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## The World Input-Output Database

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CONTENT, CONCEPTS AND APPLICATIONS**

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# **THE WORLD INPUT-OUTPUT DATABASE: CONTENT, CONCEPTS AND APPLICATIONS\***

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This article describes the contents and construction of the World Input-Output Database (WIOD). This database contains annual time-series of world input-output tables, covering the period from 1995 onwards. Underlying concepts, construction methods and data sources are considered. In addition, the WIOD provides data on labour and capital inputs for forty countries, making it useful for a wide range of applications. We illustrate this by analysing recent trends in international production fragmentation, competitiveness and patterns of specialisation. We give guidance to prudent use and discuss possible improvements and extensions.

\* The World Input-Output Database (WIOD) is an outcome of a project that was funded by the European Commission, Research Directorate General from 2009 to 2012 as part of the 7th Framework Programme, Theme 8: Socio-Economic Sciences and Humanities, grant Agreement no: 225 281. The project was carried out by a consortium of 12 research institutes (see Appendix 1 for list). We are grateful to all participants in the project for their contributions in the construction and validation of preliminary versions of the database. In particular we wish to thank Abdul Azeez Erumban, Umed Temurshoev, Neil Foster-Mc Gregor, Johannes Pöschl and Reitze Gouma for their invaluable research assistance without which the construction of this database would have been impossible. Continued support from the OECD and the WTO, in particular Hubert Escaith, is also gratefully acknowledged.

## Introduction

Stimulated by declining coordination and transport costs, production processes increasingly fragment across borders. This fundamentally alters the nature of international trade, away from trade in goods towards trade in tasks and activities, with profound implications for the geographical location of production, the patterns of gains from trade and the functioning of labour markets (Feenstra, 2010). However, current statistical frameworks are not well equipped to provide the necessary data to analyse these phenomena. Grossman and Rossi-Hansberg, for example, state that “the globalization of production processes mandates a new approach to trade data collection, one that records international transactions, much like domestic transactions have been recorded for many years.” (Grossman and Rossi-Hansberg, 2008, p.1996). What is needed is a world input-output table that not only contains transactions within a domestic economy, but also includes cross-border flows of goods and services. Without such data, we are groping in the dark about the causes and consequences of the changing nature of international trade.

Until recently, researchers had to compile their own databases, typically merging international trade statistics with a collection of input-output tables from the GTAP project (see e.g. Trefler and Zhu, 2010; Johnson and Noguera 2012a; Koopman et al. 2014). These ad-hoc efforts are difficult to replicate however as GTAP is a proprietary database, not grounded in official statistics and only available for certain benchmark years. This article describes the construction of the World Input-Output Database (WIOD) which is the first database that provides annual time-series of world input-output tables, covering the period from 1995 to 2011. These tables have been constructed in a clear conceptual framework on the basis of officially published input-output tables merged with national accounts data and international trade statistics. In addition, the WIOD provides data on labour and capital inputs at the industry level that can be used in conjunction, enlarging the scope of potential applications considerably.

A first version of the database has been publicly available on <http://www.wiod.org> since April 2012. It has proved very useful in describing trends in global supply chain trade and research into the formation of regional production clusters in the world economy (e.g. Baldwin and Lopez-Gonzales, 2013). It also found its way into numerous policy-oriented studies on the effects of globalisation conducted by international organizations, such as the ECB (Di Mauro et al., 2013), European Commission (European Commission, 2013) and IMF (Saito, Ruta and Turunen, 2013) and in an influential study for the UK (Greenaway, ed. 2012). The availability of WIOD contributed to the development of new accounting methods in order to improve the measurement of international vertical specialisation and factor content of trade, building upon earlier work by Hummels, Ishii and Yi (2001) and Trefler and Zhu (2010). Koopman et al. (2014) used the data from WIOD in combination with a new accounting method to provide a decomposition of the domestic value added content of gross exports. In related work, Timmer et al. (2013) developed new measures of competitiveness and analysed the value added and job contributions of countries to global value chains of manufacturing goods. The data is also suitable for calibrating general equilibrium models as used in a wide variety of settings to evaluate the effects of trade policies. Costinot and Rodríguez-Clare (2013), for example, relied on data from WIOD to estimate key structural parameters in a set of gravity models and to conduct counterfactual analysis of the effects of trade on real income and factor prices. Due to its cross-country and cross-industry nature, the WIOD panel data provides new opportunities for econometric estimations in which the cross-

section panel dimension in the data can relate to both countries and industries. Foster-McGregor, Stehrer and de Vries (2013) and Schwörer (2013) used the new WIOD data to revisit the debate on the effects of off-shoring and skill-biased technological change on labour demand in the tradition of Feenstra and Hanson (1999), Hijzen, Görg and Hine (2005) and Michaels, Natraj and van Reenen (2013). Other potential applications of the WIOD could address various topics in macro-economics, such as models of structural change mapping consumption structure on the sectoral structure of the economy by modelling intermediate inputs demand (Herrendorf, Rogerson and Valentinyi, 2013), the transmission of fluctuations and synchronisation of business cycles across sectors and countries (Bems, Johnson and Yi, 2011; Acemoglu et al., 2012), the role of input-output linkages in propagating productivity shocks and their effects on factor reallocation (Jones, 2011), and measuring upstreamness (the distance of an industry to final use, see Dietzenbacher and Romero, 2007; Antràs et al., 2012).

To optimise the benefit of this new database, users need to understand its conceptual and practical underpinnings. The main purpose of this article is therefore to summarise the methodology employed in constructing the database, guiding researchers on appropriate uses. This requires that we also consider the practical limitations of the database and indicate areas for further improvement. In addition we illustrate the usefulness of the database by highlighting some interesting findings on global trends in the international fragmentation of value chains, which might stimulate further research on its causes and consequences.

The remainder of this article is organised as follows. Section 1 describes the basic conceptual framework of a world input-output table, summarises its basic data sources and describes how these were integrated. The main challenges in construction are discussed in a non-technical manner, deferring technical details to a companion paper (Dietzenbacher et al., 2013). It also introduces the supplementary data on labour and capital inputs at the industry level which is an elaboration of the EU KLEMS dataset (O’Mahony and Timmer, 2009). Section 2 contains a set of applications of the WIOD, illustrating its power in analyses of global production fragmentation. Section 3 considers specific measurement issues that are important for prudent use of the data, and identifies areas that are most in need for improvements. The WIOD is meant to serve as a dynamic resource that will be expanded over time and section 4 considers future developments.

## **1. Framework and practical implementation**

In this section we first outline the basic conceptual framework of a world input-output table (WIOT) and the main accounting identities that govern its compilation. Section 1.2 discusses the major challenges in the construction of a WIOT and describes the underlying data sources. Section 1.3 describes the construction of labour and capital input data.

### *1.1 Conceptual framework of a world input-output table*

A world input-output table can be regarded as a set of national input-output tables that are connected with each other by bilateral international trade flows. In Figure 1a the basic structure of a national input-output table (NIOT) is presented. This table is of the industry-by-industry type.

For ease of discussion we assume that each industry produces only one product.<sup>1</sup> A NIOT provides a comprehensive summary of all transactions in an economy indicating the value of supply and use of products in a particular year. An important accounting identity is the basic market-clearing condition stating that supply must equal use for each product, such that all flows in the economic system are accounted for. Products are supplied by domestic industries or imported, and are used as intermediates by domestic industries, for final use by domestic residents or exported.<sup>2</sup> The use of products is indicated in the rows of the table. The columns in the NIOT contain information on domestic production processes. They indicate the values of all intermediate, labour and capital inputs used in the production activities of a particular industry. By definition, gross output of an industry is equal to the value of all intermediates and factor inputs used in production. When expressed as ratios to gross output, the cells in a column provide information on the shares of intermediate, labour and capital inputs in total costs. Such a vector of cost shares in gross output is often referred to as the domestic production technology.<sup>3</sup> An important accounting identity in the NIOT is that gross output of each industry (given in the last element of each column) is equal to the sum of all uses of the output from that industry (given in the one but last element of each row). It should be noted that imports in this NIOT are also represented by a column. There is no information about the distribution of these imports across various use categories. Nor is there information on the country and industry supplying the imports. The main challenge in constructing a WIOT is to estimate the origins and use of these import flows.

*[Figure 1 about here]*

A world input-output table (WIOT) is basically an extension of the NIOT in which the origins and destinations of imports and exports are made explicit. This is illustrated by the schematic outline for a WIOT involving three countries in the lower panel of Figure 1. In the WIOT, forty countries and a Rest of the World region are distinguished, but the basic structure remains the same. Compared to a NIOT, imports are broken down according to the country and industry of origin. This allows one, for example, to trace the country of origin of the chemicals used in the food industry of country A. The combination of national and international flows of products provides a powerful tool for analysis of global production networks. While NIOTs are routinely produced by national statistical institutes, WIOTs are not as they require integration of national account statistics across countries. So far, this has not been institutionalised at a global level and currently remains a task to be taken up outside official statistical systems. In the following section we outline our efforts in doing so.

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<sup>1</sup> In fact, the WIOTs are built up from national supply and use tables, allowing for output of multiple products output by an industry, see section 1.2.

<sup>2</sup> Final use includes all products that are consumed by households and the government, or used for investment purposes. The NIOT also includes “changes in inventories” as a final use category, capturing possible intertemporal differences between production and use.

<sup>3</sup> The time-series characteristic of the database allows for analysis that go beyond the usual assumptions of fixed cost shares of the Cobb-Douglas type of production functions, as shown in the applications section later on. When traced over time, changing shares can be interpreted within a translog production function, which provides a second-order approximation to any functional form. In these production models, shifting cost shares summarise the combined effects of changes in relative input prices, in cross-elasticities and input-biased technological change (Christensen, Jorgenson and Lau, 1971).

### *1.2 Data sources and practical implementation*

The second release of the WIOD in November 2013 provides a time-series of world input-output tables (WIOTs) from 1995 to 2011. It covers forty countries, including all EU 27 countries and 13 other major advanced and emerging economies, namely Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey and the United States (see Appendix Table 1). These countries have been chosen by considering both the requirement of data availability of sufficient quality and the desire to cover a major part of the world economy. Together, the countries cover more than 85 per cent of world GDP in 2008, at current exchange rates. In addition a model for the remaining non-covered part of the world economy is estimated, called the “rest of the world” region. To address several important research questions it is crucial to have a closed model of the world economy.

The WIOTs are built up from published and publicly available statistics from national statistical institutes around the world, plus various international statistical sources such as OECD and UN National Accounts, UN Comtrade and IMF trade statistics. As building blocks for the WIOTs, we used national supply and use tables (SUTs). In short, we derive time series of national SUTs and link these across countries through detailed bilateral international trade statistics to create so-called international SUTs. These are subsequently used to construct the WIOTs. In this section we discuss how we dealt with four major challenges in data construction: harmonisation of basic SUT data; derivation of time-series of SUTs; disaggregation of imports by country of origin and use category, and global closure. This will be brief and non-technical; more detail can be found in Dietzenbacher et al. (2013).

*Harmonisation of national SUT data.* The WIOTs have been constructed on the basis of sets of national supply and use tables (SUTs) that are the core statistical sources from which statistical institutes derive national input-output tables. A supply table is of the product-by-industry type and indicates for each product the values of its deliveries by domestic industries or imports. The Use table indicates the values of purchases of each product by each of its destinations: intermediate use by domestic industries, domestic final demand or exports. It is also of the product-by-industry type. SUTs provide a more natural starting point for building WIOTs than national input-output tables. The latter contain less information and are typically derived from the former with additional assumptions. Moreover, SUTs can easily be combined with trade statistics that are product-based and employment statistics that are industry-based. It also allows one to take the multi-product nature of firms into account: the outputs of firms are classified in a supply table on a product basis, such that these might be recorded in different product classes.

National supply and use tables were collected from national statistical institutes and harmonised in terms of concepts and classifications. They have been tailored to dimensions of 35 industries and 59 product groups. The 35 industries cover the overall economy and are mostly at the 2-digit ISIC rev. 3 level or groups thereof. These include agriculture, mining, construction, utilities, fourteen manufacturing industries, telecom, finance, business services, personal services, eight trade and transport services industries and three public services industries (see Appendix Table 2). The product groups are more finely defined and are all two-digits in the 2002 Classification of Products by Activity (CPA), including twenty-three manufacturing products. This level of detail was dictated by the available data, reflecting the lowest common denominator across countries. Construction involved aggregation of more detailed source data and sometimes

disaggregation based on additional data from detailed production surveys. The national SUTs have also been harmonised to a basic price concept. Basic prices reflect all costs borne by the producer, whereas purchasers' prices reflect the amounts paid by the buyer. The difference between the two is given in so-called valuation matrices with product-specific trade and transportation margins and net taxes. National SUTs in basic and purchasers' prices are separately estimated and reported in the WIOD. The tables expressed in basic prices are more appropriate for most applications (see section 2). International trade flows were accordingly expressed in "free on board" (fob) prices through estimation of international trade and transport margins.

*Time-series of national SUTs.* A second challenge in data construction is the derivation of time-series of SUTs. National tables are only available for particular benchmark years that are unevenly spread over time and asynchronous across countries. Moreover, they are not designed for comparisons over time, which becomes clear when comparing data from the SUTs with the national accounts statistics. While the latter are frequently revised, the former are not.<sup>4</sup> To deal with both these issues simultaneously, a procedure was applied that imputes SUT coefficients subject to hard data constraints from the National Accounts Statistics (NAS). As such, the solution matches exactly the most recent NAS data on final expenditure categories (household and government consumption and investment), total exports and total imports, and gross output and value added by industry. The unknown product shares are imputed using a constrained optimization method akin to the well-known bi-proportional (RAS) updating method (Temurshoev and Timmer, 2011). In this way the tables will also satisfy another important accounting identity that is related to the measurement of gross domestic product (GDP) in the System of National Accounts: the sum of value added over all industries (representing incomes for labour and capital) will be equal to the sum of final domestic use expenditures and the net trade balance (exports minus imports).<sup>5</sup> Appendix Table 1 gives for each country the years for which a benchmark national SUT was available and used in the construction of the time-series.

*Use categories of imports.* A third challenge was the breakdown of imports of a product for each use category by country and industry of origin. This type of information is not available in published supply and use tables. Typically, researchers rely on the so-called import proportionality assumption, applying a product's economy-wide import share for all use categories (as e.g. Johnson and Noguera, 2012a). Various studies have found that this assumption can be rather misleading as import shares vary significantly across use category (Feenstra and Jensen, 2012). To improve upon this, bilateral trade statistics have been used in WIOD to derive import shares for three end-use categories. Bilateral import flows of all countries covered in WIOD from all partners in the world at the 6-digit product level of the Harmonized System (HS) were taken from the UN COMTRADE database. We used the detailed product descriptions to refine the well-known BEC ("broad economic categories") codes, which allocates imported goods to intermediate use, final consumption use, or investment use. Within each end-use category, the allocation was based on the proportionality assumption (as dictated by a lack of additional information). For intermediate use by industries, for example, we applied ratios between imported use and total use that were equal

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<sup>4</sup> More recently, national statistical institutes of some countries in the European Union and the US Bureau of Economic Analysis have moved to the publication of annual SUTs that include revisions as well.

<sup>5</sup> Value added should be measured at purchasers' prices (that is including net taxes on products) for this identity to hold.



across industries, but differed from the corresponding ratio for consumption purposes. We find that these ratios differ widely across use categories and country of origin. Imports by the Czech Republic from Germany, for example, are characterized by a much higher share of intermediates than the Czech imports from Japan. The latter are mostly purchased by Czech consumers and the former for further processing by Czech industries. By using detailed bilateral trade data this type of information is incorporated into the national SUTs. We labelled the resulting tables “international” SUTs.

*Global closure.* In order to obtain a description of the structure of the global economy according to the concept of a SUT, we integrated the “international” SUTs for all forty countries into a “world” SUT. In doing this, we inferred bilateral exports as mirror flows from the bilateral import statistics as given in the “international” SUTs. Hence, we ensured that import and export flows between partner country-industry pairs mirror each other. In a final construction step, the “world” SUT, which is also of the product-by-industry type, was transformed into a world input-output table of the industry-by-industry type. Many applications require such a square matrix reflecting the economic linkages across industries. The WIOT was constructed by using the so-called “fixed product sales” model which assumes that each product has its specific use structure, irrespective of the industry that produced it.<sup>6</sup> To have a closed model of the world economy, we also defined a rest-of-the-world region which proxies for all other countries in the world. Exports to this region for each product and country from the set of WIOD countries are defined residually to achieve consistency of global trade flows. It ensures that exports summed over all countries-of-destination (including the rest-of-the-world region) are equal to total exports as given in the national SUTs.

The resulting WIOT has the dimension of 1443 rows and 1641 columns. It contains 1435 industry-country pairs as suppliers in the rows (41 countries times 35 industries) with additional rows covering value added and various adjustment items (see Appendix Table 3). There are again 1435 industry-country pairs as users of intermediates in the columns and 205 additional columns for final users per country (41 countries times 5 types of final use, see Appendix Table 3). The values in WIOTs have been expressed in millions of US\$ and exchange rates were used for currency conversion of the SUTs, which originally contain values in national currencies.

### *1.3 Supplementary data on labour and capital inputs*

In addition to the WIOTs, the WIOD provides data on the quantity and prices of factors inputs, including data on workers and wages by level of educational attainment and capital inputs. This data is provided in the so-called *Socio-economic accounts*. One unique characteristic of the WIOD is that this type of data can be used in conjunction with the WIOTs as similar industry classifications are used. Compared to existing international data sources such as Barro and Lee (2013), WIOD provides an extension in two directions. First, it provides industry level data, which reflects the large heterogeneity in the skill levels used in various industries. Second, it provides relative wages by skill type that reflect the differences in remuneration of workers with different levels of education. Labour skill types are classified on the basis of educational attainment levels as

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<sup>6</sup> Alternative assumptions could be made here, and similarly a product-by-product type table could be derived. Each model has its specific advantages, see Miller and Blair (2009). Interested users can produce alternative WIOTs by themselves as the underlying international SUTs have been made public as well.

defined in the International Standard Classification of Education (ISCED): low-skilled (ISCED categories 1 and 2), medium-skilled (ISCED 3 and 4) and high-skilled (ISCED 5 and 6).<sup>7</sup>

This type of information is not part of the core set of national accounts statistics reported by NSIs. For most advanced countries labour data is constructed by extending and updating the EU KLEMS database ([www.euklems.org](http://www.euklems.org)) using the methodologies, data sources and concepts described in O'Mahony and Timmer (2009). For other countries additional data has been collected according to the same principles, mainly from national labour force surveys, supplemented by amongst others earnings surveys for relative wages. 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. Data has been collected for the number of workers involved in production, including employees, self-employed and family workers.<sup>8</sup> Additional imputations of the labour income of self-employed and family workers were made to adjust for the underestimation of the labour income share in the National Accounts Statistics, in particular for less advanced nations (Gollin, 2002).

Capital compensation is derived as a residual and defined as gross value added minus labour income. Hence it is the gross compensation for capital, including profits and depreciation allowances. Due to its derivation as a residual, it reflects the remuneration for capital in the broadest sense. This does not only include traditional reproducible assets such as machinery and buildings, but also includes non-reproducible assets. Examples are mineral resources and land, intangible assets (such as R&D knowledge stocks, software, databases, brand names and organisational capital) and financial capital. The WIOD also includes measures of the capital stocks. These are based on a perpetual inventory method building up from investment series for those assets that are currently covered by the national accounts statistics.<sup>9</sup>

## 2. Applications

Given its conceptual framework, the WIOD is particularly fit to be used in combination with input-output analysis. Ever since the pioneering work of Wassily Leontief, input-output techniques have been part of the standard toolkit of economists.<sup>10</sup> In this section we provide three novel findings based on tracing the value added contributions of countries to final output in global production networks using the WIOD and input-output analysis. These findings relate to new measures of the extent of global production fragmentation, to the competitiveness of nations and to patterns of specialisation in the world economy. To introduce this type of analysis, we first start with an illustrative example for the production of German cars.

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<sup>7</sup> Despite attempts at international harmonisation, comparisons of skill shares across countries have still to be made with care, given the differences in national educational systems. Developments over time in skill-shares can be traced with more confidence.

<sup>8</sup> Although hours worked would be a preferable measure of labour inputs, this data is not abundantly available.

<sup>9</sup> The assets covered by the system of national accounts 1993 are mainly related to reproducible physical capital and software. In the new system of national accounts 2008 another step is made towards inclusion of other intangibles, in particular R&D stocks. Corrado et al. (2012) provided experimental estimates for a wider set of intangibles.

<sup>10</sup> See Miller and Blair (2009) for an introduction to input-output analysis.

### 2.1 Decomposing global value chains: an illustrative example

To decompose value added in production, use is made of Leontief's (1949) seminal insight about how to trace the amount of factor inputs needed to produce a certain amount of final demand. Leontief started from the fundamental input-output identity that states that all products produced must either be consumed or used as intermediate inputs.<sup>11</sup> This can be written as  $Q=BQ+C$  where  $Q$  denotes a vector of output levels,  $C$  is a vector with consumption levels and  $B$  is a matrix with intermediate input coefficients describing how much intermediates are needed to produce a unit of output of a given industry.  $BQ$  is then the total amount of intermediates used. The identity can be rewritten as  $Q=(I-B)^{-1}C$ , in which  $I$  is the identity matrix.  $(I-B)^{-1}$  is famously known as the Leontief inverse. It represents the gross output values that are generated in all stages of the production process of one unit of consumption.<sup>12</sup> The value added by all factors that are involved in any stage of the production of  $C$ , is then given by the vector  $K=F(I-B)^{-1}C$ , where  $F$  represents a diagonal matrix of value added to gross output ratios in all industries in all countries.

Leontief's insight has extensively been used in the burgeoning literature on trade in value added and related concepts, starting from the seminal work by Hummels, Ishii and Yi (2001) and including Trefler and Zhu (2010), Johnson and Noguera (2012a,b) and Koopman et al. (2014). These studies basically start from observed exports of a country and provide a decomposition of its value into value that is domestically added, and value that is added in supplying countries. A related branch of studies analyses the distribution of value added in a particular global value chain (GVC). A GVC of a good is defined as the set of all value-adding activities needed in its production. It is characterised by the industry and country in which the last stage of production takes place, which we call the industry-of-completion and country-of-completion. Through application of Leontief's technique, a full decomposition of the final product's value can be given, indicating the value added by each of the contributing countries and industries. As such, they can be seen as macro-economic equivalents of well-known product case studies such as the iPod (Dedrick et al., 2010) or the Nokia mobile phone (Ali-Yrkkö et al., 2011).

In Table 1 we provide an example of such a decomposition for the GVC of output from the German transport equipment manufacturing industry, in short "cars". With the new availability of cheap and relatively skilled labour, firms from Germany relocated parts of the production process to Eastern Europe (Marin, 2011). Between 1995 and 2008, the share of value added outside Germany increased rapidly to 34 per cent of the value of a German car. At the same time, the value added in the domestic manufacturing sector declined. Perhaps surprisingly, value added in domestic services sectors that deliver intermediate inputs increased, reflecting a process of fragmentation that has both a national and an international nature. Similarly, a decomposition regarding numbers of workers can be carried out. This reveals that offshoring by German car makers contributed to a doubling of the number of foreign jobs associated with German car manufacturing. But it was not accompanied by a decline in local employment as the number of domestic jobs increased from 1.3 to 1.7 million. This increase was exclusively outside the

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<sup>11</sup> For ease of exposition, we denote all final demand (including investment demand) as consumption in this section.

<sup>12</sup> To see this, let  $Z$  be a column vector of which the first element represents the global consumption of cars produced in Germany, and all other elements are zero. Then  $BZ$  is the vector of intermediate inputs, both German and foreign, needed to assemble the cars in Germany. But these intermediates need to be produced as well and  $B^2Z$  indicates the intermediate inputs directly needed to produce  $BZ$ . This continues until the mining and drilling of basic materials required to start the production process are taken into account. Summing up across all stages of production, the gross output generated in any country-industry that contributes to the production of cars from Germany is given by  $(I-B)^{-1}Z$ .

manufacturing sector, emphasising the increased interlacing of manufacturing and services activities. We now turn to a brief discussion of some major findings based on this type of analysis.

*[Table 1 about here]*

### *2.2 Globalisation of production processes*

Previous studies of globalisation tended to claim that fragmentation is mainly taking place within regional trade blocs rather than being a truly global phenomenon (e.g. Baldwin and Lopez-Gonzalez, 2013). Los, Timmer and de Vries (2013) test this hypothesis using the WIOD and study the changes in the geographical distribution of value added in global value chains. They study three trade blocs (NAFTA, the EU and East Asia) and define regional foreign value added as all value that is added outside the country-of-completion, but in the region to which this country-of-completion belongs. Global value added is the value added in all countries outside this region. In this study they focus on activities that are directly and indirectly involved in production of final manufacturing goods. These activities are particularly prone to fragmentation and have a high degree of international contestability.

The first three columns in Table 2 present the domestic, regional and global value added shares of final manufacturing goods from 12 countries in the world in 2008. By definition, these shares add up to 100 per cent. Perhaps surprising is the finding of a strong home-bias in value added in GVCs. In all major countries, at least two-thirds of the value is still added domestically. For small and open economies, the domestic share is smaller but still around 50 per cent. This indicates that the potential for further fragmentation is still sizeable. In 2008, the major part of foreign value was added outside the region. Even for products for which the last stage of production takes place in the European Union, foreign value added inside the EU is lower than outside the EU. Only for Eastern European GVCs, regional foreign value added still dominated. The last columns in Table 2 indicate that this process of global fragmentation has been strong since 1995 in all countries as global shares increased much faster than regional shares. The UK appears to be country that has been least affected by the global fragmentation process of manufacturing as its domestic value added content remained relatively high. Similarly, British participation in foreign GVCs remained low and this stagnation went hand-in-hand with a severe loss in competitiveness as will be shown below.

*[Table 2 about here]*

### *2.3 New measures of competitiveness*

The rise of global value chains is posing new challenges to analyses of countries' competitiveness. Traditional measures like gross export values are based on the assumption that all activities in production are carried out in the exporting economy. This assumption can no longer be maintained, as shown above. Timmer et al. (2013) propose an alternative measure called "GVC income", which measures the value added in a country related to the production of final manufacturing goods.<sup>13</sup> The overall GVC income of a country is measured by summing over its contributions to

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<sup>13</sup> This is akin to the work by Johnson and Noguera (2012a) and Koopman et al. (2014) who proposed a new measure of the domestic value added content of exports. But in contrast to these studies Los et al. (2013) focus on output for both domestic and foreign final demand. The GVC income concept can in principle also be applied to the production of

every manufacturing GVCs in the world. This includes the GVCs for which the country itself is the country-of-completion, but also GVCs for which the last stage of production takes place somewhere else.

Figure 2 provides an overview of the trends since 1995 in GVC income for major groups of countries in the world. It shows that the location of value added has clearly shifted away from the advanced towards the emerging regions. Over the period up to 2007 the value added in the NAFTA region has been basically stagnant, signalling that the dynamic gains from trade liberalization in the early 1990s had petered out. Since the mid-2000s, NAFTA has clearly been outperformed by the European Union which retained much of its competitiveness in activities related to the production of manufacturing goods. The reorganization of production in Europe has strengthened its position in global markets, although the backlash of the financial crisis in 2008 was more severe than elsewhere. Within Europe, the contribution of new member states (EU12) increased from 4 to 9 per cent of the EU27 between 1995 and 2008. Shares in Germany and France declined slightly. The biggest decline by far was in the UK: its share fell from 12 to 10 per cent (Timmer et al., 2013, Table 1). GVC income in East Asia (including Japan, South Korea and Taiwan) declined strongly in the 1990s, in particular in Japan. The process of offshoring to other Asian countries, in particular to China, did not set a dynamic process of increased competitiveness in motion. In contrast, emerging regions have rapidly increased value added in manufacturing GVCs. China is responsible for the major part of this increase, accelerating growth after joining the WTO in 2001 and tripling its GVC income share between 2002 and 2008. GVC income also rapidly increased in other emerging economies, including Brazil, Russia, India, and Turkey. These countries also withstood the global crisis much better and continued to experience upward trends in their GVC incomes after 2009.

*[Figure 2 about here]*

#### *2.4 Specialisation in high-skilled and services' workers*

Many policy concerns surrounding globalization issues are ultimately about jobs - good jobs in particular. The disappearance of manufacturing jobs in advanced nations is occasionally linked to production fragmentation and associated offshoring of activities. It is thus useful to look at the structure of employment in global value chains, in short, "GVC jobs", characterized by sector of employment and level of educational attainment). By using number of workers, rather than value added, per unit of output as the factor requirements matrix  $F$  in the Leontief decomposition above, we can trace the number of workers directly and indirectly involved in the production of manufacturing goods. The results in the upper panel of Table 3 show these numbers have been dwindling in the former industrial strongholds. GVC jobs declined severely in Japan and the US. Job losses in the UK stand out in particular, as more than 1.6 million GVC jobs disappeared in this country alone. Declines occurred across all UK industries, but in particular in textiles and metal manufacturing. Exceptions to the downward trend are countries like Germany and Spain, but their success in job creation coincided with limited real wage growth, as shown in Timmer et al. (2013). At the same time, there was a strong shift regarding sectors of employment of these workers, away from the manufacturing sector towards the services sector. In Germany and Italy, GVC job increases in services were even larger than the job losses in manufacturing. These findings testify

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services. The necessary data is currently not detailed enough to do so in a meaningful way as only a small set of services is internationally fragmented.

to the increasing interdependencies of manufacturing and services activities and argue against a myopic view on manufacturing jobs in discussions on GVC issues. In particular, they do not lend support to policies that are solely targeted at manufacturing industries in an attempt to revive employment.

The lower panel of Table 3 provides strong evidence of increased specialization of advanced countries in GVC activities performed by high-skilled workers. Numbers of low-skilled jobs declined everywhere, while employment of high-skilled workers increased in all countries, except in the U.S. This is in line with broad Heckscher-Ohlin-based predictions of comparative advantage as suggested by Baldwin and Evenett (2012): countries will carry out activities which local value added content is relatively intensive in their relatively abundant factors when possibilities for international production fragmentation increase. For the set of advanced countries listed in Table 4, the results suggest that international fragmentation of production has gone hand-in-hand with increased job opportunities for high-skilled workers, in particular outside manufacturing. The displaced manufacturing workers are likely to be absorbed in personal and distributional services where low-skilled employment opportunities are still growing, contributing to the so-called job polarization in advanced economies (Goos, Manning and Salomons, 2011).

*[Table 3 about here]*

### **3. Measurement issues**

The WIOD has a number of distinguishing characteristics when compared with current and previous attempts to construct international input-output tables, such as the Asian International Input–Output Tables constructed by IDE-JETRO (Meng, Zhang and Inomata, 2013), the OECD-WTO Database on Trade in Value-Added (OECD and WTO, 2013), Eora (Lenzen et al., 2013), and various ad-hoc alternatives based on the GTAP database (such as Johnson and Noguera, 2012a; Andrew and Peters, 2013).<sup>14</sup> First and above all, the WIOTs from WIOD have been specifically designed to trace developments over time through benchmarking the SUTs to time-series from the National Accounts, and adhering to the concepts and framework of the System of National Accounts. In contrast, the IDE-JETRO and GTAP data sets have been compiled for particular benchmark years, and cannot be reconciled over time. Second, WIOD is based on official and publicly available statistics from NSIs to ensure a high level of data quality. This is in contrast to e.g. GTAP, for which the underlying sources also include non-official statistics.<sup>15</sup> This obviously restricted the number of countries that could be covered in WIOD as there is a trade-off between quality and coverage. The Asian tables by IDE-JETRO are arguably of the highest statistical quality but only cover a limited number of countries. On the other hand, Eora covers all countries in the world, but heavily relies on imputation methods to fill up the many blanks in tables. More experimentation on the sensitivity of the results in data-scarce environments is needed, which will be dependent on the research questions at hand. Third, the WIOD is yet the only database that is publicly available for free (at [www.wiod.org](http://www.wiod.org)). The OECD-WTO Database on Trade in Value-Added, which probably comes closest to WIOD in terms of coverage and

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<sup>14</sup> See Tukker and Dietzenbacher (2013) for an overview of existing global input-output databases.

<sup>15</sup> The input-output tables in GTAP are based on submissions of national tables by individual researchers according to common guidelines.

construction philosophy, currently provides only derived indicators and does not share the underlying international input-output tables. The WIOD is also the only database that provides full transparency by providing all the underlying data sources and methodologies. This not only allows for full replication of its construction and results based on it, but also invites users to build alternative datasets based on the same data but with different assumptions.

As with any database, prudent use requires researchers to familiarize themselves with particular measurement issues. As is clear from the description above, various assumptions in the construction process had to be made and various weaknesses in the data remain. We briefly discuss the most important of these to indicate avenues for further work, as well as to serve as health warnings for users of the WIOD, or for that matter, any international input-output table that currently exists.

*Import proportionality.* In the construction of the WIOTs, a new mapping of trade data to three use categories has been used. In this way, the common practice of assuming a similar import proportion across all uses could be relaxed. This mapping is not unique however, and various products can have multiple end-use categories, such as gasoline (intermediate or final consumption) or cars (household consumption or investment). It should also be noted that within each of the three end-use categories, the allocation is still based on the proportionality assumption. This might be particularly binding when industries differ in their import intensity of intermediates. Some national statistical institutes, such as the UK Office of National Statistics, publish a separate import matrix as part of the national input-output statistics. Personal communication with these institutes led us to conclude that procedures to arrive at these tables differ widely across countries. They are often based on the assumption of import proportionality, but at a lower level of aggregation than published. Tables constructed along these lines do therefore not necessarily provide more information. Only a few countries use additional firm-level survey data on the sourcing and use of products (such as data from Statistics Denmark). We therefore opted for a second-best solution and used a harmonised procedure on import allocation common across all countries, based on the new product-use mapping.

*Technology heterogeneity.* Another limiting assumption in any input-output table is the assumption of homogeneity within industries: there is no information on the possible differences in the production processes across products within a firm, or across firms. A column in the Use table only provides the average production structure across all firms in a particular industry. These structures might be rather different for various types of firms. For example, Chen et al. (2012) and Koopman, Wang and Wei (2012) found that for China the import content of exports differed substantially between foreign processing firms and domestic firms. Based on data for European firms, Ottaviano et al. (2009) found technological differences across exporters and non-exporters. Information on heterogeneity in production processes from firm-level data (e.g. by exporter status or firm size) is a promising avenue for future work.

*Rest-of-the-world region.* To have a complete description of all flows in the global economy, the WIOD also contains an input-output model for the so-called *Rest of the World* (RoW) region which proxies for all other countries in the world, apart from the forty already covered. Given the relatively large size of this region (with a share of world GDP of around 15 per cent), this is

empirically important, as also stressed by Johnson and Noguera (2012b). It was modelled based on totals for industry output and final use categories from the UN National Accounts for non-covered countries, to capture the unusual large size of its mining and natural resource sectors compared to WIOD countries. This was combined with an input-output structure reflecting the average of a set of emerging countries. Exports to this region need to be modelled as well. A simple approach would be to define these residually to ensure that for each WIOD country the summation of exports over all destinations equals total exports as given in the national SUTs. However, in this way it becomes possible that exports to the ROW are negative as all inconsistencies between import and export mirror-flows tend to accumulate in the residual. An alternative approach was followed in which the RoW was treated as an additional trade reporter alongside the other forty countries. Bilateral trade shares were re-calculated using a RAS procedure and shares that were originally computed from the UN COMTRADE data are not necessarily maintained in all cases. A better reconciliation of export and import mirror flows would be major step forward in improving this estimation, which includes a clear treatment of international trade and transportation margins (Streicher and Stehrer, 2013).

*Trade in services.* One of the novel features of the WIOT is that it not only covers bilateral trade in goods but also in services, integrating various international data sources, including UN, OECD, Eurostat, IMF and WTO data. This covers so-called Mode 1 (cross-border) services trade: services supplied from the territory of one country into the territory of another. In total about 20 economic activities according to the Balance of Payments classification were distinguished and mapped onto the services industries. In addition, WIOD also contains data on consumption abroad by resident consumers or firms (such as tourism expenditure, so-called Mode 2) which can make up a sizable part of trade in various countries. As is well-known, services trade data has not been collected at the same level of detail and accuracy as goods trade data. There is still much to be improved, in particular in the coverage of intra-firm deliveries (Francois and Hoekman, 2010).

*Exports and imports for processing.* The construction of the WIOTs follows the standards of the SNA 1993, which stipulate that trade is recorded according to the change-in-ownership principle (ISWGNA, 1993). Movement of products across borders should only be recorded as imports and exports when there is a change in ownership involved. The SNA 1993 also recommends one exception, namely for goods that are sent abroad for processing without a change in ownership, if the processing involves a “substantial” physical change in the goods (ISWGNA 1993, p.665). In practice, countries differ considerably in the application of these principles due to increasing problems in the definitions of ownership and “substantial” as global production networks expand. For some countries, official input-output tables only report the net effect of processing trade flows, excluding the associated gross trade flows. This circumvents the need to define ownership, but blurs the analytical usefulness of the table. To properly reflect the underlying technology all imports should be recorded under intermediate consumption by the processing country. We therefore followed the SNA 1993 recommendation and harmonised across countries by adding imports and exports of the processing industries back into the original SUTs (when the required additional information was available, like for the US and China). However, some inconsistencies across countries likely remain as statistical practices are unclear on this point. To improve international comparability, the new System of National Accounts (ISWGNA, 2010) does no



longer allow for exceptions to the ownership principle. While conceptually clear, it represents a financial perspective on trade and will obscure the actual flow of goods which is needed to study global production networks. To date, it is unclear whether countries will (be able to) carry out this recommendation.

*Profit recording and transfer pricing* Related to the services trade data problems described above is the problem of profit recording and the practice of transfer pricing. Originally, the main concern was about the misreporting of trade values, as firms used accounting prices for intra-firm flows of goods to benefit from cross-country differences in tax codes (Clausing, 2003). More recently, attention has shifted to the practice of profit shifting involving the implicit pricing of the use of intangibles such as brand names, trademarks, software and other knowledge systems by affiliates. The use of these intangibles is typically not compensated for by a direct money flow from the users. For example, the product case studies by Dedrick et al. (2010) suggest that the profits by lead firms are not made by charging other firms in the production chain for the use of intangibles, but by having the exclusive right to sell the particular product with a premium through its own, or otherwise tightly controlled, sales channels.<sup>16</sup> This is actually a broader conceptual issue with deep implications for measurement as one needs to trace where in the value chain profits are realised, and how these are recorded in the current statistical system. One particular example is the existence of so-called “factoryless goods producers” (FGPs). These are firms that are manufacturer-like in that they perform many of the tasks and activities found in manufacturing establishments, except for the actual production process. In the current US statistical system they are often classified in wholesaling, and their output is recorded as a wholesale margin, rather than as sales of manufactures (Bernard and Fort, 2013). Further research into how current statistical systems are dealing with different price concepts and the recording of profits should be high on the agenda.

*Domestic versus national income.* A final issue relates to the interpretation and attribution of value added. Input-output tables are constructed on the basis of the location principle rather than the ownership principle. As such, they are consistent with the concept of domestic product, but not with national income. The building of global value chains involves sizeable flows of foreign investment and part of the value added in plants in emerging regions will accrue as income to multinational firms headquartered in advanced regions. For example, it is likely that GVC income in East Asia would decline less than indicated in Figure 2, when returns to investment in China were accounted for on an ownership basis. To do so, data on foreign ownership is needed but this type of information is notoriously hard to acquire (Baldwin and Kimura, 1998; Lipsey 2010).<sup>17</sup> This difference between domestic and national income might also arise with regard to labour compensation, but this will be much smaller given the more elusory nature of profits.

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<sup>16</sup> This will show up as a difference between the final purchasers’ and ex-factory basic prices of the product. The latter price concept includes trade and transport margins. The WIOD provides national tables using both price concepts.

<sup>17</sup> To establish the full link from production value added to factor incomes and finally to personal income distributions, one would additionally need data on the actual ownership of firms.

#### 4. Future developments

Global input-output tables have become an important data source for research in various fields of economics, including international trade, economic growth and (international) macro, in particular when used in conjunction with analytical tools developed in input-output economics. Since April 2012, the World Input-Output Database (WIOD) provides an open-access platform for this type of analysis and its uptake in the profession has been quick, as illustrated in this paper. The database is meant to be a dynamic resource and various extensions are currently being undertaken. Besides additional socio-economic data described here, the WIOD also contains so-called environmental accounts providing data on energy use, carbon dioxide emissions and other polluting emissions to air at similar industry and country detail. This has spawned a stream of studies on the ecological consequences of trade including carbon foot printing and energy use (see e.g. Voigt, De Cian, Schymura and Verdolini, 2014).

Currently, activities are underway to provide constant-price input-output tables to allow for analyses based on changes in volumes alongside values. This is needed in for example estimates of substitution across inputs and rates of technological change, both in econometric studies as well as in growth accounting analysis (e.g. the seminal study by Jorgenson, Gollop and Fraumeni, 1987). To allow for comparisons of volumes across countries, relative prices of output and inputs have been developed (Inklaar and Timmer, 2012). In addition, the WIOTs will be backdated to 1970 to allow for a longer time-perspective. International fragmentation of production is not a recent phenomenon as suggested by increasing trade in intermediates in the 1970s and 1980s (Johnson and Noguera 2012b). Likely this cross-country fragmentation is much more regional in nature than the current globalisation trend, but firm evidence is lacking so far.

Another line of development is to focus on subnational fragmentation processes through the development of input-output tables in which the geographical units are regions rather than countries. In many countries, some regions perform much better in an economic sense than others. Stimulation policies targeted at weaker regions should not consider these in isolation, but within a broader network of interregional and global value chains. One of the major challenges in constructing such tables is the modelling of interregional trade flows using information from transportation surveys or estimation of gravity equations. Regional production accounts can also be used to analyse differences in regional specialisation patterns.

We also expect much additional insights by delving more deeply into the nature of jobs. With fragmentation, the task-content of jobs is changing. Countries are likely to specialize in particular tasks and activities in production chains. This is only roughly captured by analysing demand for workers characterised by educational attainment levels. In particular, it has been often suggested that advanced nations specialise in pre- and post-production activities (such as R&D, design, marketing and after-sales services) thereby becoming “headquarter economies”. We currently develop panel data on the occupational structure of the workforce in various countries that, in combination with the WIOTs, could be used to substantiate these claims.

Ideally, the future development of international input-output tables should be shouldered by its incorporation in regular statistical programs. Given the international nature of these tables, the most viable option is through coordination by international agencies. Therefore we welcome the current OECD-WTO initiative in taking this work forward in the international statistical community (OECD and WTO, 2013). We hope that it will also make the underlying sources and

materials of its current Database on Trade in Value-Added public, which will allow researchers to make full use of the available data. With WIOD we hope to have shown that the benefit to economists and the research community at large can be substantial.

## References

- Acemoglu, D., V.M. Carvalho, A. Ozdaglar and A. Tahbaz-Salehi (2012), "The Network Origins of Aggregate Fluctuations," *Econometrica*, vol. 80(5), pp. 1977-2016.
- Ali-Yrkkö, J., P. Rouvinen, T. Seppälä and P. Ylä-Anttila (2011), *Who Captures Value in Global Supply Chains?*, ETLA Discussion Papers, No 1240, ETLA: Helsinki.
- Andrew, R. and G. Peters (2013), "A Multi-region Input-Output Table Based on the Global Trade Analysis Project Database (GTAP MRIO)", *Economic Systems Research*, vol. 25(1), pp.99-121.
- Antràs, P., D. Chor, T. Fally and R. Hillberry (2012). "Measuring the upstreamness of production and trade flows", *American Economic Review*, vol 102(5), pp. 412-16.
- Baldwin, R.E. and J. Lopez Gonzalez (2013), "Supply-Chain Trade: A Portrait of Global Patterns and Several Testable Hypotheses", NBER Working Paper 18957
- Baldwin, R.E. and S.J. Evenett (2012), "Value Creation and Trade in the 21<sup>st</sup> Century Manufacturing: What Policies for UK Manufacturing?", Chapter 4 in Greenaway (ed. 2012).
- Baldwin, R.E. and F. Kimura (1998), "Measuring U.S. International Goods and Services Transactions," in: R.E. Baldwin, R. E. Lipsey, and J.D. Richardson (eds), *Geography and Ownership as Bases for Economic Accounting*, NBER Chicago, pp. 49-80.
- Barro, R.J. and J-W Lee (2013), "A new data set of educational attainment in the world, 1950–2010", *Journal of Development Economics*, vol. 104, pp. 184-98.
- Bems, R., R.C. Johnson and K.-M. Yi (2011). "Vertical Linkages and the Collapse of Global Trade." *American Economic Review*, vol. 101(3), pp.308–12.
- Bernard, A.B. and T.C. Fort (2013), "Factoryless goods producers in the US", *NBER Working Paper* 19396.
- Chen, X. L.K. Cheng, K.C. Fung, L.J. Lau, Y.-W. Sung, K. Zhu, C. Yang, J. Pei, Y. Duan (2012), "Domestic value added and employment generated by Chinese exports: A quantitative estimation", *China Economic Review*, vol. 23(2), pp. 850-64.
- Clausing, K. A. (2003), "Tax-motivated transfer pricing and US intrafirm trade prices", *Journal of Public Economics*, Vol.87(9–10), pp. 2207-23.
- Corrado, C., J.Haskel, C.Jona-Lasinio and M. Iommi, (2012), "Intangible Capital and Growth in Advanced Economies: Measurement Methods and Comparative Results" Working Paper, June, available at <http://www.intan-invest.net>.
- Costinot, A. and A. Rodriguez-Clare (2013), "Trade Theory with Numbers: Quantifying the Consequences of Globalization", *NBER Working Paper* No. 18896 .
- Christensen, L. R., D. W. Jorgenson and L.J. Lau (1971), "Conjugate Duality and the Transcendental Logarithmic Function", *Econometrica*, vol. 39, pp. 225-56.

- Dedrick, J., K.L.Kraemer and G. Linden (2010), "Who Profits From Innovation in Global Value Chains? A Study of the iPod And Notebook PCs", *Industrial and Corporate Change*, vol. 19 (1), pp. 81-116.
- Dietzenbacher, E. and Romero, I. (2007), "Production chains in an interregional framework: identification by means of average propagation lengths". *International Regional Science Review*, vol. 30, pp.362-83.
- Dietzenbacher, E., B. Los, R. Stehrer, M. Timmer and G.J. de Vries (2013), "The Construction of World Input-Output Tables in the WIOD Project", *Economic Systems Research*, vol. 25, pp. 71-98.
- di Mauro, F., H. Plamper and R. Stehrer (2013), "Global Value Chains: A Case for Europe to Cheer Up", *Compnet Policy Brief 03/2013*, European Central Bank.
- European Commission, DG Enterprise and Industry (2013), *European Competitiveness Report 2012: Reaping the Benefits of Globalization*, Brussels.
- Feenstra, R.C. and G.H. Hanson (1999), "The Impact of Outsourcing and High-Technology Capital on Wages: Estimates for the U.S., 1979-1990," *Quarterly Journal of Economics*, vol. 114(3), pp. 907-40.
- Feenstra R.C. and J. Bradford Jensen (2012), "Evaluating Estimates of Materials Offshoring from U.S. Manufacturing," *NBER Working Papers 17916*, National Bureau of Economic Research, Inc.
- Feenstra, R. (2010) *Offshoring in the Global Economy: Microeconomic Structure and Macroeconomic Implications*, MIT Press
- Foster-McGregor, N., R. Stehrer and G.J. de Vries (2013), "Offshoring and the Skill Structure of Labour Demand", *Review of World Economics*, vol. 149, pp.631-62.
- Francois, J. and B. Hoekman (2010), "Services Trade and Policy", *Journal of Economic Literature*, vol. 48(3), pp. 642-92.
- Gollin, D. (2002), "Getting Income Shares Right," *Journal of Political Economy*, vol. 110(2), pp. 458-74.
- Goos, M., A. Manning and A. Salomons (2011), "Explaining job polarization: the roles of technology, offshoring and institutions", mimeo, Katholieke Universiteit Leuven.
- Greenaway, D. (ed., 2012), *The UK in a Global World*, Centre for Economic Policy Research, London.
- Grossman, G. and E. Rossi-Hansberg (2008), "Trading Tasks: A Simple Theory of Offshoring," *American Economic Review*, vol. 98(5), pp. 1978-97.
- Herrendorf, B., R. Rogerson and A. Valentinyi (2013), "Two perspectives on preferences and structural transformation", *American Economic Review*, vol.103(7), pp. 2752-89.
- Hijzen, A., H. Görg and R.C. Hine (2005), "International Outsourcing and the Skill Structure of Labour Demand in the United Kingdom," *Economic Journal*, vol. 115(506), pp. 860-78.
- Hummels, D., J. Ishii and K-M. Yi (2001), "The nature and growth of vertical specialization in world trade," *Journal of International Economics*, vol. 54(1), pp. 75-96.
- Inklaar R. and M.P. Timmer (2012), "The Relative Price of Services", *Review of Income and Wealth*, published on-line.
- ISWGNA (1993), *System of National Accounts 1993*, Brussels/Luxembourg, New York, Paris, Washington, D.C..

- ISWGNA (2010), *System of National Accounts 2008*, United Nations, Department of Economic and Social Affairs.
- Johnson, R. C. and G. Noguera (2012a), “Accounting for Intermediates: Production Sharing and Trade in Value Added”, *Journal of International Economics*, vol. 86(2), pp. 224-36.
- Johnson, R. C., and G. Noguera (2012b), “Fragmentation and Trade in Value Added over Four Decades.” NBER Working Paper 18186
- Jones, C. (2011), "Intermediate Goods and Weak Links in the Theory of Economic Development" *American Economic Journal: Macroeconomics*, vol. 3(2), pp. 1-28.
- Jorgenson, D.W., F.M. Gollop and B. M. Fraumeni (1987), *Productivity and U.S. economic growth*, Harvard University Press.
- Koopman, R., Z. Wang, and S-J. Wei (2012), “How Much of Chinese Exports Is Really Made in China? Assessing Foreign and Domestic Value-Added in Gross Exports”, *Journal of Development Economics*, vol. 99(1), pp. 178-89.
- Koopman, R., Z. Wang, and S.-J. Wei (2013), “Tracing Value-Added and Double Counting in Gross Exports”. *American Economic Review*, forthcoming.
- Leontief, W. (1949), “Structural matrices of national economies”, *Econometrica*, vol. 17, pp.273–82.
- Lenzen, M., D.Moran, K.Kanemoto and A. Geschke (2013), “Building Eora: A Multi-Region Input-Output Database at High Country and Sector Resolution”, *Economic Systems Research*, vol. 25(1), pp. 20-49.
- Lipsey, R.E. (2010), "Measuring The Location of Production in a World of Intangible Productive Assets, FDI and Intrafirm Trade", *Review of Income and Wealth*, vol. 56(s1), p.S99-S110.
- Los, B., M.P. Timmer and G.J. de Vries (2013), “Globalization or Regionalization? A New Approach to Measure International Fragmentation of Value Chains”, GGDC Research Memorandum 138.
- Marin, D. (2011), “The Opening Up of Eastern Europe at 20: Jobs, Skills, and ‘Reverse Maquiladoras’ in: M. Jovanovic (Ed.), *Handbook of International Economics*, Vol. 2, Edward Elgar.
- Meng, B. Y.Zhang and S. Inomata (2013), “Compilation and Applications of IDE-JETRO’s International Input-Output Tables”, *Economic Systems Research*, vol. 25(1), pp.122-42.
- Michaels, G., A. Natraj and J. Van Reenen (2013), “Has ICT polarized skill demand?: evidence from eleven countries over 25 Years”, *Review of Economics and Statistics*, Online. 1-63.
- Miller, R.E. and P.D. Blair (2009), *Input-output Analysis: Foundations and Extensions*, Cambridge University Press.
- OECD and WTO (2013), “Trade in Value Added: Concepts, Methodologies and Challenges”, Joint OECD-WTO note, available at <http://www.oecd.org/sti/ind/statisticalqualityoftiva.htm>
- O’Mahony, M. and M.P. Timmer (2009), “Output, Input and Productivity Measures at the Industry Level: the EU KLEMS Database” *Economic Journal*, vol. 119(538), pp. F374-F403.
- Saito, M., M. Ruta and J. Turunen (2013), "Trade Interconnectedness: The World with Global Value Chains", *IMF Policy Paper*, August 2013
- Streicher, G. and R. Stehrer (2013), “Whither Panama? Constructing a consistent and balanced world SUT system including international trade and transport margins”, *WIOD Working Paper* No. 13.

- Schwörer, T. (2013), "Offshoring, Domestic Outsourcing and Productivity: Evidence for a Number of European Countries", *Review of World Economics*, vol. 149, pp. 131-49.
- Timmer, M.P., B. Los, R. Stehrer and G. J. de Vries (2013), "Fragmentation, Incomes and Jobs. An Analysis of European Competitiveness", *Economic Policy*, vol. 28(76), pp. 613-61.
- Trefler, D. and S. C. Zhu (2010), "The Structure of Factor Content Predictions", *Journal of International Economics*, Volume 82(2), pp. 195-207.
- Tukker, A. and Dietzenbacher, E. (2013), "Global multiregional input-output frameworks: an introduction and outlook", *Economic Systems Research*, vol. 25(1), pp. 1-19.
- Temurshoev, U, and M.P. Timmer (2011), "Joint estimation of supply and use tables", *Papers in Regional Science*, vol. 90 (4), pp. 863-82.
- Voigt, S., E. De Cian, M. Schymura and E. Verdolini (2014), "Energy intensity developments in 40 major economies: Structural change or technology improvement?", *Energy Economics*, vol.41, pp. 47-62.

**Figure 1 Schematic outline of Input-Output Tables**

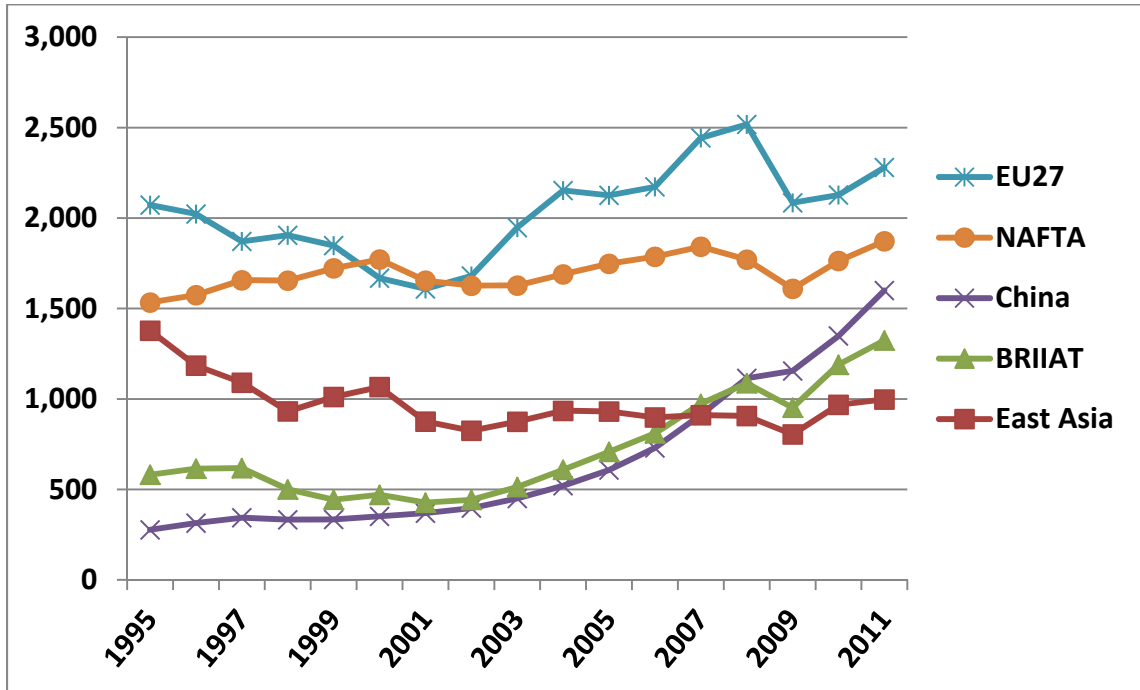
**A. National Input-Output Table**

|              | Industry                          | Final use          |         | Use       | Supply          |         |
|--------------|-----------------------------------|--------------------|---------|-----------|-----------------|---------|
| Industry     | Intermediate use                  | Domestic final use | Exports | Total use | Domestic supply | Imports |
|              | Value added by labour and capital |                    |         |           |                 |         |
| Gross output |                                   |                    |         |           |                 |         |

**B. World Input-Output Table (WIOT), three regions**

|                    | Country A Industry                       | Country B Industry                       | Country C Industry                       | Country A                         | Country B                         | Country C                         | Total       |
|--------------------|--|--|--|-----------------------------------|-----------------------------------|-----------------------------------|-------------|
| Country A Industry | Intermediate use by A of domestic output | Intermediate use by B of exports from A  | Intermediate use by C of exports from A  | Final use by A of domestic output | Final use by B of exports from A  | Final use by C of exports from A  | Output in A |
| Country B Industry | Intermediate use by A of exports from B  | Intermediate use by B of domestic output | Intermediate use by C of exports from B  | Final use by A of exports from B  | Final use by B of domestic output | Final use by C of exports from B  | Output in B |
| Country C Industry | Intermediate use by A of exports from C  | Intermediate use by B of exports from C  | Intermediate use by C of domestic output | Final use by A of exports from C  | Final use by B of exports from C  | Final use by C of domestic output | Output in C |
|                    | Value added by labour and capital in A   | Value added by labour and capital in B   | Value added by labour and capital in C   |                                   |                                   |                                   |             |
|                    | Output in A                              | Output in B                              | Output in C                              |                                   |                                   |                                   |             |

**Figure 2 Value added contribution to global value chains of manufactures**



Note: Value added (in billion US\$) by regions in the production process of final manufacturing goods worldwide. East Asia includes Japan, South Korea and Taiwan. BRIIAT includes Brazil, Russia, India, Indonesia, Australia, and Turkey. EU27 includes all European countries that have joined the European Union. NAFTA includes Canada, Mexico and the US. The value added is in US\$ and in constant prices of 1995, using the US CPI as deflator.

Source: Authors' calculations based on World Input-Output Database, November 2013, following Timmer, Erumban, Los, Stehrer and de Vries (2013)



**Table 1 Illustrative example of global value chain decomposition: German car manufacturing.**

|                              | Value added shares (%) |       | Number of workers (thousands) |       |
|------------------------------|------------------------|-------|-------------------------------|-------|
|                              | 1995                   | 2008  | 1995                          | 2008  |
| Domestic, <i>of which</i>    | 78.9                   | 66.0  | 1,336                         | 1,694 |
| Transport manufacturing      | 40.2                   | 29.8  | 611                           | 633   |
| Other manufacturing          | 12.7                   | 8.5   | 253                           | 223   |
| Non-manufacturing industries | 26.0                   | 27.8  | 472                           | 839   |
| Foreign                      | 21.1                   | 34.0  | 1,308                         | 2,809 |
| Total                        | 100.0                  | 100.0 | 2,644                         | 4,504 |

*Notes:* Left-hand side columns provide a decomposition of the value of final products from the German transport equipment industry (ISIC rev. 3 industries 34 and 35) into the value added in German transport equipment industry itself, other German manufacturing industries, all German non-manufacturing industries and in foreign industries. Right-hand side columns show the number of workers directly and indirectly involved in production of these products, decomposed into the same set of industries. Numbers may not sum due to rounding.

*Source:* Authors' calculations based on World Input-Output Database, November 2013 release.

**Table 2 Domestic, regional and global value added shares in output of final manufactures by country**

|                | Value added shares in 2008<br>(%) |               |        | Value added shares in 2008<br>minus shares in 1995<br>(%-points) |               |        |
|----------------|-----------------------------------|---------------|--------|--|---------------|--------|
|                | Domes-<br>tic                     | Re-<br>gional | Global | Domes-<br>tic  | Re-<br>gional | Global |
| United States  | 79.8                              | 4.2           | 16.0   | -8.0   | 1.8           | 6.2    |
| Japan          | 80.7                              | 2.9           | 16.4   | -12.8  | 1.9           | 10.9   |
| China          | 79.2                              | 4.9           | 15.9   | -6.2   | -1.0          | 7.2    |
| Germany        | 69.9                              | 14.4          | 15.7   | -12.1  | 4.4           | 7.7    |
| France         | 68.8                              | 14.8          | 16.4   | -9.5   | 1.8           | 7.7    |
| United Kingdom | 73.8                              | 12.2          | 14.0   | -4.3   | 0.2           | 4.1    |
| Italy          | 72.1                              | 11.5          | 16.4   | -7.4   | 0.0           | 7.4    |
| Spain          | 67.6                              | 15.0          | 17.4   | -10.3  | 1.7           | 8.6    |
| Netherlands    | 54.3                              | 18.9          | 26.8   | -9.5   | -0.6          | 10.1   |
| Poland         | 66.5                              | 18.0          | 15.5   | -15.4  | 6.3           | 9.1    |
| Hungary        | 46.1                              | 31.6          | 22.3   | -20.1  | 11.6          | 8.5    |
| Czech Republic | 50.7                              | 28.5          | 20.8   | -15.7  | 5.8           | 9.9    |

*Notes:* Domestic, regional and global value added shares in final output of 14 manufacturing product groups by country-of-completion. Shares are weighted with final output for each product group. Regional value added includes value added by countries in the region to which the country-of-completion belongs (European Union, NAFTA or East Asia), but excludes value added in the country-of-completion itself. Global value added is the value added by all countries outside this region. By definition, domestic, regional and global shares add up to 100 per cent.

*Source:* Authors' calculations based on the World Input-Output Database, November 2013 release, following Los, Timmer and de Vries (2013).

**Table 3 Workers involved in global value chains of manufactures****(A) Workers by sector (in thousands)**

|                | 2008   | Change between 1995 and 2008 |                   |              |                |
|----------------|--------|------------------------------|-------------------|--------------|----------------|
|                |        | Agricu<br>lture              | Manufa<br>cturing | Servic<br>es | All<br>sectors |
| United States  | 16,872 | -331                         | -3,144            | -1,138       | -4,612         |
| Japan          | 12,207 | -794                         | -2,225            | 148          | -2,871         |
| Germany        | 10,647 | -161                         | -666              | 1,388        | 561            |
| France         | 4,853  | -96                          | -423              | 368          | -151           |
| United Kingdom | 3,992  | -128                         | -1,148            | -347         | -1,624         |
| Italy          | 6,444  | -192                         | -234              | 517          | 91             |
| Spain          | 3,592  | -97                          | 185               | 353          | 440            |
| Netherlands    | 1,661  | -42                          | -87               | 158          | 29             |

**(B) Workers by skill type (change between 1995 and 2008, in thousands)**

|                | Low<br>skilled | Medium<br>skilled | High<br>skilled | All    |
|----------------|----------------|-------------------|-----------------|--------|
| United States  | -1,125         | -3,286            | -201            | -4,612 |
| Japan          | -1,834         | -1,399            | 361             | -2,871 |
| Germany        | -168           | 115               | 614             | 561    |
| France         | -768           | 52                | 566             | -151   |
| United Kingdom | -1,236         | -560              | 172             | -1,624 |
| Italy          | -1,201         | 853               | 439             | 91     |
| Spain          | -507           | 391               | 556             | 440    |
| Netherlands    | -119           | -54               | 202             | 29     |

*Notes:* Number of workers (including employees and self-employed) directly and indirectly involved in the production of final manufacturing goods. The upper panel shows the distribution of workers across the sector of employment in 2008 and the change during 1995-2008. The lower panel splits the latter into change in the number of high-skilled workers, medium- and low-skilled workers based on educational attainment. Numbers may not sum due to rounding.

*Source:* Authors' calculations based on World Input-Output Database, November 2013 release, following Timmer, Los, Stehrer and de Vries (2013).

**Appendix Table 1 Countries in WIOD and years for which benchmark table was used.**

| <b>Country</b>  | <b>Benchmark years</b> |
|-----------------|------------------------|
| Australia       | 1996, 2003, 2004       |
| Austria         | 1995, 1997, 1999-2007  |
| Belgium         | 1995, 1997, 1999-2007  |
| Brazil          | 2000-2008              |
| Bulgaria        | 2000-2004              |
| Canada          | 1997-2006              |
| China           | 1997, 2002, 2007       |
| Cyprus          | 2001 (based on Greece) |
| Czech Republic  | 1995-2007              |
| Denmark         | 1996, 1999-2007        |
| Estonia         | 1997, 1999-2007        |
| Finland         | 1995-2007              |
| France          | 1995, 1997-2007        |
| Germany         | 1995, 1997-2007        |
| Greece          | 2000-2009              |
| Hungary         | 1998, 1999, 2002-2007  |
| India           | 1998, 2003, 2006       |
| Indonesia*      | 1995, 2000, 2005       |
| Ireland         | 2001-2007              |
| Italy           | 1995-2007              |
| Japan*          | 1995-2007              |
| South Korea*    | 1995, 2000, 2005       |
| Latvia          | 1996, 1998             |
| Lithuania       | 1996, 1998, 2003-2005  |
| Luxembourg      | 1995-2006              |
| Malta           | 2000, 2001             |
| Mexico          | 2003                   |
| Netherlands     | 1995-2007              |
| Poland          | 1996-2007              |
| Portugal        | 1995-2006              |
| Romania         | 2000, 2003-2006        |
| Russia          | 1995                   |
| Slovak Republic | 1995-2007              |
| Slovenia        | 2000-2007              |
| Spain           | 1995-2007              |
| Sweden          | 1995-2007              |
| Taiwan*         | 1996, 2001, 2006       |
| Turkey          | 1996, 1998, 2002       |
| United Kingdom  | 1995-2008              |
| United States   | 1998-2010              |

*Note:* \* For Indonesia, Japan, South Korea and Taiwan only national input-output tables are available from the statistical offices. These have been separated into a supply and use table using additional data on secondary production structures.

**Appendix Table 2 Industries in WIOT**

| ISIC rev.3 code | Industry name  |
|-----------------|--|
| AtB             | Agriculture, Hunting, Forestry and Fishing                             |
| C               | Mining and Quarrying   |
| 15t16           | Food, Beverages and Tobacco  |
| 17t18           | Textiles and Textile Products  |
| 19              | Leather, Leather Products and Footwear                                 |
| 20              | Wood and Products of Wood and Cork                                     |
| 21t22           | Pulp, Paper, Printing and Publishing                                   |
| 23              | Coke, Refined Petroleum and Nuclear Fuel                               |
| 24              | Chemicals and Chemical Products  |
| 25              | Rubber and Plastics  |
| 26              | Other Non-Metallic Mineral   |
| 27t28           | Basic Metals and Fabricated Metal                                      |
| 29              | Machinery, Not elsewhere classified                                    |
| 30t33           | Electrical and Optical Equipment                                       |
| 34t35           | Transport Equipment  |
| 36t37           | Manufacturing, Not elsewhere classified; Recycling                     |
| E               | Electricity, Gas and Water Supply                                      |
| F               | Construction   |
| 50              | Sale and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel |
| 51              | Wholesale Trade, Except of Motor Vehicles and Motorcycles              |
| 52              | Retail Trade and Repair, Except of Motor Vehicles and Motorcycles;     |
| H               | Hotels and Restaurants   |
| 60              | Inland Transport   |
| 61              | Water Transport  |
| 62              | Air Transport  |
| 63              | Other Supporting Transport Activities                                  |
| 64              | Post and Telecommunications  |
| J               | Financial Intermediation   |
| 70              | Real Estate Activities   |
| 71t74           | Renting of Machinery & Equipment and Other Business Activities         |
| L               | Public Administration and Defence; Compulsory Social Security          |
| M               | Education  |
| N               | Health and Social Work   |
| O               | Other Community, Social and Personal Services                          |
| P               | Private Households with Employed Persons                               |

### Appendix Table 3 Additional columns and rows in WIOT

|  |
|--|
| <b>Final use columns (by country)</b>  |
| Final consumption expenditure by households  |
| Final consumption expenditure by non-profit organisations serving households (NPISH) |
| Final consumption expenditure by government  |
| Gross fixed capital formation  |
| Changes in inventories and valuables   |
| Total output (total)   |
|  |
| <b>Additional rows</b>   |
| Total intermediate consumption   |
| Taxes less subsidies on products   |
| Cif/ fob adjustments on exports  |
| Direct purchases abroad by residents   |
| Purchases on the domestic territory by non-residents                                 |
| Value added at basic prices  |
| International transport margins  |
| Output at basic prices   |

### Appendix A Participants in the WIOD project.

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