese, and a sizeable part of capital income might end up in foreign hands. The extent of this will depend on the importance of foreign ownership in a particular industry and country.

*Factor content of net trade*

Recently, research into the factor content of trade has boomed in the international trade literature (e.g. Reimer 2006, Johnson and Noguera 2010). This line of research proceeds by determining the factor content of exports and import flows between countries. Although progress is being made in the way indirect factor contributions are being measured by using techniques that resemble those in input-output analysis, it is unclear whether the task at end has an answer even in theory. In this section we present a more intuitive approach and calculate the factor content of net trade based on the factors needed to satisfy final demand in a country and the factors available for production. The difference between the two we call the factor content of net trade and it indicates for each factor whether the country in principle has enough of it to satisfy domestic demand. This is akin to the so-called carbon footprint concept in the environmental literature (see next section).

Let matrix **Kj** (FC x NC) indicate the amount of each production factor in each country needed to satisfy demand of country j for the output of each industry in each country. This will include direct and indirect factor inputs, both domestic and foreign. **Kj** is defined as follows:

 (16)

where **Dj** is a (NC x NC) diagonal matrix with only final demand from country j and zero otherwise. To derive the factor content of net exports for each factor the needs as given in **Kj** (summed across all countries and industries) are subtracted from domestic availability.

Figure 16 provides for China, Germany, Japan and the US the factor content of net exports as defined above, expressed in million US$. It is shown that China had a large and growing surplus of low-skilled workers. In 1996 almost 50 billion $ worth of low-skilled labour services were deployed to satisfy non-Chinese final demand. (Note that this does not mean that China actually exported this amount of labour services in embodied form.) This surplus has been growing rapidly to more than 250 billion in 2006. For medium- and high-skilled workers on the other hand, domestic availability was not enough to satisfy domestic demand and net imports had to be made. Unexpectedly, countries like Japan and the US were large net importers of low-skilled labour services. Germany and Japan are increasingly net exporting medium- and high skilled labour. Perhaps most surprising is the large net import of capital by the US. Reflecting its huge current account deficit in 2006, all factors of production were net imported, in particular capital. Explaining these differences across countries and over time is high on our research agenda.

It should be stressed that these results are provisional and subject to change as they are based on a preliminary version of the database. Both the world input-output matrix **A** and the **F** matrix will be revised in the upcoming months to include more detailed information.

**[Figure 16 about here]**

**5.2 Greenhouse-gas emissions: production and consumption accounting**

Emissions of greenhouse gases during production play a key role in climate policy discussions. For example, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto protocol use a territorial-based approach. However, indirect consumer emissions may be very different due to the effects of trade and this raises new issues of responsibility. In a consumer-based approach, all emissions occurring along the chains of production and distribution are allocated to the final consumer of products (Wiedmann 2009). A consumer-based approach complements the production-based approach. It is useful in relation to the participation of developing countries in reducing carbon leakage, it quantifies environmental trade linkages between countries, and it raises awareness among consumers. In this section, we examine the relation between trade and CO2 emissions.

Related literature to this is reviewed in Wiedmann (2009) describing different methodologies to estimate consumption- and production-related greenhouse gas emissions. Basically, previous literature on this subject can be divided into single-region input-output analyses, and multi-region input-output analyses. Because a single-region approach does not allow for a distinction between domestic and foreign production technology, a multi-regional approach is preferred, such as adopted by Davis and Caldeira (2009). For 2004, Davis and Caldeira (2009) find that developed countries are net importers of CO2 emissions. The US, Japan, and large European countries are the biggest net importers of CO2 emissions. Vice versa, developing countries are net exporters of CO2 emissions. In particular, Russia, China, and India are large net exporters of CO2 emissions.

It is important to make a distinction between the amount of embodied gases in exports of a country emitted from the domestic territory and the amount of embodied gases emitted anywhere. The latter also includes gas emitted during the production of intermediates outside the domestic territory. For a discussion about a country’s responsibility it is the former concept that is most informative and this is the one we use in our analysis. Most other studies, e.g. Davis and Caldeira (2009) however provide information on emissions based on the second concept. Dietzenbacher and Serrano (2010) provide a critical discussion of the measures used.

Our application contributes to the literature by using a time-series input-output database. Previous studies examine consumption- and production-related CO2 emissions for a particular moment in time. The time-perspective in WIOD allows us to examine change over time due to increased globalization. In addition, the environmental accounts allow us to consider a larger set of greenhouse gases. This is relevant, because in addition to CO2 various other gases emitted during production are potent greenhouse gases (e.g. methane).

The approach follows the one described in 5.1. The only difference is the (1 x NC) vector **g**, which considers country- and industry-specific CO2 emissions per unit of gross output. The vector **g** replaces the matrix **F** in section 5.1 and measures direct CO2 emissions per unit of output. Therefore, a (1 x NC) total emission vector **g\*** (including direct and indirect emissions)is imputed by:

 (16)

Note that **E** includes both direct and indirect factor inputs, and contains coefficients. The *amounts* of CO2 emissions that can be attributed to observed levels of final demand can be found by using the expression

 (17)

in which **D** is an (NC x NC) diagonal matrix with final demand levels and **E\*** is the (C x NC) matrix of amounts of CO2 emissions attributed to each of the NC final demand levels. A typical element in **E\*** indicates the amount of CO2 emissions by a country, embodied in final output produced in a particular industry and country.

As for factor content, we analyse the CO2 emissions needed to satisfy German demand for final products (both domestically produced and imported) by setting the appropriate elements of the D matrix to zero. Figure 17 shows the embodied CO2 emissions in kilo tons. It appears that the German demand has become less CO2 intensive since 1995. In particular CO2 emissions on the German territory declined strongly, partly counteracted by increased CO2 emissions in China and the rest of EU on behalf of German consumers. But on balance there was a decline. Decomposition techniques will allow us to analyze this decline further and make a distinction between improvements in technology, shifting patterns of German demand and changes in trade patterns.

The industry detail in WIOD allows us also to examine the emissions embodied in final demand by industry. Figure 18 shows emissions made anywhere in the world to satisfy German demand for final output of a particular industry (German and foreign) in 2006. For example, German final demand for utilities and construction is responsible for about 40% of all embodied CO2 emissions. Petroleum products take up about 15 per cent, as much as all services products.

**[Figure 17 about here]**

**[Figure 18 about here]**

As for factor contents, we can also calculate the net exports of CO2 emissions of a country by comparing the amount of CO2 emissions embodied in final demand of this country with the amount actually emitted from its territory during production. These are shown in Figure 19. During the period from 1995 to 2006, Germany, Japan, and the United States are all net importers of CO2 emissions, a finding in line with results in Davis and Caldeira (2009), see also Nakano et al. (2009). This suggests that if a consumption-based approach is taken, these countries share a greater responsibility for the emission of greenhouse gases than on the basis of production only. In contrast, Chinese is a large net exporter of embodied CO2 emissions, virtually making up the net imports by the other three countries.

**[Figure 19 about here]**

**6. Concluding Remarks**

In this paper we presented the outline of the World Input-Output Database (WIOD) which contains a World Input-Output Table and socio-economic and environmental satellite accounts. The database construction is part of the WIOD-project currently carried out by a consortium of eleven research institutes across Europe. This new initiative has a number of distinguishing characteristics compared with alternative initiatives such as the GTAP database (Narayan and Walmsley 2009), the OECD Input-Output database, EXIOPOL (Tukker at al. 2009) and Institute of Developing Economies, JETRO (IDE –JETRO 2006).

The main novelty of the WIOD is that it is focused on time-series analysis. This motivates a number of methodological choices such as the reliance on national accounts time series for industry output and inputs and final demand categories to link supply and use tables over time in a consistent way. In addition, the tables will also be deflated by appropriate price indices to facilitate analysis of volume movements over time.

Secondly, the world input-output table is linked explicitly to international trade statistics. This is greatly facilitated by starting from supply- and use-tables that contain both the product and industry dimensions, rather than starting from input-output tables as most other initiatives do.

Thirdly, it has an explicit attention for (trade in) services, whereas most other initiatives are mainly geared towards agricultural and industrial activities. This is achieved by providing industry detail in services sectors, an explicit treatment of the trade and transport industries (through tables at basic and purchasers’ prices) and a new bilateral database on international trade in services.

Fourthly, the world input-output table is extended with socio-economic and environmental satellite accounts. This opens up a wide area of research into issues as diverse as trends in global income distributions, global value chain analysis and consumption accounting of air and other pollutants.

Finally, it is based on official statistics that are publicly available, aiming for maximum of transparency in calculations and methodologies. This is achieved by making all data publicly available, not only of the resulting WIOT, but also of the intermediate products such as harmonised basic national SUTs, international SUTs, world SUTs, international trade data and national accounts series for extrapolation. The data will be made public starting in the summer of 2011 with full data availability by May 2012, free of charge through our website [www.wiod.net](http://www.wiod.net).

We showed some possible applications of the database by decomposing global value chains, analysing the factor content of net exports and studying the differences between production and consumption accounting of greenhouse-gas emissions. Although the results are still preliminary, they illustrate the type of analysis that can be made and questions that can answered. It is hoped that the development of the WIOD will stimulate new research in this area and researchers are invited to contribute to future development e.g. by making available additional databases with new variables that can be easily linked into the structure of the WIOD. We also hope that this initiative is carried forward in due time by the international statistical community. Maintaining and updating a WIOT will require additional international effort and coordination. But given the relevance of such type of data for policy analysis and research purposes, it should be high on the agenda. The standardisation of environmental accounts in the new System of Environmental and Economic Accounting is an important development in this respect. And efforts initiated and supported by Eurostat and the OECD are hopeful signs that this type of data work will eventually be taken out of the research domain and become part of the routine statistical practice.

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**Figure 1 Schematic outline of national Input-Output (IO) Table**



**Figure 2 Schematic outline of World Input-Output Table (WIOT), three regions**



**Figure 3 Schematic outline of National Supply-Use table**



**Figure 4 Schematic outline of International Supply-Use table**



**Figure 5 Dataflows and construction steps in WIOT**



**Figure 6 World Supply-Use table for three regions**



**Figure 7 Schematic outline of extended National Supply-Use table**



**Figure 8 Schematic representation of product flows in two economies**

**Figure 9 Global value chain of final output from German transport equipment manufacturing, country shares, 1995 and 2006.**



Note: based on WIOD, results are preliminary

**Figure 10 Global value chain of final output from German transport equipment manufacturing, factor shares, 1995 and 2006.**



Note: based on WIOD, results are preliminary

**Figure 11 Global value chain of final output from transport equipment manufacturing, factor shares, China, Germany, Japan and USA, 2006.**



Note: based on WIOD, results are preliminary

**Figure 12 Global value chain of final output from global transport equipment manufacturing, country shares, 1995 and 2006.**



Note: based on WIOD, results are preliminary

**Figure 13 Global value chain of final output from global transport equipment manufacturing, factor shares, 1995 and 2006.**

Note: based on WIOD, results are preliminary



**Figure 14 Global value chain of final output from global textile manufacturing, country shares, 1995 and 2006.**

Note: based on WIOD, results are preliminary



**Figure 15 Global value chain of final output from global textile manufacturing, factor shares, 1995 and 2006.**

Note: based on WIOD, results are preliminary



**Figure 16 Factor content of net exports by China, Germany, Japan and USA (1995 and 2006)**



**Figure 16 continued**



Note: based on WIOD, results are preliminary

**Figure 17 Emissions embodied in net exports (China, Germany, US and Japan, 1995 and 2006)**



Note: based on WIOD, results are preliminary

**Figure 18 Embodied CO2 emissions of final domestic demand, Germany 1995 and 2006**



**Figure 19 Emissions embodied in final domestic demand, Germany, 2006 (shares in total)**



Note: based on WIOD, results are preliminary. The following industries are shown:

|  |  |  |  |
| --- | --- | --- | --- |
| 15t16 | Food, beverages, and tobacco | 25 | Rubber and plastics |
| 17t18 | Textiles and textile products | 26 | Other non-metallic minerals |
| 19 | Leather, leather and footwear | 27t28 | Basic metals and fabricated metals |
| 20 | Wood, and products of wood and cork | 29 | Machinery, n.e.c. |
| 21t22 | Pulp, paper, and printing and publishing | 30t33 | Electrical and optical equipment |
| 23 | Coke, refined petroleum and nuclear fuel | 34t35 | Transport equipment |
| 24 | Chemicals and chemical products | 36t37 | Manufacturing n.e.c. |

**Table 1 National supply-use and input-output tables used for construction of WIOD**



**Table 1 National supply-use and input-output tables used for constructing of WIOD (continued)**



Note: All tables are at purchasers' prices unless otherwise indicated (PR stands for producer prices, FC for factor cost and BP for basic price), i stands for industry dimension and c for commodity. \* Cyprus SUTs based on Greece.

**Appendix Table 1 Industries and columns in Use table**

**Appendix Table 2 Products and rows in Use table**



**Appendix Table 2 Products and rows in Use table (continued)**



1. Over the period we cover (1995 – 2006) the share of trade in intermediates in total trade is relatively stable and around 50 pre cent [↑](#footnote-ref-1)
2. See Blair and Miller (2009) for an elaborate introduction to input-output tables and analysis. [↑](#footnote-ref-2)
3. Though recently, most countries in the European Union have moved to the publication of annual SUTs. [↑](#footnote-ref-3)
4. In addition, in WIOD the EUKLEMS industry 17-19 is split into textiles and wearing apparel (17-18) and footwear (19) because of the large amount of international trade in these industries. [↑](#footnote-ref-4)
5. A mixed category for products which are likely to have multiple uses was used as well; this category was allocated over the other use categories when splitting up the use tables. [↑](#footnote-ref-5)
6. At a later stage we shall use information from existing imports SUTs or IOTs. [↑](#footnote-ref-6)
7. These can be found at http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95\_supply\_use\_input\_tables/introduction. [↑](#footnote-ref-7)
8. Currently, we use the expost approach to capital measurement such that labour and capital compensation will exhaust value added. In a later stage we will use the ex-ante or exogenous approach such that a residual value remains which is called profit (Schreyer, 2009). [↑](#footnote-ref-8)
9. Taxes have not been included due to a lack of data. Also, the assets do not cover land and inventories. [↑](#footnote-ref-9)
10. This text is based on the detailed documentation on the environmental accounts by Villaneuva, Genty and Neuwahl (2010) from Institute for Prospective Technological Studies (IPTS) in Seville. IPTS, an EC’s joint research center, is responsible for the environmental accounts in the WIOD project. [↑](#footnote-ref-10)
11. See Foster and Stehrer (2010) for a recent overview. [↑](#footnote-ref-11)
12. We provide only shares in final output, not the absolute value of the output to highlight the changes in shares. [↑](#footnote-ref-12)
13. In the remainder of this section final consumption is used as a shorthand for final private consumption, government consumption and gross fixed capital formation. [↑](#footnote-ref-13)
14. A split between the direct and indirect domestic shares can be easily made. [↑](#footnote-ref-14)