Slicing up Global Value Chains

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Appendix METHOD: Quantifying global value distributions

We model the global production system through input-output tables and international trade statistics. The approach follows the seminal insight from Leontief (1949) and traces the amount of factor inputs needed to produce a certain amount of final demand. The key element in this approach is that not only direct, but also indirect contributions are taken into account. The direct contribution is by labour and capital employed in the final stage of production, that is in the industry delivering the so-called *final* product to the consumer. But the value of the product will also contain value added by factors employed in earlier stages of production. To take account of the interrelatedness of production across industries and countries, a world input-output table is needed. Variations of this approach are also used in the bourgeoning literature on trade in value added, e.g. Reimer (2006), Trefler and Zhu (2010) and Johnson and Noguera (2011). But rather than using Leontief's insight to analyse factor content of trade flows, we focus on analyses of global value distributions.

Let g=1,..,G index products, let i and j =1,.., N index countries and let f=1,..,F index production factors.[1] Every product is consumed as a final product and/or used as an intermediate input. Let Y_{ij} be a G x 1 vector denoting j's usage of intermediate inputs produced in country i. For all variables in this section with two subscripts, the first indicates the producer and the second the user. Country i's output Q_i is split between production for final consumption C_{ij} and for intermediate inputs:

$$Q_i \equiv \sum_j \left(C_{ij} + Y_{ij}\right) \qquad (1)$$

Let $B_{ij}(g,h)$ be the amount of intermediate input g used to produce one unit of good h, where g is made in country i and h is made in country j. Let $Q_j(h)$ be a typical element of Q_j. Then $B_{ij}(g,h)Q_j(h)$ is the amount of input g used to produce $Q_j(h)$ and $\Sigma_h B_{ij}(g,h) Q_j(h)$ is the amount of intermediate input g produced in country i and used by country j. Restated, $\Sigma_h B_{ij}(g,h)Q_j(h)$ is the gth element of Y_{ij}.

Country j's vector of imports from country i is defined by

$$M_{ij} \equiv C_{ij} + Y_{ij}, \quad j \neq i, \qquad (2)$$

and country i's exports to the world is

$$X_i \equiv \sum_{j \neq i} \left(C_{ij} + Y_{ij}\right). \qquad (3)$$

[1] We follow the convention of Trefler and Zhu (2010) to introduce matrix algebra only at a later stage to facilitate interpretation.

In a consistent framework, the exports of country *i* must equal the sum of all imports from country *i*:

$$X_i = \sum_j M_{ij} \quad (4)$$

This completes the definition of the variables that we will use.

To decompose the value of products into the various value added parts, we will construct a regional input-output table of the world economy where each region is a country. This will allow us to track the movement of intermediate inputs both within and across countries. Let **B** be the world input-output matrix with intermediate input coefficients of dimension (NG x NG).

$$B \equiv \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1N} \\ B_{21} & B_{22} & \cdots & B_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ B_{N1} & B_{N2} & \cdots & B_{NN} \end{bmatrix}$$

where $\mathbf{B}_{ij}$ is the GxG matrix with typical elements $B_{ij}(g,h)$.[2] The matrix **B** describes how a given product in a country is produced with different combinations of intermediate products. The diagonal sub-matrices track the requirement for domestic intermediate inputs, while the off-diagonal elements track the requirements for foreign intermediate inputs.

We will also need the following NG x NG matrices:

$$Q \equiv \begin{bmatrix} diag\ Q_1 & 0 & \cdots & 0 \\ 0 & diag\ Q_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & diag\ Q_N \end{bmatrix}, \ C \equiv \begin{bmatrix} diag\ C_{11} & diag\ C_{21} & \cdots & diag\ C_{N1} \\ diag\ C_{12} & diag\ C_{22} & \cdots & diag\ C_{N2} \\ \vdots & \vdots & \ddots & \vdots \\ diag\ C_{1N} & diag\ C_{2N} & \cdots & diag\ C_{NN} \end{bmatrix}$$

where diag X indicates a diagonal matrix of vector X with the elements of X on the diagonal and zero's otherwise.

We will rely on the fundamental input-output identity introduced by Leontief (1949) which states that **Q**=**BQ**+**C** which can be written as $\mathbf{Q}=(\mathbf{I}-\mathbf{B})^{-1}\mathbf{C}$ with **I** an (NC x NC)

[2] Note that we use coefficients here, that is the B-elements are divided by gross output in the industry.

identity matrix.[3] $(\mathbf{I}-\mathbf{B})^{-1}$ is famously known as the Leontief inverse. It represents the total production value that is – directly and indirectly – required to produce for final demand. To see this, let Z be a vector column with first element representing the global consumption of iPods produced in China, and the rest zero's. This is equal to the final output of the Chinese iPod industry. Then BZ is the vector of *direct* intermediate inputs, both Chinese and foreign, needed to assemble the iPods in China, such as the hard-disc drive, battery and processors. But these intermediates need to be produced as well. B^2Z indicates the intermediate inputs directly needed to produce BZ, and so on. Thus $\sum_{n=2}^{\infty} B^n Z$ represents all intermediate inputs indirectly needed. By adding the final output to all direct and indirect intermediate input requirements, the total gross output value related to the production of a unit of final output Z is given by $Z + BZ + \sum_{n=2}^{\infty} B^n Z = \sum_{n=0}^{\infty} B^n Z = (I-B)^{-1} Z$.

Using this identity, we can derive production factor requirements for any vector Z. We define matrix **F** as the direct factor inputs per unit of *gross output* with dimension FN x NG. 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 low-skilled labour used in the Chinese electronics industry to produce one dollar of output. The elements in **F** are direct factor inputs in the industry, because they do not account for production factors embodied in intermediate inputs used by this industry. For the latter we need to define a matrix **A** (FN x NG) as follows:

$$A = F(I-B)^{-1} \qquad (5)$$

where **A** is the matrix of factor inputs required per unit of final demand. Note that **A** 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 then be found by using the expression

$$K = AC \qquad (6)$$

in which **K** is the (FN x NG) matrix of amounts of factor inputs attributed to each of the NG final demand levels. Each column of K provides the domestic and foreign factor inputs needed for the production of final output of a particular good *g* in country *j*. A typical element in K indicates the amount of a production factor *f* from country *i*, embodied in final output of *g* in country *j*. By the logic of Leontief's insight, the sum of

[3] See Miller and Blair (2009) for an introduction to input-output analysis.

all elements in a column will be equal to the final output of this product. Thus we have completed our decomposition of the value of final output into the value added by various production factors around the world.

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 **C** by setting all values to zero, except for the final demand flows of interest.

Our GVC metric is akin to the measure of vertical specialisation (VS) introduced by Hummels, Ishii and Yi (2001). They proposed to measure the degree of international integration of production in a country by the share of imported intermediate inputs over gross output. This measure basically presumes a production process of maximum two stages such that any good exported by a country is a final good, or will never be used by any other country (directly or indirectly) to produce exports destined for that country. However, in reality production processes are organised as interacting networks, and exports of intermediate goods is extensive. As a result, the VS measure suffers from various double counting problems and is not consistent defined across industries and countries. Johnson and Noguera (2011) propose a new measure defined as a value added to export ratio measured within a global input-output framework that remedies the double counting problem at the country level and show that differences can be sizeable.

Our GVC measure takes an additional step to be also globally consistent, that is, there is a complete decomposition of value added world-wide. This can only be achieved by focusing on value of final output as at the global level total value added created in all countries has to equal final domestic demand from all countries. While at the country level total value added is equal to domestic demand plus exports minus imports, the latter two cancel out at the global level. A decomposition starting from exports as in Johnson and Noguera (2011) will still suffer from double counting problems as the measures cannot be aggregated across countries. In addition, we provide a further breakdown of value added into the contributions of various types of labour and capital. This is important given the expected differential effects of outsourcing and off-shoring on various production factors such as low-skilled labour.

Database construction

To implement the new GVC metric, one needs to have a database with linked consumption, production and income flows within and between countries. For individual countries, this type of information can be found in input-output tables. However, national tables do not provide any information on bilateral flows of goods and services between countries. For this type of information researchers have to rely on datasets constructed on the basis of national input-output tables in combination with international trade data. Various alternative datasets have been built in the past of which the GTAP database is the most widely known and used (Narayanan and Walmsley, 2008). Other datasets are constructed by the OECD (Yamano and Ahmad 2006) and IDE-JETRO (2006). However, all these databases provide only one or a limited number of benchmark year input-output tables which preclude an analysis of developments over time. And although they provide separate import matrices, there is no detailed break-down of imports by trade partner. For this paper we use a new database called the World Input-Output Database (WIOD) that aims to fill this gap. The WIOD provides a time-series of world input-output tables from 1995 onwards, distinguishing between 35 industries and 59 product groups. Using a novel approach national input-output tables of forty major countries in the world are linked through international trade statistics, covering more than 85 per cent of world GDP. The construction of the world input-output tables will be discussed in section 3.1.

Another crucial element for this type of analysis are detailed value-added accounts that provide information on the use of various types of labour (distinguished by educational attainment level) and capital in production, both in quantities and values. While this type of data is available for most OECD countries (O'Mahony and Timmer, 2009), it is not for most developing countries. In Section 3.2 we describe our data strategy, with a particular emphasis for the Chinese data that is most important for the topic of this paper, but at the same time the most challenging.

3.1 World Input-Output Tables (WIOTs): concepts and construction

In this section we outline the basic concepts and construction of our world input-output tables. Basically, a world input-output table (WIOT) is a combination of national input-output tables in which the use of products is broken down according to their origin. In contrast to the national input-output tables, this information is made explicit in the WIOT. For each country, 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. It 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.

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

		Country A Intermediate *Industry*	Country B Intermediate *Industry*	Rest of World Intermediate *Industry*	Country A Final domestic	Country B Final domestic	Rest of Final domestic	Total
Country A	*Industry*	Intermediate use of domestic output	Intermediate use by B of exports from A	Intermediate use by RoW of exports from A	Final use of domestic output	Final use by B of exports from A	Final use by RoW of exports from A	Output in A
Country B	*Industry*	Intermediate use by A of exports from B	Intermediate use of domestic output	Intermediate use by RoW of exports from B	Final use by A of exports from B	Final use of domestic output	Final use by RoW of exports from B	Output in B
Rest of World (RoW)	*Industry*	Intermediate use by A of exports from RoW	Intermediate use by B of exports from RoW	Intermediate use of domestic output	Final use by A of exports from RoW	Final use by B of exports from RoW	Final use of domestic output	Output in RoW
		Value added	Value added	Value added				
		Output in A	Output in B	Output in RoW				

The rows in the WIOT indicate the use of output from a particular industry in a country. This can be intermediate use in the country itself (use of domestic output) or by other countries, in which case it is exported. Output can also be for final use[4], either by the country itself (final use of domestic output) or by other countries, in which case it is exported. Final use is indicated in the right part of the table, and this information can be used to measure the C matrix defined in section 2. The sum over all uses is equal to the output of the industry, denoted by Q in section 2.

A fundamental accounting identity is that total use of output in a row equals total output of the same industry as indicated in the respective column in the left-hand part of

[4] Final use includes consumption by households, government and non-profit organisations, and gross capital formation.

the figure. The columns convey information on the technology of production as they indicate the amounts of intermediate and factor inputs needed for production. The intermediates can be sourced from domestic industries or imported. This is the B matrix from section 2. The residual between total output and total intermediate inputs is value added. This is made up by compensation for production factors. It is the direct contribution of domestic factors to output. We prepare the F matrix from section 2 on this information after breaking out the compensation of various factor inputs as described in Section 3.2.

As building blocks for the WIOT, 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. The construction of our WIOT has a number of distinct characteristics.

We rely on national supply and use tables (SUTs) rather than input-output tables as our basic building blocks. SUTs are a natural starting point for this type of analysis as they provide information on both products and 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 factor use that is industry-based, can be naturally made in a SUT framework.[5]

To ensure meaningful analysis over time, we start from industry output and final consumption series given in the national accounts and benchmark national SUTs to these time-consistent series. Typically, SUTs are only available for a limited set of years (e.g. every 5 year)[6] 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. By benchmarking the SUTs on consistent time series from the National Accounting System (NAS), tables can be linked over time in a meaningful way. This is done by using a SUT updating method (the SUT-RAS method) as described in Temurshoev and Timmer (2011) which is akin to the well-known bi-proportional (RAS) updating method for input-output tables. For this updating data on gross output and value added by industry is used, alongside data on final expenditure categories from the National Accounts.

Ideally, we would like to use official data on the destination of imported goods and services. But in most countries these flows are not tracked by statistical agencies. Nevertheless, most do publish an import IO table constructed with the import

[5] As industries also have secondary production a simple mapping of industries and products is not feasible.
[6] Though recently, most countries in the European Union have moved to the publication of annual SUTs.

proportionality assumption, applying a product's economy-wide import share for all use categories. For the US it has been found that this assumption can be rather misleading in particular at the industry-level (Feenstra and Jensen, 2009; Strassner, Yuskavage and Lee, 2009). Therefore we are not using the official import matrices but use detailed trade data to make a split. Our basic data is bilateral 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 description products are allocated to three use categories: intermediates, final consumption, and investment, effectively extending the UN Broad Economic Categories (BEC) classification. We find that import proportions differ widely across use categories and importantly, also across country of origin. For example, imports by the Czech car industry from Germany contain a much higher share of intermediates than imports from Japan. This type of information is reflected in our WIOT by using detailed bilateral trade data. The domestic use matrix is derived as total use minus imports.

Another novel element in the WIOT is the use of data on trade in services. As yet no standardised database on bilateral service 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 (see Stehrer et al., 2010, for details). Although the maximum of existing information is used, there are clear gaps in our knowledge in particular at a low level of aggregation.

Based on the national SUTs, National account series and international trade data, international SUTs are prepared for each country. As a final step, international SUTs are transformed into an industry-by-industry type world input-output table. 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 (see e.g. Eurostat, 2008). For a more elaborate discussion of construction methods, practical implementation and detailed sources of the WIOT, see the Data appendix.

3.2 Factor input requirements

For factor input requirements we collected country-specific 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. These series are not part of the core set of national accounts statistics reported by NSIs; at best only total hours worked and wages by industry are available from the National Accounts. 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 information 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. This is particularly important for less advanced economies that typically feature a large share of self-employed workers in industries like agriculture, trade, business and personal services. We make an imputation by assuming that the compensation per hour of self-employed is equal to the compensation per hour of employees. Capital compensation is derived as gross value added minus labour compensation as defined above.

For most OECD countries labour data was taken from the EU KLEMS database (www.euklems.org, described in O'Mahony and Timmer 2009). For other countries additional data has been collected, which is described in full in Erumban et al. (2011). Here we discuss the sources for China, being the most important country for our analysis and one for which labour data is particularly scarce.

The main data source for relative wages by educational attainment and broad sectors of the economy for China are from the China Household Income Project (CHIP) survey, 2002. The CHIP study is considered the best available data source on household income and expenditures and the only available source for wage data by educational attainment. The CHIP survey is split into an urban and a rural survey. These two surveys were combined, resulting in about 18,500 observations on wages per hour, level of education, and broad sector of activity (after cleaning the dataset by dropping the 1st and 99th percentile of wage per hour). The broad sectors distinguished are agriculture, other industries, manufacturing, transport, storage and communication, distributive trade, other market services, and government services. The yearly wage from work is measured as the sum of total income, subsidy for minimum living standard, living hardship subsidies from work unit, and monetary value of income in kind. We distinguish three classes.

Construction of the World Input-Output Table

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.

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).[7] Hence WIOD can be easily linked to additional variables on investment, labour and productivity in the EU KLEMS database (see 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, are best applied at a high level of product detail.

In Appendix 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. Appendix Table 1 provides details

[7] 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.

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.[8] 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. (2011).

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. 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:

$$S_i = \sum_j S_{i,j}^D + M_i \qquad (1)$$

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

$$U_i = F_i + E_i + \sum_j I_{i,j} \quad (2)$$

The identity of supply and use is then given by

$$F_i + E_i + \sum_j I_{i,j} = \sum_j S_{i,j}^D + M_i \qquad \forall i \qquad (3)$$

The second accounting identity can be written as follows

[8] These can be found at http://epp.eurostat.ec.europa.eu/portal/page/portal/ esa95_supply_use_input_tables/introduction.

$$\sum_i S_{i,j}^D = VA_j + \sum_i I_{i,j} \qquad \forall j \qquad (4)$$

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.

Typically, SUTs are only available for a limited set of years (e.g. every 5 year) [9] 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. Therefore they are benchmarked on consistent time-series from the NAS in a second step. Data 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 is done by using official exchange rates from IMF. This data is used to generate time series of SUTs using the so-called SUT-RAS method (Temurshoev and Timmer 2011). 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. (2011) for more detail.

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

[9] Though recently, most countries in the European Union have moved to the publication of annual SUTs.

$$I_{i,j} = I_{i,j}^{D} + I_{i,j}^{M} \quad \forall i, j$$
$$F_i = F_i^{D} + F_i^{M} \quad \forall i \quad (5)$$
$$E_i = E_i^{D} + E_i^{M} \quad \forall i$$

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

$$\sum_j I_{i,j}^{D} + F_i^{D} + E_i^{D} = \sum_j S_{i,j}^{D} \quad \forall i \qquad (6)$$

and total imports equal total use of imported products

$$\sum_j I_{i,j}^{M} + F_i^{M} + E_i^{M} = M_i \quad \forall i \qquad (7)$$

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

$$\sum_k \sum_j I_{i,j,k}^{M} + \sum_k F_{i,k}^{M} + \sum_k E_{i,k}^{M} = \sum_k M_{i,k} = M_i \quad \forall i \quad (8)$$

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).

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.[10] This resembles the well-known

[10] 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.

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. [11] 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 $m_{i,k}^{l}$ 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

$$m_{i,k}^{l} = \frac{\tilde{M}_{i,k}^{l}}{\tilde{M}_{i}} \text{ such that } \sum_{k}\sum_{l} m_{i,k}^{l} = 1 \qquad (9)$$

[11] At a later stage we shall use information from existing imports SUTs or IOTs.

where $\tilde{M}^{l}_{i,k}$ 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 $\tilde{M}_{i}$ 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. $I^{M}_{i,j,k}$ is the amount of product group *i* imported from country *k* and used as intermediate by industry *j*. It is given by:

$$I^{M}_{i,j,k} = m^{I}_{i,k} M_{i} \frac{I_{i,j}}{I_{i}} \quad \forall j \qquad (10)$$

where $I_{i} = \sum_{j} I_{i,j} \quad \forall i$ such that $\frac{I_{i,j}}{I_{i}}$ 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*, $FC^{M}_{i,f,k}$, is given by:

$$FC^{M}_{i,f,k} = m^{FC}_{i,k} M_{i} \frac{FC_{i,f}}{FC_{i}} \qquad (11)$$

The amount of product group *i* imported from country *k* and used as investment, $GFCF^{M}_{i,k}$, is given by:

$$GFCF^{M}_{i,k} = m^{GFCF}_{i,k} M_{i} \qquad (12)$$

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

$$\begin{aligned} I^{D}_{i,j} &= I_{i,j} - \sum_{k} I^{M}_{i,j,k} \quad \forall i, j \\ FC^{D}_{i,f} &= FC_{i,f} - \sum_{k} FC^{M}_{i,f,k} \quad \forall i \qquad (13) \\ GFCF_{i}^{D} &= GFCF_{i} - \sum_{k} GFCF^{M}_{i,k} \quad \forall i \end{aligned}$$

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.

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.

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.

For an elaborate discussion of construction methods, practical implementation and detailed sources of the WIOT, see Timmer et al. (2012, forthcoming).