Draft, April 2012, submitted to the IIOA conference, Bratislava, Slovakia, June 24-29, 2012

Measuring the EU value added embodied in EU foreign exports by consolidating 27 national supply and use tables for 2000-2007

Maaike C. Bouwmeester[a*], Jan Oosterhaven[a], José M. Rueda-Cantuche[b]

[a] *University of Groningen, Faculty of Economics and Business, PO Box 800, 9700 AV Groningen, The Netherlands*
[b] *European Commission, Institute for Prospective Technological Studies, Inca Garcilaso 3, E 41092 Seville, Spain*

Abstract

This paper develops a method to consolidate national supply and use tables into a single supra-regional supply and use table (SUT). The method deals with mirror trade statistics problems, such as the different valuation of imports and exports, and it corrects for the double-counting of re-exports. To test the contribution of the various construction steps, the second part of the paper decomposes the EU value added that is embodied in the EU exports to third countries into seven components. When the national SUTs for the period 2000-2007 are used, neglecting intra-EU spillovers and feedbacks effects between the 27 EU-members results in an underestimation of the embodied value added of 12-15%. Not consolidating the national tables leads to a further underestimation of 11-16%. Both types of errors are not negligible and refer exclusively to a mismatch in the estimation of the intra-European spillover and feedback effects. With these underestimations removed, the EU27 exports to third countries still explains around 11% of the EU27 GDP.

[*] Corresponding author. University of Groningen, Faculty of Economics and Business, PO Box 800, 9700 AV Groningen, The Netherlands. Tel.: +31 50 363 7974; fax +31 50 363 7337.

E-mail addresses: m.c.bouwmeester@rug.nl, j.oosterhaven@rug.nl, jose.rueda-cantuche@ec.europa.eu

1. Introduction

The European Union (EU) acknowledges openness to trade as a core component of the renewed strategy for economic growth and job creation (Council of the European Union 2009, European Commission 2010a). Increasing the competitiveness of the EU in global markets is considered to be of key importance to a trade policy that fits EU's 2020 strategy (European Commission 2010b). The size and importance of the external market are emphasized in European Commission (2010b, p. 4): 'Our economy is the largest in the world. It is also the biggest exporter. Our firms exported € 1.6 trillion of goods and services in 2009, which is about 13 % of our GDP.'

Although the volume of EU's external trade is sizeable, assessing its importance as percentage of GDP is flawed. The comparison goes awry by relating trade flows, which are gross flows, to the value added of an economy, which is a net flow. Trade flows include flows of intermediate goods and services, whereas GDP explicitly excludes these. Intermediate goods and services account for as much as 61% to 63% of EU external imports over the years 2000 to 2007.[1] However, in policy analysis the use of trade/GDP ratios as measure of openness to trade (Roca Zamora, 2009) or as market integration indicator (Ilkovic, 2007) are still commonplace.

Recent literature has focused on measuring trade as a net flow by computing the value added content of trade (Belke and Wang 2006; Daudin *et al.* 2011)[2]. Johnson and Noguera (2012) show that across countries, value added exports are about 73% of gross exports with substantial variation between countries. The variation in the value added to gross trade (VAX) ratios is largely attributed to the variation in sector composition of exports. Countries that primarily export manufacturing products tend to have lower VAX ratios, which should have consequences for their score on openness to trade. Explicitly considering the inter-industry dimension of value added trade offers important insights in the overestimation of the importance of trade.

The increasing importance of decision making at a supra-regional level, like the European Union and the Euro-zone, underlines the need for model building at that same level. To enable such model building, consistent time series of consolidated national accounts are a *conditio sine qua non*. These times series need to be derived from supply and use tables (SUTs) in order to increase their empirical reliability, to secure their internal consistency, and to estimate interindustry models, such as input-output and general equilibrium models. The required set of supply, use and input-output tables covering a series of years and all EU Member States has been incomplete until recently. In addition, estimating intra-European impacts of external exports by means of the available, but unconsolidated national tables is not free from methodological problems, such as the different valuation of national domestic

[1] Derived from the input-output tables used in this paper, available via (last accessed 06-03-2012): http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/data/workbooks

[2] Recent working papers are: Koopman *et al*, 2008; Koopman *et al*, 2010, Foster *et al*, 2011.

use at basic prices and imports at c.i.f. prices, the double-counting of re-exports, and reporting errors.

Within this context, the first contribution of this paper is to develop a method for the consolidation of national SUTs into a single consolidated supra-regional SUT. The method will include a solution to the methodological issues outlined above.[3] The second contribution of this paper is an evaluation of the extent to which the use of existing national SUTs instead of the new consolidated EU27 SUT will underestimate EU value added embodied in extra-EU exports. In fact, the embodied value added proved to be underestimated by 25-30% over the period of 2000 to 2007, being they the intra-European spillover and intra-European feedback effects. Moreover, nearly half of these omitted effects will be ascribed to the lack of use of the new consolidated EU27 SUT.

The description of the consolidation process starts from a harmonized set of national SUTs in Section 3.[4] Before that, Section 2 discusses related research and earlier attempts to construct supra-regional SUTs and input-output tables (IOTs), in order to indicate what our methodology adds to the existing literature. In Section 3, we show how harmonized national SUTs can be consolidated into a single supra-regional SUT. A crucial element in our method is the re-pricing of the sum of the national import tables from the basic prices of the importing country into the basic prices of the exporting country (i.e. exclusive of all taxes, subsidies, and trade and transport margins). If this is not done properly, impact analyses of policy measures and scenario analyses will attribute all kinds of indirect effects to the wrong industries (i.e. to commodity producing industries instead of to trade and transport industries), and will not identify the impacts on taxes and subsidies. Besides, double-counting of re-exports and statistical discrepancies also play a role in miscalculating indirect effects, particularly with respect to intra-European trade. At the end of Section 3 it is indicated how the consolidated SUTs are transformed into consolidated IOTs, which are needed to formulate the input-output models used the next section.

Section 4 shows how the correct estimation of the interindustry impact of EU27 foreign exports on EU27 value added may be decomposed into: domestic impacts, first round intra-EU spillover effects, higher round intra-EU spillover and feedback effects, and four types of measurement errors (of the intra-EU spillover and feedback effects) that occur when national IOTs are used instead of the consolidated EU27 IOT. Section 5 then shows the actual empirical size of these three impacts and the four measurement errors for the period 2000-2007, both at the level of the 59 homogenous EU-branches and for the EU27 as a whole. It appears that not including the intra-EU spillovers and feedbacks leads to an aggregate underestimation of

[3] The result of the method is a set of annual consolidated supply, use and input-output tables for the EU27 for 2000-2007, published on the Eurostat website last May 2011. Technical documentation related to the dataset (Eurostat, 2011) is available at (last accessed: 30-01-2012):
http://epp.eurostat.ec.europa.eu/portal/pls/portal/!portal.wwpob_page.show?_docname=2530266.pdf

[4] To derive that set for the EU27, lacking SUT data needed to be estimated. See Rueda-Cantuche, Beutel, Neuwahl, Mongelli & Loeschel (2009) for an early account, and see Eurostat (2011) for the final details.

the embodied EU27 value added of 12-15%, while the four partly compensating measurement errors together lead to an additional aggregate underestimation of the intra-EU spillover and feedback effects of 11-16% over this period. Even with these underestimations corrected, EU27 external exports still explain only a little more than 11% of the EU27 gross value added or GDP. Section 6 concludes, inter alia, that strengthening the intra-European market (Single Market) may be worthwhile compared with policies oriented to increase the EU´s external competitiveness.

2. Data sources and literature overview

2.1 Data sources

For a correct consolidation of national SUTs into a single supra-regional SUT and IOT, a full set of national SUTs at basic prices is required.[5] These national SUTs need to include a distinction between intra-European and extra-European exports and imports. Such a database did not exist until recently. The annual national SUT and IOT database, generated jointly by Eurostat and the European Commission's Joint Research Centre (JRC) finds its first use in this paper. This database allows us to estimate both a consolidated EU27 and a consolidated Euro-area time series of SUTs and IOTs for the period 2000-2007. The authors participated actively and collaborated with Eurostat and the JRC, not only in estimating the missing national SUTs and IOTs, but also in developing the consolidation method described in this paper. The final database and the method of consolidation have been endorsed by a technical group of European National Statistical Offices and the European Central Bank for future internal use by Eurostat (see further Eurostat, 2011)[6].

2.2 Construction of IOTs

Input-output tables are usually derived from supply and use tables. Generally speaking, SUTs contain the output mix of industries and the industries' use of inputs, respectively. More precisely, the Supply table consists of a matrix of products produced by industries, plus additional rows comprising: imports, distribution margins (trade and transport), and taxes less subsidies on products. The Use table consists of a matrix with the use of intermediate products by domestic industries, and the use of consumption and investment products by households, governments and investing industries. Besides, there are additional columns with changes in stocks and exports, and additional rows with the various components of gross value added, such as labour costs, capital use, net taxes on production and net operating surplus. According to Eurostat (2008), such a rectangular SUT, with, for example, *m* industries

[5] For a detailed definition of basic prices, see Eurostat (2008, p. 163). Basically, basic prices refer to the valuation of goods and services before they are conveyed to markets.
[6] The IOT tables constructed with the method described in this paper can be downloaded from: http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/data/database.
The relevant metadata can be found at: http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/naio_esms.htm

and *n* products, represents the most appropriate framework for balancing the supply and demand of products, and to compile the Gross Domestic Product (GDP), because it is not based on analytical assumptions, but on statistical data.

Symmetric IOTs can be derived from SUTs by means of behavioural assumptions. Their dimension can be either product-by-product or industry-by-industry. Rueda-Cantuche (2011) discussed recently the pros and cons of the choice of dimension of IOTs. The fact that IOTs are square is crucial for input-output modelling, because that requires an homogenous representation of the relationships between either products or industries. Productivity, energy and environmental analyses are well-known examples of impact studies for which symmetric IOTs need to be constructed.

A rectangular SUT is transformed into a square IOT by adding assumptions about the technology with which products are produced (Eurostat, 2008). Basically, the choice of the type of IOT is related to the treatment of secondary outputs. Product-by-product IOTs can be derived by either assuming that similar products are produced with the same technology regardless of the industry that produces them (i.e. the product technology assumption) or by assuming that they are produced according to the technology of the industry that produces them (i.e. the industry technology assumption). Besides, there are other less usual assumptions possible (see ten Raa and Rueda-Cantuche, 2003, for an overview).

2.3 Construction of consolidated IOTs

There are essentially two approaches to construct an IOT for a group of countries. First, one may use a variant of what are known as *non-survey* methods. This type of method is generally used for a top-down estimation of a regional IOT from a national IOT (see Miller & Blair, 2009, for an overview). Only the subset of methods that uses one region´s or the nation´s IOT to estimate another region´s IOT (e.g. Hewings, 1977) is suited to estimate unknown supra-national IOTs. This approach requires that, for the target country, total output, value added, total use, and imports and exports are given by industry, along with at least the totals, but preferably the full columns of the various domestic final demand categories. These totals are then used to define the row and column constraints of the unknown inner part of the target IOT, while the IOT of another country is used as the base for the application of the RAS biproportional adaptation method (see Bacharach, 1970, for an extensive treatment, and see Lenzen *et al*. 2004, and Eder *et al*, 2006 for applications to the Rest of the World and the EU). Recently Minguez *et al*. (2009) developed a cell-correction to the RAS method (CRAS), which uses not a single IOT but multiple IOTs to improve the estimate of the target IOT (see Oosterhaven & Escobedo, 2011, for the first cross-region application).

In this paper, however, we apply a method that uses mainly *survey* data to estimate the target supra-national IOT. For such a method, there are essentially two alternative routes. The route followed in this paper involves the direct aggregation of the national IOTs and the intra-group imports and exports of the countries concerned. Remarkably, this route has hardly been chosen before, even though national IOTs are available for many countries.[7] In that sense this paper presents a new and more direct approach. The second route involves the estimation of a full international IOT, which is then aggregated to the required supra-regional group of countries. This approach requires more work, but also generates more information, while it offers the possibility of a flexibly spatial aggregation into a series of supra-regional groupings of countries. Due to the heavy data requirements, databases that allow for the second route are not widely available, and most are in fact still being developed.

All earlier work relates to the direct *bottom-up* construction of a supra-regional IOT from national IOTs. Nowadays, however, practically all IOTs are constructed from SUTs (Eurostat, 2008; European Commission et al. 2009). Hence, this will most certainly also hold for the future construction of an IOT for a supra-regional group of countries. Only recently, a start has been made with the construction of international IOTs from international SUTs, due to two large EU-financed research projects, namely EXIOPOL (see Tukker *et al*. 2009) and WIOD (see Erumban *et al*. 2011). In that sense, this paper also presents a new approach, as we derive a consolidated group SUT directly from national SUTs. Only as a very last step, for modelling purposes, a consolidated group IOT is derived from the consolidated group SUT.

The first international IOTs were constructed for the much smaller old EU, directly from the national IOTs for 1959, 1965, 1970 and 1975 (Schilderinck, 1984). The harmonized IOTs of the individual countries for those years already had a split up of the matrix with foreign imports, into a matrix with intra-EU imports and one with extra-EU imports, as well as a comparable split-up of the column with foreign exports. The essence of the construction method consisted of further splitting up the national intra-EU import matrices by country of origin. This was done by means of row-wise uniform national import ratios, which were derived from international import statistics.[8] The resulting full matrix with bilateral trade flows was disaggregated by sector and country of origin (over the rows), and by sector, domestic final demand category and country of destination (over the columns). The rows of these bilateral import matrices implicitly represent exports as they show all sectoral and geographic destinations of industry output. The difference between the overall row sums of the bilateral import matrices and the actual intra-EU export columns was assigned to a column with so-called "expenditure balances".

[7] See Ungar & Heuschling (1994) for the construction of an EU12 IOT for 1991 based on 1985 national tables, Brockmeier (1997) for an EU12 IOT for 1992, Van Leeuwen & Verhoog (1999) for an EU15 IOT for 1993 and Van Leeuwen (2002) for an EU15 IOT for 1995. The documentation of the construction of these tables is, however, rather scanty. More recently, Rueda-Cantuche et al. (2009) constructed an EU27 IOT for 2000.

[8] The use of row-wise uniform ratios has been termed the 'proportionality assumption' in recent literature, following Trefler and Zhu (2010). It signifies the implicit assumption that each industry uses a particular imported product in the same proportion, which is given by total imports of the product over its total use. This assumption is often used to separate out imported goods and services from domestically produced goods and services. National Statistical Institutes, for example, obtain import matrices by applying it at very detailed levels of data. In order to construct international IOTs the assumption was refined to obtain bilateral trade matrices.

This procedure is statistically clear, but economically unsatisfactory, as the off-diagonal submatrices with the bilateral trade flows were measured in ex customs' import prices, whereas the domestic transaction submatrices on the diagonal of the IO checkerboard were measured in producer prices. Moreover, intra-EU export matrices were estimated by means of the import data of the receiving country, without taking the size and composition of their own intra-EU export data in to account. Finally, double counting intra-EU re-exports was not corrected for. Most likely for these reasons, the resulting "expenditure balances" were as large as 11.5% for manufacturing, 21.5% for fuel and power and even 40% for agriculture (see Oosterhaven, 1995). The current WIOD project partly follows the same procedure in constructing a time series of intercountry SUTs for 1995-2009 with 40 countries, but it combines its equivalent of Schilderinck's "expenditure balances" with the exports to their small Rest of the World (sRoW). Given the nature of this procedure and the smallness of their sRoW, some of these export flows may easily turn out to be negative for some products.

Van der Linden and Oosterhaven (1995) re-estimated Schilderinck's intercountry EU-IOTs for 1965-1975, and elongated the series for 1975-1985. They rearranged the re-export flows to avoid double counting, and used RAS to re-price and balance the bilateral intra-EU import tables with the rescaled intra-EU export columns of the countries at hand. The difference between the original intra-EU exports and its rescaled equivalent was put in a "rescaling column" that amounted to only 1% of the original intra-EU exports value.

The second major effort to construct intercountry IOTs is the Asian Input-Output Table (AIOT) project (IDE, 2006; Inomata et al. 2006). The AIOTs combine nine Asian countries and the USA, and are constructed with five year intervals for 1985-2000. The harmonization of the ten national IOTs is the most complicated part of the construction of the AIOTs. The rest of the construction, in essence, follows the EU-method, while incorporating additional information from two extensive surveys. The first collects data on the domestic distribution of foreign imports over intermediate and final demand. The use of uniform foreign import ratios and uniform self-sufficiency ratios along the rows of the IOTs can thus be avoided. This would otherwise have been necessary, as all ten original national IOTs are inclusive of foreign imports.

The second survey collects national data on international trade and transport margins. Lacking data are estimated with regression equations that are based on the available data. Besides, taxes are subtracted from the imports. Hence, opposed to the EU-approach, the AIOT-method does not use RAS to re-price the import matrices, but does so directly. Moreover, it rescales the bilateral imports to match the bilateral exports total, and combines the rescaling difference with the imports from third, non-AIOT countries, which has the disadvantage of possibly distorting the IO column coefficients.

Some evidence is reported in the literature that international IOTs obtained by applying the proportionality assumption may strongly deviate from results obtained when using survey data. Oosterhaven, Stelder and Inomata (2008) compare the survey AIOT for 2000 with the outcomes of four simple, less time-consuming, semi-survey methods. All four methods report differences in the intercountry trade flows of 10-50% compared to the semi-survey AIOT for 2000. Using increasingly more information from the export statistics reduces the differences, but not systematically for each and every country. The second method and the AIOT data situation closely resemble the method of Van der Linden and Oosterhaven (1995). Puzzello (2011) finds that using the proportionality assumption results in countries being more intensive in their own factors. However, the net effect from combining biases in exported and imported factor content is reported to be small. Koopman *et al.* (2010) show that the assumption may overestimate the share of intermediate goods in imports of developed countries, whereas it underestimates the proportion of final goods in exports of many developing countries.

Most contributions to the recent literature on factor content of trade and value added trade construct an international IOT starting from the GTAP database[9]. The core of the GTAP construction process is the FIT program, which uses entropy methods to update and create the database. It enforces consistency among the IOTs, trade, protection, macro and energy data.[10] The GTAP database includes total import matrices, and consistent international trade data, but not bilateral trade matrices. Trefler and Zhu (2010) and Johnson and Noguera (2012) both use the proportionality assumption to derive the bilateral trade matrices.

The method described in this paper differs from the international IOT methods in several ways. Our method is based on a different organization of the data as we use SUTs instead of to IOTs and only derive a consolidated IOT after constructing the consolidated SUT. Full information on intra-EU and extra-EU imports[11] is used, but at the aggregate EU level and not at the national level. Our focus on the supra-national level allows us to correct the data for re-export flows without making assumptions about the intra-EU geographical distribution of the re-exports.

The above discussed international IOT construction procedures all aim to provide the data for the *ideal* interregional IOT and model (Isard, 1951). This so-called ideal, however, represents only one member of a whole family of possible multi-regional IOTs and models. As for multi-regional SUTs, there is also a whole family of possible accounting schemes with accompanying models (Oosterhaven, 1984).

The EXIOPOL project (Bouwmeester & Oosterhaven, 2009) and the WIOD project (Erumban *et al*. 2011) have chosen for the combination of a single intercountry Use table with a set of national Supply tables. From the single intercountry Use table one may derive a full intercountry **A**-matrix with intermediate input coefficients, while from the set of national Supply tables one may derive a single diagonal block matrix $\mathbf{S_b}$ with national industry shares in

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[9] The Global Trade Analysis Project (GTAP) is coordinated by the Center for Global Trade Analysis at Purdue University.
[10] www.gtap.org, last accessed 08-03-2012
[11] See Eurostat (2011) for the details on the construction of the missing intra-EU and extra-EU import matrices.

the domestic supply of each product on the diagonal blocks. Together, these two matrices enable the calculation of an intercountry Leontief-inverse, $\mathbf{L_{use}} = (\mathbf{I} - \mathbf{S_b}\ \mathbf{A})^{-1}$, with all its associated applications.

A second option would have been the combination of a set of national Use tables, all inclusive of foreign imports, with a single, full intercountry Supply table. This also delivers an intercountry Leontief-inverse, but in that case **A** is replaced by a diagonal block matrix $\mathbf{A_b}$ with national technical coefficients, while $\mathbf{S_b}$ is replaced by a full intercountry **S**-matrix with national industry supply shares in the total demand by product, by country. Hence, in that case the Leontief-inverse is calculated as: $\mathbf{L_{supply}} = (\mathbf{I} - \mathbf{S}\ \mathbf{A_b})^{-1}$.

In our case of constructing a consolidated SUT for a supra-regional group of countries, instead of an intercountry SUT, the choice between these two main alternatives is much less pressing. We could have chosen to construct two EU-supply tables, one with the supply of EU-industries to EU-product markets, and the second with the supply of EU-industries to the World outside the EU27 (eRoW). Combined with a single consolidated EU-use table, inclusive of imports from the eRoW, this delivers a regular Leontief-inverse $(\mathbf{I} - \mathbf{S}^{\mathbf{EU,EU}}\mathbf{A}^{\mathbf{EU}})^{-1}$, in which $\mathbf{S}^{\mathbf{EU,EU}}$ represents the EU-industry supply shares per EU-product market, with $\mathbf{i}'\mathbf{S}^{\mathbf{EU,EU}} + \mathbf{i}'\mathbf{S}^{\mathbf{eRoW,EU}} = \mathbf{i}'$, while $\mathbf{A}^{\mathbf{EU}}$ represents the matrix with the unit use of intermediate inputs from all over the world per EU-industry.

However, due to the registration of import duties, the split-up of the national Use tables into the use of EU-origin products and non-EU origin products, is to be considered more reliable, than the also possible split-up of the national Supply tables into sales to the EU-market and sales to non-EU markets. Hence, we have chosen to construct a consolidated EU-use table with two sub-tables, a first for the EU-use of EU-products and a second for the EU-use of non-EU products. To derive the consolidated IOT, we subsequently combine the first sub-table with the consolidated EU-supply table, with only one row with aggregate extra-EU imports,.

3. Consolidation of national SUTs into a supra-regional SUT

From the above overview, it follows that the core of the consolidation process requires the redefinition and re-estimation of the national intra-EU trade flows, as domestic transactions at the EU27 level. Therefore, a prerequisite for the consolidation procedure is the availability of an intra-EU import use matrix (separated from the extra-EU import matrix) and an intra-EU export column (separated from the extra-EU export column). The method developed in this paper presupposes the availability of 27 harmonized national SUTs, in which this distinction between intra-EU and extra-EU trade has been made.

The construction method for the consolidated EU27 SUT consists of three main steps, and seven sub-steps. First, the national use tables are aggregated into a *draft* EU27 use table, as shown in Figure 1. It consists of the simple sum of (1) all domestic use tables, (2) all intra-EU import tables, (3) all extra-EU import tables, each including all domestic final use categories, and (4) the simple sum of all intra-EU and extra-EU export columns, and re-exports columns.[12] Second, in a seven sub-steps procedure, the gray-marked intra-EU trade flows in Figure 1 are merged with the domestic intermediate and final use matrix to get the consolidated EU27 Use table. Third, the main, domestic part of the national Supply tables are simply aggregated to the domestic industry part of the consolidated EU27 Supply table, while the imports row of the consolidated EU27 equals the simple column-wise aggregation of the import matrix of the re-estimated extra-EU import use matrix. After this final step, the consolidated EU27 Supply-Use Table is transformed into the consolidated EU27 input-output table.

Figure 1: Scheme of the aggregated, draft Use table

Domestic intermediate use	**Domestic final use**	**1**	**2**
Intra-EU intermediate imports	**Intra-EU final imports**	**3**	**4**
Extra-EU intermediate imports	**Extra-EU final imports**	**5**	**6**
TLS	**TLS**	**7**	**8**

Legend for the columns in Figure 1

1: Exports to intra-EU countries

2: Exports to extra-EU countries

3: Re-exports, imported from intra-EU, exported to intra-EU

4: Re-exports, imported from intra-EU, exported to extra-EU

5: Re-exports, imported from extra-EU, exported to intra-EU

6: Re-exports, imported from extra-EU, exported to extra-EU

7: Taxes less subsidies on products (TLS) on intra-EU exports

8: Taxes less subsidies on products (TLS) on extra-EU exports

The first and the third step of the overall procedure only involve a simple aggregation, which requires no further discussion. The core of the overall construction method thus consists of the seven sub-steps needed to derive the consolidated EU27 use table from Figure 1. The main problem of the seven sub-steps is to balance the intra-EU import table with the information on intra-EU exports in column 1, as each trade flow is reported by two countries, which two values usually do not match. This problem is known as the *mirror trade statistics puzzle*. There is a series of factors explaining the puzzle, such as time lags between exports and imports, different statistical coverage and response rates, statistical confidentiality,

[12] The individual country SUTs and this aggregate draft use table have been prepared by Eurostat, the Joint Research Centre's Institute for Prospective Technologies (JRC-IPTS) and the Konstanz University of Applied Sciences (Eurostat, 2011).

different treatment of revisions, and currency conversion issues (see section 2.17 of Eurostat, 2006).

The economically most important explanation of the puzzle is the structural difference in the prices used: exporting countries usually report their exports in free-on-board prices, whereas importing countries usually report their imports in cost-insurance-freight prices (c.i.f.) (see section 2.13 of Eurostat, 2006). The difference between these two prices is made up of international trade and transport margins. In the free-on-board priced exports, the exported trade and transport services are recorded in the rows pertaining to the service sectors that produce them. In the cost-insurance-freight priced imports, however, the trade and transport margins used are included in the value of imported goods, which are produced by industries that are different from those that produce the trade and transport services.

In the aggregated draft EU27 use table exports are actually valued in basic prices. The difference between the exports in basic prices and the imports in c.i.f. prices consists of three valuation layers (see Table 1): (1) taxes less subsidies levied in the country of export, (2) trade and transport margins within the country of export, and (3) the international trade and transport margins discussed above.

Table 1: Valuation layers in international trade

Country	
R	**Exports by *R* in basic prices of *R***
R	+ Valuation layer: taxes and subsidies
R	+ Valuation layer: trade and transport
R	**= Exports by R in f.o.b. price of *R***
International	+ Valuation layer: international trade and transport margins
S	**= Imports by *S* in c.i.f. price of *S***
S	+ Valuation layer: taxes and subsidies
S	+ Valuation layer: trade and transport
S	**Imports by *S* in purchaser prices of *S***

In order to merge the intra-EU import use table with the domestic use table, both need to be valued in the same prices. Since all kind of applications require that employment, value added, and environmental impacts are allocated to the industries that actually produce the products traded, it is necessary to measure all transactions in *basic prices of the country of origin*. The domestic use table is already measured in basic prices, in contrast to the table with the aggregated intra-EU import use. Only the latter therefore needs to be re-priced into basic price of the exporting country. Fortunately, information on intra-EU exports in basic prices can be used to balance the intra-EU import table. This is the most important step in the seven sub-steps procedure that changes the draft EU-Use table shows in Figure 1 into the consolidated EU27 Use table. Table 2 gives an overview of all seven steps.

Table 2: Overview of steps taken to arrive at the consolidated EU-Use table

Step 1:	Adjust for taxes less subsidies on intra-EU imports (cell 7)
Step 2:	Correct trade flows imported from intra-EU, re-exported to intra-EU (column 3)
Step 3:	Correct trade flows imported from intra-EU, re-exported to extra-EU (column 4)
Step 4:	Correct trade flows imported from extra-EU, re-exported to intra-EU (column 5)
Step 5:	Re-scale all import values to the total of the intra-EU exports (column 1)
Step 6:	Balance the rescaled intra-EU import table with the intra-EU export vector, using GRAS
Step 7:	Aggregate the domestic and balanced intra-EU import table

Step 1: Adjust for taxes less subsidies on intra-EU imports

Since intra-EU imports are valued at c.i.f. prices of the importing country (see Table 1), they include, among others, the taxes less subsidies on products (TLS) associated with these transactions. The first step will be to reallocate (deduct) the amounts of TLS from the intra-EU import matrix. The total amount to be reallocated is given by cell 7 of Figure 1, which contains the taxes less subsidies linked to the same transactions, as reported by the exporting country. In order to do this, we proportionally distribute the value in cell 7 of Figure 1 over the values in the row identified by 'TLS', as indicated in Figure 1.

In other words, we reallocate the net taxes levied by exporting countries to the domestic industries and the domestic categories of final demand of the importing countries by means of the shares of taxes less subsidies paid by industries (intermediate uses), final consumption and gross capital formation. The changes in the TLS row represent an average increase of 0.38% over the period 2000-2007, whereas the changes in intra-EU import columns show an average decrease of 0.25%. At the end of this step, which is summarized in Figure 2, the intra-EU imports are adjusted to cost-insurance-prices, net of taxes less subsidies.

Step 2: Correct for double counting intra-EU trade flows that are re-exported within the EU

An example best clarifies how re-exports within the EU are double counted. Take Italian shoes that are re-exported by Austria to the Czech Republic. Clearly, this transaction will be reported in the Italian use table as an intra-EU export (column 1 in Figure 1), and by the Czech supply and use tables as an intra-EU import of final goods. Therefore, the transaction on re-exports reported by the Austrian tables is redundant (column 3 in Figure 1). Both the exporting country and the importing country record these trade flows in the correct way, so no adjustment has to be made. Maintaining the re-exports of Austria would result in double counting.[13] Therefore, the values in column 3 are simply deleted.

Figure 2: Step 1

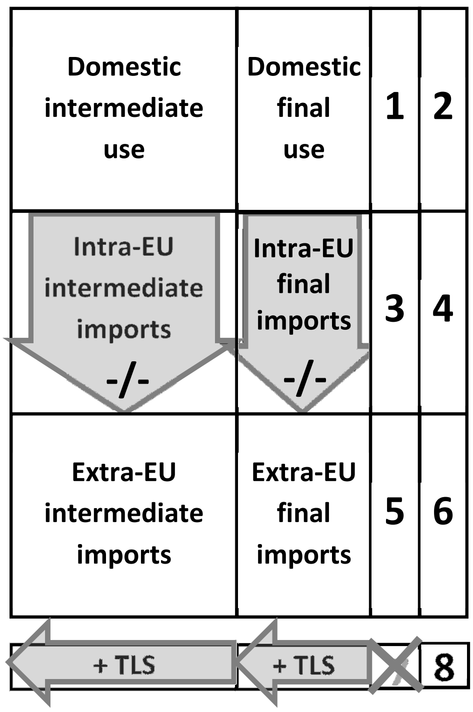
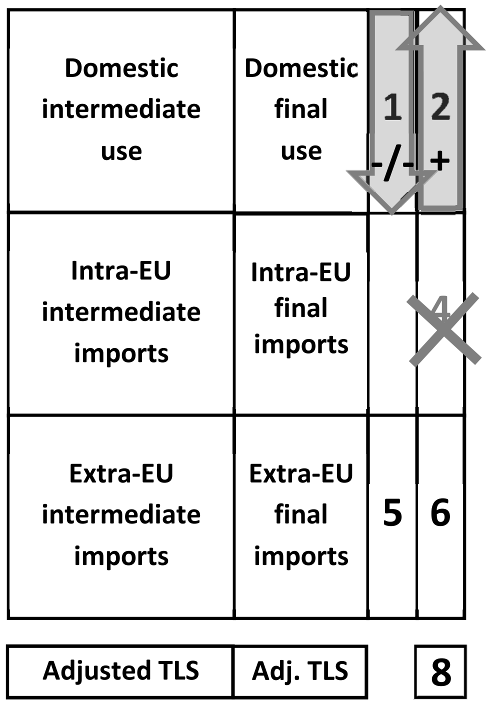


Figure 3: Step 3



Step 3: Correct for trade flows imported from within the EU and re-exported outside the EU

Next, assume that Austria re-exports the Italian shoes to Switzerland (outside the EU) instead of to the Czech Republic (inside the EU). Because Italy does not necessarily know what Austria is doing with its shoes, in this case, Italy wrongly records this transaction as an intra-EU export, while it should have been reported as an extra-EU export. When constructing an inter-country SUT the necessary correction cannot be made at the individual country level, because origin or destination of the re-exports is not recorded in the individual country SUT. At the level of a consolidated EU Use table, however, this correction can be made due to the differentiation between intra-EU re-exports and extra-EU re-exports. Column 4 of Figure 1 depicts precisely the goods and services that are imported from intra-EU countries and re-exported outside the EU. The values of column 4 are therefore subtracted from the column 1 with the intra-EU exports, and added to the column 2 with the extra-EU exports as indicated in Figure 3. This correction leads to a considerable average decrease of 7.6% in total intra-EU exports, along with an even larger average increase of 12.4% in total extra-EU exports over the period 2000-2007.

[13] By correcting for the re-exports as described in step 2, 3 and 4, it is assumed that re-exports are not again re-exported by the "final" importer.

Step 4: Correct for trade flows imported from outside the EU and re-exported within the EU

Next, consider the reverse case of the re-export of Swiss chocolate by Spain to Portugal. Portugal will wrongly record this transaction as an intra-EU import, since it does not necessarily knows that Spain has imported these goods from Switzerland. Spain will report this transaction in column 5 of Figure 1. The correction therefore entails reducing the reported imports from EU countries, and increasing the reported imports from countries outside the EU, as indicated in Figure 4. This is done by subtracting the values of column 5 proportionally, row-by-row, from the values of the intra-EU imports, and adding the subtracted values to the corresponding cells of the extra-EU import matrix. These changes lead to an average decrease of 11.6% in total intra-EU imports, and an average increase of as much as 17.4% in total extra-EU imports over the period 2000-2007.

Finally, as regards the re-exports, note that the re-export column 6 is maintained without any change in the consolidated table, as indicated in Figure 5. Both the original exporting country and the final importing country are non-EU countries. This combination is correct and does not require adjustments in the consolidated EU27 Use table.

Figure 4: Step 4

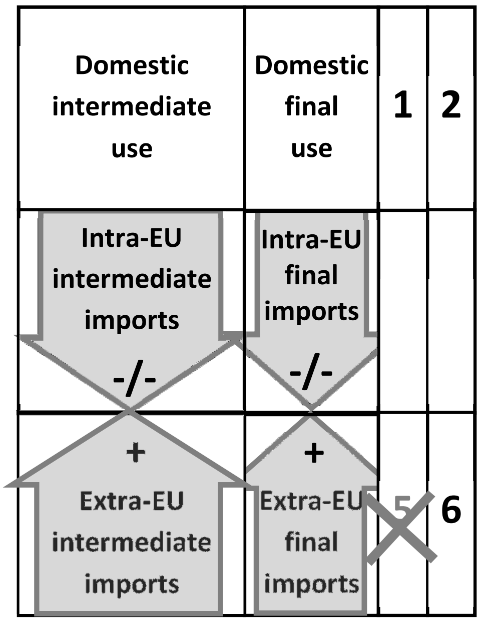
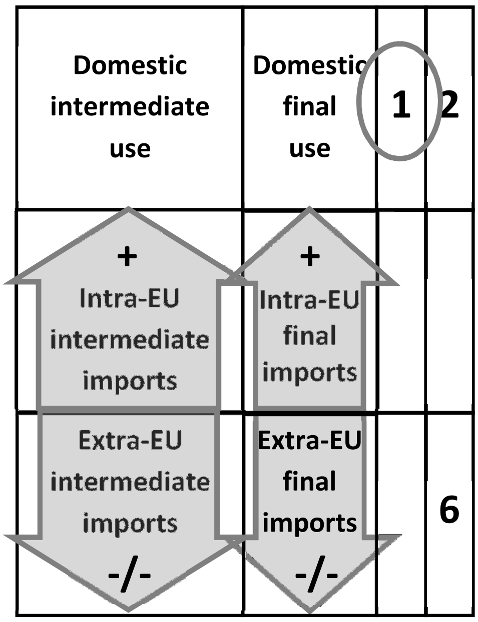


Figure 5: Step 5



Step 5: Rescale all intra-EU imports such that their total equals that of the intra-EU exports

After the above tax and the re-export corrections, each of the row sums of the intra-EU import table has to match the values reported in the adapted intra-EU export column 1. The actual matching is done in the next step, but to undertake this procedure successfully, it is required that the overall total of the intra-EU import table is equal to that of the adjusted intra-EU export column 1 in Figure 5. To achieve this, all cells in the intra-EU import table, i.e., both intermediate and domestic final demand, are rescaled by multiplying each cell with the sum of the adapted intra-EU export values and dividing it by the overall sum of the intra-EU import table, as indicated in Figure 5.

Theoretically, the rescaling factors reflect the share of trade and transport margins included in imported goods from country *r* by *s* that do not balance against the trade and transport margins recorded as exports of *r* to *s*. This discrepancy occurs when foreign carriers deliver another part of the trade and transport services. In practice, however, all factors identified to contribute to the *mirror trade statistics puzzle* may contribute to the difference in the total values of an import flow and the corresponding export flow.

The rescaling factor for the EU tables for 2000-2007 is on average 1.10, with all yearly values within a 0.02 maximum deviation from this value. Hence, the reported total intra-EU export value is about 10% higher than the total intra-EU import value reported. The up scaling of the intra-EU imports is offset by a, cell-by-cell absolutely equally large, down scaling of the extra-EU imports, as illustrated in Figure 5.

Step 6: Balancing the intra-EU import table with the intra-EU export column using GRAS

Next, the generalized RAS method of Junius & Oosterhaven (2003) is used to balance the intra-EU import totals by product, with the intra-EU exports by product. GRAS is a bi-proportional adjustment method very similar to RAS (Stone, 1961), with the difference that it can deal with negative values in the same fashion as with positive values. RAS and GRAS can be applied to any table for which an initial structure is given (or assumed), and new row and column totals are supplied, provided that the total of the row totals equals the total of the column totals. The method is fully mechanical, i.e. no ad hoc adjustments need to be made. Its solution is equivalent to adding minimum information to the table obtained after Step 5, such that it just satisfies the new totals. RAS has been widely used to update input-output tables (see Miller & Blair, 2009), but it can also be used to balance import matrices with given export totals, as done by Van der Linden & Oosterhaven (1995) and Oosterhaven et al. (2008).

By using the export values in basic prices as row constraint in the GRAS procedure, the trade and transport margins included in the c.i.f. priced import values are effectively redistributed to the rows with the corresponding services. In this way, the balanced intra-EU import use table is implicitly re-priced into basic prices. At the end of this step, the adapted intra-EU export column 1 of figure 5 has become redundant.

Step 7: Aggregation of the domestic use table and the balanced intra-EU import table

In the last step of the Use table consolidation, the balanced intra-EU import table is added to the table with the sum of the unchanged domestic use tables. The resulting consolidated EU27 Use table now only contains one import table, namely the imports from extra-EU countries.

Two final observations are of importance. First, note that the balance of total demand and total supply by product, and the balance of total input and total output by industry, in each of the national SUTs, is maintained in the consolidated SUT. Intra-EU export values and intra-EU import values are merged with the domestic transactions. The difference between the balanced import use table and the unbalanced import use table is offset against the extra-EU trade flows.

Second, note that gross domestic product (GDP) of the EU27 is not altered by the consolidation method. The expenditure approach to calculate GDP entails summing household consumption, non-profit institution consumption and government consumption, gross fixed capital formation (investment), and exports less imports. In the procedure, exports are decreased by the amount of intra-EU exports and imports are decreased by the amount of intra-EU imports, as these flows are merged with the domestic transactions. As both exports and imports decrease by the same amount, the net values of exports less imports do not change, and the EU27 GPD remains unchanged.

Once the consolidated supply and use tables have been constructed, a product-by-product consolidated EU27 input-output table (IOT) is estimated by using the *industry technology assumption*. This implies that all products of a certain homogenous branch of activity (in short: industry[14]) are assumed to be produced according to the input use coefficients of that industry, a_{pi}. Next, these input use coefficients are multiplied by the industry shares in the domestic supply of that product, s_{ip}, to obtain the input-output coefficient matrix, $a_{pp} = \sum_i a_{pi} s_{ip}$, with $\sum_i s_{ip} = 1$ (see Eurostat, 2008, p. 349 – Model B).

However, we have used a different procedure for the derivation of the national IOTs from the national SUTs, as well as for the derivation of the consolidated IOT from the consolidated SUT. Provided that value added is predominantly linked to industries rather than to products, we opted for the construction of industry by industry IOTs using the fixed product sales structure assumption (see Eurostat, 2008, p. 349 – Model D). The resulting IOTs are used in the decomposition of the EU27 value added embodied in exports.

4. Decomposition of the 'true' value added embodied in the EU27 exports

We evaluate the empirical consequences of the different consolidation steps by estimating the EU27-value added embodied in the EU27-exports to third countries (extra-EU exports). This specific test is chosen for two reasons. First, value added impacts are chosen as GDP represents the single most important policy indicator available. Second, extra-EU exports are chosen to weight the implicitly used product multipliers, because external competitiveness is

[14] The reader must not get confused with the use of "industry" as a synonym of "homogeneous branch of activity", hereafter. The "industry" concept to which supply and use tables refer does not correspond to the concept of homogenous branches of activities, as in product by product input-output tables.

a major EU policy goal. Besides, it is also of direct interest to evaluate the actual importance of extra-EU exports for the EU-value added by industry.

The empirical consequences of the new consolidation method are evaluated from two perspectives. First, we estimate the embodied EU27-value added only by means of the national IOTs, i.e. by summing the outcomes of the 27 national Leontief models. Second, we study how this summed estimate changes when the consolidated IOT is used to specify a single Leontief model for the whole of the EU27.

The core variables of the product-by-product input-output (IO) model are: **x** = the column vector of the total output of products by industry, **Z** = the intermediate input matrix of products used by industry, and **y** = the column vector with total final demand (the sum of consumption, investments, government expenditures and exports) by product. In the IO model the supply of products follows the total demand for them, i.e. **x** = **Z i** + **y** (with **i** being a summation vector of ones). Final demand **y** is assumed to be determined exogenously, while intermediate demand is determined by total product output per industry, i.e. **Z i** = **A x**. The matrix **A**, with the intermediate input coefficients a_{pp}, is calculated from the IOT data by means of $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$ (with $\hat{\mathbf{x}}$ being a diagonal matrix of **x**). The well-known solution of this model then reads: $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$.

In our application of the IO model we only add **v**, the vector with total value added by industry, and let it be determined by total output by industry, i.e. $\mathbf{v} = \hat{\mathbf{c}}\ \mathbf{x}$, with $\hat{\mathbf{c}}$ = a diagonal matrix with value added coefficients, calculated from the IOT data by means of $\mathbf{c}' = \mathbf{v}'\ \hat{\mathbf{x}}^{-1}$. Consequently, the value added embodied in total final demand is given by: $\mathbf{v} = \hat{\mathbf{c}}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$, which equals the value added shown in the respective IOTs. The test variable in this paper only considers a part of final demand, namely, the exports to non-EU countries. Hence, replacing final demand **y** by extra-EU exports **e** in $\hat{\mathbf{c}}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$ will yield the value added by industry embodied in the EU exports to third countries.

A first approximation of the EU-wide value added impact, using only national IO data, can be made by taking the *EU-sum of the domestic impacts* of each and every Member State's exports to third countries:

$$\mathbf{v}(1\mathrm{a}) = \sum_r \hat{\mathbf{c}}^r\ (\mathbf{I} - \mathbf{A}^{rr})^{-1}\mathbf{e}^r \qquad (1a)$$

where r = 1, …, 27 (EU-member countries), and

$\mathbf{e}^r$= vector with extra-EU exports by industry of Member State *r*, taken from the final demand part of the IOT of Member State *r*, i.e. uncorrected for re-exports.

$\mathbf{A}^{rr}$= industry-by-industry matrix of domestic intermediate input coefficients of country *r* (this matrix does not change during the consolidation procedure), and

$\hat{\mathbf{c}}^r$= diagonal matrix with the value added coefficients by industry, of country *r* (this vector also does not change during the consolidation procedure).

Note that by taking the diagonal matrix of $\mathbf{c}^r$, and not that of $\mathbf{e}^r$, we measure value added by the industry in which the impact occurs, and not by the exporting industry that causes the impact.

Evidently, (1a) systematically under-estimates the EU-wide impacts, as it ignores each country´s intra-EU spillover effects on the value added of the remaining EU-Member States. This means, for example, that the value added of French car parts' makers that service the German car export to China is ignored. These *first order intercountry spillovers* can also be estimated by means of the national IOTs, namely as follows:

$$\mathbf{v}(1\text{b}) = \sum_r \hat{\mathbf{c}}^r \mathbf{A}^{er} (\mathbf{I} - \mathbf{A}^{rr})^{-1} \mathbf{e}^r \qquad (1\text{b})$$

where, additionally:

$\mathbf{A}^{er}$= interindustry matrix of intra-EU intermediate import coefficients of Member State *r*, taken from *r*'s national IOT, i.e. uncorrected for re-pricing and balancing these imports with the corresponding exports.

However, taking the sum of (1a) and (1b) still systematically underestimates the EU-wide impacts of the extra-EU exports. This second underestimation results from the fact that the *higher order intercountry spillovers and feedbacks* are not included. This means, for example, that the value added of EU27 subpart producers that service the French car parts' makers that service the German car export to China is not included. When these subpart producers are located in Germany one speaks of intercountry *feedback* effects of German exports via the rest of the EU27 back to German industries. When the subpart producers are located in the rest of the EU one speaks of *higher order* intercountry *spillover* effects (see Oosterhaven, 1981; Miller and Blair, 2009). These higher order effects may be estimated, again using only national IOTs, by taking the difference between the total EU-wide impacts, and the sum of (1a) and (1b), as follows:

$$\mathbf{v}(1\text{c}) = \sum_r \hat{\mathbf{c}}^r (\mathbf{I} - \mathbf{A}^{rr} - \mathbf{A}^{er})^{-1} \mathbf{e}^r - \mathbf{v}(1\text{a}) - \mathbf{v}(1\text{b}) \qquad (1\text{c})$$

Note that taking the sum of $\mathbf{A}^{rr}$ and $\mathbf{A}^{er}$ in (1c) implies the use of the incorrect assumption that, for example, the French auto part products that are exported to the German car industry are produced by means of the technology of the German auto part producers.

The sum of (1a), (1b) and (1c) gives an estimate of the *total EU-impacts* of all extra-EU exports, when only national IOTs would be available. This total can, of course, also be calculated directly as:

$$\mathbf{v}(1) = \sum_r \hat{\mathbf{c}}^r \, (\mathbf{I} - \mathbf{A}^{rr} - \mathbf{A}^{er})^{-1} \mathbf{e}^r \qquad (1)$$

but then it would not be possible to study the decomposition of the EU-wide impact into domestic impacts, first order intra-EU spillovers, and higher order intra-EU spillovers and feedbacks.

Next follows the question whether the construction of a consolidated SUT, and its transformation into a consolidated IOT, does make a difference to the outcomes of (1). To study this, we separately consider the consequence of the adjustments made to each of the sets of coefficients present in (1).

The first source of error in (1) relates to using $\mathbf{c}^r$. These are used correctly in (1a) to estimate the domestic value added impacts, but they are used in (1b) as a proxy for the weighted average of the value added coefficients of the rest of the EU, while they are used as a proxy for the value added coefficients of the whole of the EU in (1c). Using the true value added coefficients for the EU27 (i.e. $\mathbf{c}^e$) in (1), corrects for these two errors in one go. The related *value added coefficient error* can therefore be calculated as follows:

$$\mathbf{v}(2\mathrm{a}) = \sum_r (\hat{\mathbf{c}}^e - \hat{\mathbf{c}}^r)(\mathbf{I} - \mathbf{A}^{rr} - \mathbf{A}^{er})^{-1} \mathbf{e}^r \qquad (2a)$$

with:

$\hat{\mathbf{c}}^e$= diagonal matrix with EU27 value added coefficients.

Note that this measurement error does not have a systematic bias. We expect that the underestimations caused by countries with small value added coefficients will compensate the overestimations of those with large value added coefficients, by industry. On average, the value added coefficient error should be close to zero.

Second, we consider the impact of aggregating the 27 national SUTs into the consolidated EU27 SUT that is directly derived from Figure 1, i.e. without redistributing taxes and re-exports, and without re-pricing and balancing the intra-EU import table with the re-estimated intra-EU exports column. After this crude SUT aggregation, a non-corrected EU27 IOT was derived by means of the industry technology assumption, in precisely the same way as the national IOTs were derived from the national SUTs. The *aggregation error* is calculated as follows:

$$\mathbf{v}(2\mathrm{b}) = \hat{\mathbf{c}}^e (\mathbf{I} - \mathbf{A}^{ee}_{non})^{-1} \mathbf{e}^e_{non} - \sum_r \hat{\mathbf{c}}^e (\mathbf{I} - \mathbf{A}^{rr} - \mathbf{A}^{er})^{-1} \mathbf{e}^r \qquad (2b)$$

with, additionally:

$\mathbf{A}_{non}^{ee}$ = interindustry matrix with the non-corrected intra-EU27 input-output coefficients, i.e. the industry output weighted average of all ($\mathbf{A}^{rr}$ + $\mathbf{A}^{er}$), which is calculated by post-multiplying the sum of the domestic input-output coefficients and the intra-EU import coefficients, calculated from Figure 1, with the EU-27 domestic industry shares, calculated from the consolidated supply table.

$\mathbf{e}_{non}^{e}$ = vector with the non-corrected EU27-exports to third countries, i.e. the simple sum of all $\mathbf{e}^{r}$ taken directly from column 2 of Figure 1.

Note that this aggregation error also should not have a systematic bias. We expect that the average aggregation error will be close to zero.

Third, the consolidation procedure includes the treatment of the re-exports, detailed in Section 3. Step 3 in that section corrects for intra-EU exports that are actually re-exported to third countries. The non-treatment of these re-exports leads to an underestimation of the impulse vector, i.e. the extra-EU exports, of around 11% on average over the years. The error due to the *underestimation of extra-EU exports* can simply be calculated as follows:

$$\mathbf{v}(2\mathrm{c}) = \hat{\mathbf{c}}^{e}(\mathbf{I} - \mathbf{A}_{non}^{ee})^{-1}(\mathbf{e}^{e} - \mathbf{e}_{non}^{e}) \quad (2c)$$

where: $\mathbf{e}^{e}$ = the vector with the corrected extra-EU exports from the consolidated IOT (see Figure 3).

Finally, we consider the error that occurs if the sum of the national intra-EU import matrices, from Figure 1, would remain unbalanced with the intra-EU exports. This error consists of four components that necessarily have to be studied simultaneously:

1. The information on taxes on intra-EU exports, cell 7 of Figure 1, is used to downscale the intra-EU import values by an average of 0.25% to get c.i.f. prices net of taxes less subsidies on products.
2. The intra-EU imports are further downscaled by an average of 11.6% to correct for intra-EU imports that are actually re-exported outside the EU, i.e. column 5 of Figure 1.
3. These downscaled intra-EU imports are scaled up by an average of 9.6% to match the total of the re-estimated intra-EU exports.
4. Finally, these imports are balanced with the intra-EU exports by product, by means of GRAS, which leads to an scaling up of the rows with trade and transport margins and scaling down of the remaining rows, in order to arrive at the basic prices of the exporting country.

The combined *non-balancing error* can be calculated as follows:

$$\mathbf{v}(2\mathrm{d}) = \hat{\mathbf{c}}^{e}(\mathbf{I} - \mathbf{A}^{ee})^{-1}\mathbf{e}^{e} - \hat{\mathbf{c}}^{e}(\mathbf{I} - \mathbf{A}_{non}^{ee})^{-1}\mathbf{e}^{e} \quad (2d)$$

where, additionally:

$\mathbf{A}^{ee}$ = the "true" interindustry matrix with intra-EU intermediate input coefficients, derived from the consolidated EU27 input-output table.

We expect this last error to be the most important one. The re-pricing into basic prices of the exporting country, i.e. the deduction of net taxes on products, the transfer of re-exports, and the transfer of trade and transport margins, represents without any doubt a major improvement compared to the crude consolidation of national SUTs. Our method of re-pricing should result in a shift of margins previously included in the prices of products, to the trade and transport services industries that generate these margins. We therefore expect values of intermediate deliveries of agriculture, mining, industry, etc. to decrease and values related to trade and transport services to increase.

However, note that the scaling up of the intra-EU imports to the total of the re-estimated intra-EU exports does not necessarily represent an improvement, as it might be argued that the value of the extra-EU imports is measured more correctly than the value of the extra-EU exports.[15] In our consolidation method, however, we give precedence to the believe that the commodity totals of the domestic sales plus intra-EU exports are better measured than the commodity totals of domestic purchases plus intra-EU imports.

Obviously, the overall error of not having a correctly consolidated SUT, when estimating EU-wide value added impacts, is the total of (2a)-(2d). This total error can also be calculated directly as:

$$\mathbf{v}(2) = \hat{\mathbf{c}}^e(\mathbf{I} - \mathbf{A}^{ee})^{-1}\mathbf{e}^e - \mathbf{v}(1) \qquad (2)$$

But, again, that would not give the insight into the decomposition of the errors that is presented in (2a)-(2d).

5. Decomposition of value added embodied in the EU27 exports for 2000-2007

In this section we discuss whether our theoretical expectations about the size and the industry composition of the different impacts (1a)-(1c), and the different measurement errors (2a)-(2d) correspond with the actual empirical outcomes for 2000-2007. To present our results at a more manageable level, we only show the industries for which the average impact on value added was equal or greater than 1% during the period 2000-2007. This resulted in a selection of 33 industries out of the total of the 59 homogenous EU-branches.

The bottom row of Table 3 shows that, on average, the value added embodied in extra-EU exports is underestimated by 13.7% if we use 27 national IOTs rather than a consolidated EU27 IOT. The underestimation varies from roughly 6% in supporting and auxiliary transport

[15] In that case, the difference between imports and exports would have been added to/subtracted from the exports to the Rest of the World instead with the imports from the rest of the world, as in the older EU-method discussed in Section 2.

services and travel agencies, to around 20% in financial services, wholesale and retail trade. This error is due to the neglect of intra-European spillover and feedback effects. In fact, the sum of the domestic value added impacts of the extra-EU exports only amounts to a little less than 73% of the "true" value of the total impact (v1+v2). This overall underestimation varies, but is largest for the crude petroleum and natural gas extraction and related services (around 46%), and smallest for water transport services and machinery and equipment, which have summed domestic impacts of over 80%.

It is quite remarkable that the error of not using the consolidated EU27 SUT is of roughly the same order of magnitude as the sum of the intra-EU spillovers and feedback effects calculated using 27 national SUTs. Moreover, provided that the former errors correspond only to errors in the estimation of intra-EU spillover and feedback effects, it turned out that these effects are actually underestimated by a half if we do not use a consolidated EU27 SUT. On average, the underestimation due to neglecting the intra-EU trade effects as calculated by means of the national IOTs represent 13.5% of the "true" impact value, while the error of not using a consolidated IOT amounts to 13.7%, which is practically the same (see the bottom row of Table 3). Indeed, the "true" impact value of intra-EU spillover and feedback effects is eventually 27.2% of the total (= 13.5% + 13.7%) while if we use 27 national SUTs, that would represent roughly half of it. Graph 1 illustrates the evolution of these two magnitudes during the whole period of 2000-2007. The error of neglecting intra-EU spillovers and feedbacks varied between 12% and almost 15%, while the error of non-consolidation varied between a little over 11% to almost 16%. Over the first half of this period, the non-consolidation error was larger, whereas the opposite result was found for the second half of this period.

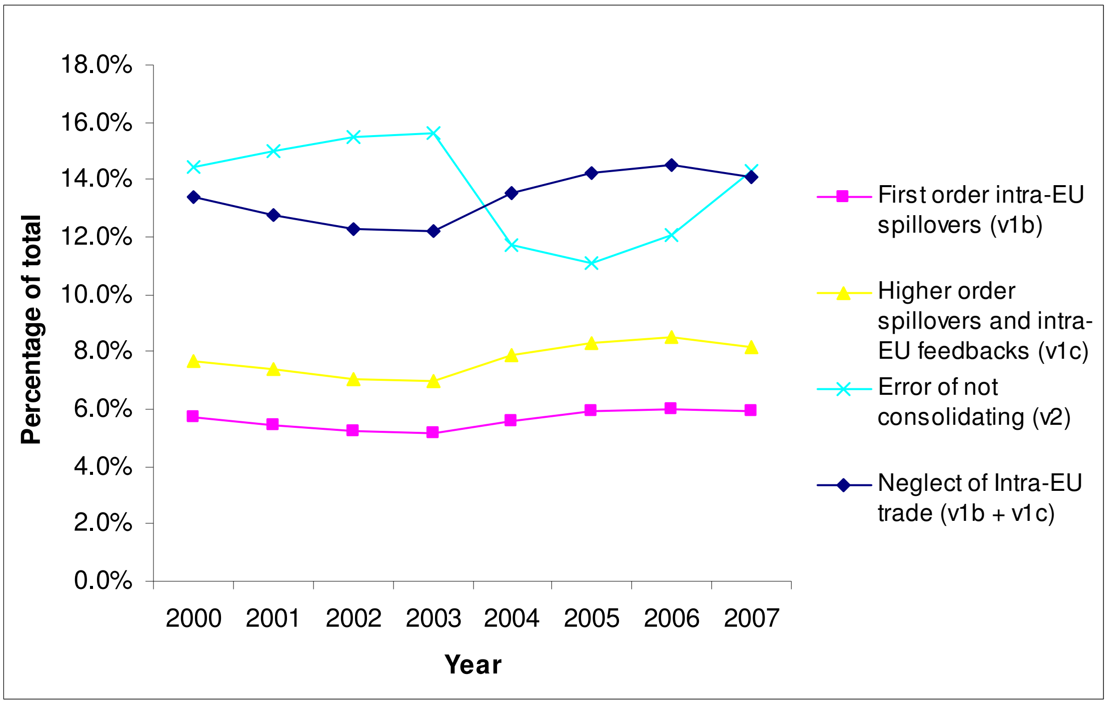
Table 3, furthermore, shows that the non-consolidation errors are much larger than the intra-EU trade effects in service type industries like: retail trade; water transport services; wholesale trade; and financial services. Conversely, intra-European spillover and feedbacks effects are much larger in commodity type industries such as: crude petroleum and natural gas extraction and related services; basic metals; pulp and paper products; and supporting and auxiliary transport services and travel agencies.

Table 3: Decomposition of EU27 value added embodied in extra-EU exports, average for 2000-2007

	Selected group of commodities with an impact larger than 1%	Using only national IO models			Errors of not using the consolidated EU27					Contribution of extra-EU exports to EU27 value added
		Domestic impacts	First order Intra-EU spillovers	Higher order intra-EU spillovers and feedback	Due to factor coefficients	Due to aggregation	Due to extra-EU exports	Due to intra-EU imports	Total of non-consolidation	
		(a)	*(b)*	*(c)*	*(d)*	*(e)*	*(f)*	*(g)*	*(h) = (d) + (e) + (f) + (g)*	*(i) = (a) + (b) + (c) + (h)*
		v1a	**v1b**	**v1c**	**v2a**	**v2b**	**v2c**	**v2d**	**v2**	**v1+v2**
23	Machinery and equipment n.e.c.	73.7%	5.9%	8.2%	-0.9%	-13.1%	9.8%	16.5%	12.2%	10.4%
18	Chemicals, chemical products and man-made fibres	62.8%	7.3%	9.7%	-0.2%	-15.9%	14.8%	21.5%	20.2%	9.7%
28	Motor vehicles, trailers and semi-trailers	62.6%	7.4%	13.4%	-2.3%	-20.6%	11.7%	27.7%	16.6%	9.1%
51	Other business services	84.9%	2.4%	2.6%	6.1%	-6.3%	4.4%	6.0%	10.1%	6.3%
36	Wholesale trade and commission trade services, except of moto	87.9%	3.4%	4.0%	3.4%	-7.7%	1.7%	7.3%	4.7%	5.8%
9	Food products and beverages	73.0%	5.8%	7.9%	2.6%	-13.8%	9.9%	14.7%	13.3%	4.0%
21	Basic metals	64.3%	7.2%	12.1%	-0.2%	-18.1%	11.3%	23.4%	16.4%	3.5%
25	Electrical machinery and apparatus n.e.c.	69.1%	6.3%	9.1%	0.1%	-14.9%	12.6%	17.7%	15.5%	3.4%
29	Other transport equipment	69.7%	6.2%	9.5%	0.3%	-16.0%	13.0%	17.4%	14.6%	3.2%
40	Water transport services	72.6%	9.2%	9.3%	-1.5%	-11.6%	3.3%	18.8%	8.9%	2.7%
27	Medical, precision and optical instruments, watches and clocks	72.1%	5.0%	6.4%	-1.6%	-10.0%	14.1%	13.8%	16.4%	2.7%
26	Radio, television and communication equipment and apparatus	63.0%	6.8%	9.2%	-2.0%	-13.3%	18.0%	18.3%	21.0%	2.7%
22	Fabricated metal products, except machinery and equipment	76.6%	5.5%	8.5%	-0.5%	-13.3%	7.2%	16.1%	9.5%	2.2%
19	Rubber and plastic products	68.2%	7.0%	10.2%	0.3%	-16.2%	10.8%	19.8%	14.6%	2.1%
44	Financial intermediation services, except insurance and pension	77.5%	4.2%	6.9%	17.9%	-19.1%	6.4%	6.1%	11.4%	1.9%
15	Pulp, paper and paper products	70.4%	6.6%	9.4%	-1.1%	-14.7%	9.9%	19.4%	13.6%	1.8%
37	Retail trade services, except of motor vehicles and motorcycles;	86.3%	1.6%	2.0%	7.3%	-4.0%	1.4%	5.4%	10.2%	1.7%
30	Furniture; other manufactured goods n.e.c.	68.9%	5.9%	8.4%	2.7%	-15.2%	12.9%	16.5%	16.8%	1.7%
42	Supporting and auxiliary transport services; travel agency service	84.5%	4.2%	5.1%	0.7%	-8.3%	3.9%	9.9%	6.2%	1.5%
35	Trade, maintenance and repair services of motor vehicles and m	89.9%	3.1%	4.7%	-3.9%	-4.5%	1.1%	9.6%	2.3%	1.5%
49	Computer and related services	86.5%	3.8%	3.4%	1.7%	-4.9%	2.8%	6.8%	6.4%	1.5%
11	Textiles	66.5%	7.4%	10.3%	1.1%	-16.9%	11.9%	19.8%	15.8%	1.5%
41	Air transport services	74.4%	5.6%	7.3%	0.4%	-12.8%	8.0%	17.1%	12.7%	1.4%
17	Coke, refined petroleum products and nuclear fuels	55.4%	16.3%	12.7%	4.2%	-31.5%	7.4%	35.5%	15.5%	1.4%
46	Services auxiliary to financial intermediation	84.4%	1.9%	2.2%	13.5%	-11.8%	3.1%	6.6%	11.5%	1.4%
50	Research and development services	82.8%	3.7%	4.4%	1.4%	-6.3%	5.1%	8.8%	9.1%	1.3%
20	Other non-metallic mineral products	81.1%	5.1%	6.3%	0.7%	-11.3%	6.3%	11.9%	7.6%	1.3%
39	Land transport; transport via pipeline services	87.0%	3.3%	3.8%	0.1%	-5.0%	4.0%	6.9%	6.0%	1.3%
24	Office machinery and computers	43.6%	7.3%	10.3%	3.5%	-16.3%	29.9%	21.8%	38.8%	1.2%
16	Printed matter and recorded media	75.6%	6.5%	6.6%	3.0%	-8.9%	4.4%	12.7%	11.2%	1.1%
1	Products of agriculture, hunting and related services	81.1%	3.6%	5.0%	2.2%	-9.5%	8.1%	9.6%	10.3%	1.0%
	Selected total (billion €)	707.1	56.4	78.0	11.4	-129.9	91.1	158.4	130.9	972.3
	Total (billion €)	**769.1**	**59.6**	**82.2**	**17.3**	**-138.0**	**98.6**	**166.3**	**144.2**	**1,055.1**
	Percentage of EU27 value added embodied in exports	72.9%	5.7%	7.8%	1.6%	-13.1%	9.3%	15.8%	13.7%	100.0%

NOTE: 1 billion = 1000 Mio Euro

Graph 1: Errors made in estimating value added embodied in EU27 exports

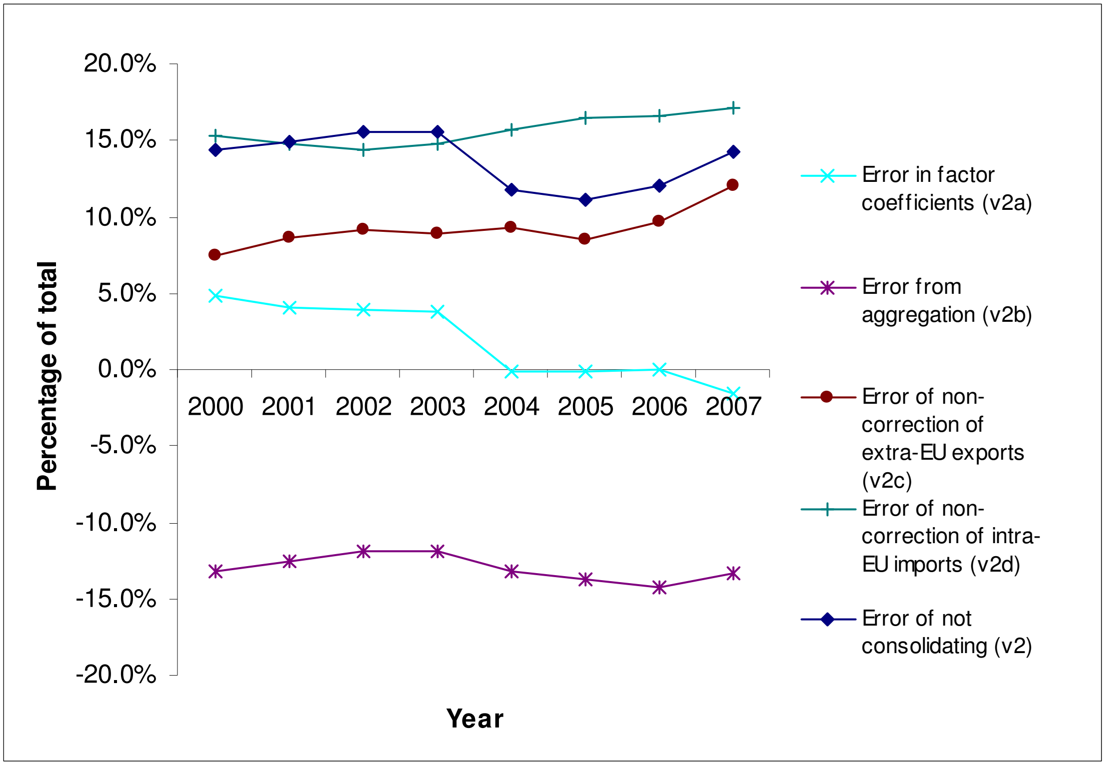


The size of the separate errors that occur when the consolidated IOT is not used fluctuates over time as is shown in Graph 2. We identified four sources of errors from using only national IOTs to account for the embodied value added of the extra-EU exports (see Section 4): errors in value added coefficients; errors from aggregation; errors from the non-correction of extra-EU exports; and errors from the non-correction of intra-EU imports (rescaling and product-wise balancing with extra-EU exports).

Not balancing and not re-pricing the intra-EU imports with the intra-EU exports (v2d) leads to the largest underestimation, as predicted in Section 4. After 2003, this error becomes even larger than the overall error of not consolidating the national SUTs properly. Moreover, this error almost persistently grows over the period 2000-2007. As expected, because of the re-pricing, this error is especially large for the trade and transport industries, but surprisingly also for basic metals and crude petroleum and natural gas (see Table 3, column v2d). The error due to the non-correction of extra-EU exports (v2c), which is responsible for around 9.3% of the total "true" impact, also persistently grew throughout the period.

The magnitude of the error due to non-aggregation (v2b) lies in between the errors of not treating the intra-EU imports and the extra-EU exports correctly. The non-aggregation error, however, leads to an overestimation of the value added embodied in extra-EU exports, whereas all other errors lead to underestimations of the "true" value. This is in contrast with our expectation of a non-biased aggregation error. Behind the weighted average aggregation error, there is an even larger variation of aggregation errors at the industry level, with again basic metals (-27.5%) and crude petroleum and natural gas (-46.9%) leading the list (see Table 3, column v2b).

Graph 2: Consolidation errors made in estimating value added embodied in EU27 exports



The error of using national value added coefficients (v2a) is much smaller than the other three non-consolidation errors, while it becomes practically irrelevant at the aggregate level of the EU27-economy for the latter years studied. In fact, the fall in total error in 2003 is mainly due to the reduction in the error of using national value added coefficients. The convergence of the national value added coefficients towards the average EU value added coefficients suggests that national production structures have been converging. The continuing EU market integration may have had an equalizing impact on the national shares of value added in total inputs.

Finally, and maybe most importantly, note that the percentage structure of the last column of Table 3 is not related to the consolidation process, but gives an indication of the industry mix of the type of applications that a consolidated SUT and IOT enables. Quite remarkable is the, mainly indirect, 12.1% large share of other business services in the value added embodied in the extra-EU exports. The total impact of a little more than 1,000 billion euro gives an indication of the relatively low importance of the exports to third countries for the value added of the EU27. This amount represents 11.2% of the total European GDP, which should be considered as relatively little. Obviously, domestic EU27 consumption, investment and government expenditures are far and far more important for EU-wide GDP than its exports to third countries!

6. Conclusion and discussion

In this paper we developed a method to consolidate a series of national supply and use tables (SUTs) into a single supra-regional SUT. The method corrects for double-counting of intra-group re-exports, rebalances intra-group imports with the intra-group exports, and re-prices intra-group import matrices from c.i.f. prices to basic prices of the exporting industries. The method was tested with a seven-fold nested decomposition of the errors made in the estimation of the EU27 value added embodied in the EU27 exports to third countries for the years 2000-2007. With this new dataset, comparable estimates can now also be made for, inter alia, embodied CO_2-emissions, water use and employment.[17]

The first set of errors relates to using a EU27 input-output table (IOT), derived from a crudely consolidated SUT, instead of simply adding the domestic impacts calculated with the national IOTs. The neglect of intra-EU spillover and feedback effects in the latter case would have resulted in an underestimation of the EU27 embodied value added of extra-EU exports of 12-15%. The second set of errors relates to using the crudely consolidated SUT without the above mentioned corrections. This would have resulted in a further underestimation of the embodied value added of 11-16% over the period 2000-2007. Moreover, large industry-by-industry variations in errors of up to plus and minus 50% were observed behind these aggregate errors.

Even without these underestimations, the total EU27 value added embodied in the EU27 exports to third countries amounts to only 11.2% of the gross domestic product (GDP) of the EU27. The remaining 88.8% is related to EU27 domestic private and public consumption and investment expenditures, of which 17.6%-point is related to intra-EU trade.[18] This suggests that internal EU27 innovativeness and efficiency is probably much more important for the level and growth of the EU27 GDP than its external competitiveness.

Acknowledgements

This article is a spin-off of two projects financed by Eurostat. We thank Stephan Moll, and in particular Jörg Beutel, for extensive discussions on the methodology. The views expressed in this article are solely the views of the authors. They do not necessarily reflect those of Eurostat or the Commission services.

[17] See, e.g., Moll and Rémond-Tiedrez (2011) for a comparable CO_2 application.
[18] This may be calculated from the last row of Table 3 as: (5.7+7.8)/72.9/0.888.

References

Bacharach, M. (1970). *Biproportional matrices & input-output change.* Cambridge University Press.

Belke A. & L. Wang (2006). The degree of openness to intra-regional trade – Towards value-added based openness measures. *Jahrbücher für Nationalökonomie und Statistik* 226 (2), 115-138.

Bouwmeester, M.C. & J. Oosterhaven (2009). Methodology for the Construction of an International Supply-Use Table. Paper presented at the International Input-Output Conference in São Paulo, Brazil, July 13 – 17, 2009.

Brockmeier M. (1997). *GTAP 3 Data Base Documentation - Chapter 16.2 EU-12*, Center for Global Trade Analysis, Purdue University.

Council of the European Union (2009). *Conclusions on "Priorities for the Internal Market in the next decade" – contribution by the Competitiveness Council to the post 2010 Lisbon agenda*, 2982nd Competitiveness (Internal market, Industry and Research) Council meeting, Brussels.

Daudin G. C. Rifflard & D. Schweisguth (2011), Who produces for whom in the world economy? *Canadian Journal of Economics* 44 (4), 1403-1437.

Eder P. (ed.) , L. Delgado (ed.), F. Neuwahl (ed.), A. Tukker, G. Huppes, L. van Oers & R. Heijungs (2006), *Environmentally extended input-output tables and models for Europe*, Report EUR 22194 EN, European Commission, Joint Research Center, Institute for Prospective Technological Studies, Seville.

Erumban, A.A., R. Gouma, B. Los, R. Stehrer, U. Temurshoev, M. Timmer & G. de Vries (2011). The World Input-Output Database (WIOD): Construction, Challenges and Applications. Paper presented at the World Bank workshop on "The Fragmentation of Global Production and Trade in Value Added", June 9-10, 2011.

European Commission (2010a). *Trade as a driver of prosperity.* Commission staff working document accompanying the Commission's Communication on "Trade, Growth and World affairs.", SEC(2010)1269, DG Trade: Brussels.

European Commission (2010b). *Trade, growth and world affairs. Trade policy as a core component of the EU's 2020 strategy*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2010)612, DG Trade: Brussels.

European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations & World Bank (2009). *System of National Accounts 2008*.

Eurostat (2006). *Statistics on the trading of goods - user guide* (Manual No. KS-BM-06-001)

Eurostat (2008). *Eurostat Manual of Supply, Use and Input-Output Tables* (Manual No. KS-RA-07-013-EN-N).

Eurostat (2011). *Creating consolidated and aggregated EU27 Supply, Use and Input-Output Tables, adding environmental extensions (air emissions), and conducting Leontief-type modeling to approximate carbon and other 'footprint' of EU27 consumption for 2000 to 2006*. Eurostat, Luxembourg.

Foster N., R. Stehrer & G. de Vries (2011), Trade in value added and factors: A comprehensive approach. Unpublished manuscript, WIOD project.

Hewings, G.J.D. (1977). Evaluating the Possibilities for Exchanging Regional Input-Output Coefficients, *Environment and Planning A*, *9*, 927-944.

IDE (2006). *How to Make Asian Input-Output Tables*. Institute of Developing Economies, JETRO, Chiba, Japan.

Ilkovic F., A. Dierx, V. Kovacs & N. Sousa (2007). *Steps towards a deeper economic integration: the Internal Market in the 21st century, A contribution to the Single Market Review*, European Commission, DG Economic and Financial Affairs: Brussels.

Inomata, S., M. Tokoyama, H. Kuwamori & B. Meng (2006). Compilation of the Asian input-output table. In: IDE, *How to Makes Asian Input-Output Tables*, Institute of Developing Economies, JETRO, Chiba, Japan.

Isard, W. (1951). Interregional and regional input-output analysis, a model of a space economy. *Review of Economics and Statistics, 33*, 318-28.

Johnson R.C. and G. Noguera (2012), Accounting for intermediates: Production sharing and trade in value added. *Journal of International Economics* 86, (2), 224-236.

Junius, T., & J. Oosterhaven (2003). The solution of updating or regionalizing a matrix with both positive and negative entries. *Economic Systems Research, 15*(1), 87-87.

Koopman R., W. Powers, Z. Wang & S. Wei (2010), Give credit where credit is due: tracing value added in global production chains. NBER working paper no. 16426.

Lahr, M. L., & L. de Mesnard (2004). Biproportional techniques in input-output analysis: Table updating and structural analysis. *Economic Systems Research, 16*(2), 115-134.

Leeuwen, M. (2002). *GTAP 5 Data Base Documentation - Chapter 11.M The European Union*, Center for Global Trade Analysis, Purdue University.

Leeuwen, M. van & D. Verhoog (1999). *GTAP 4 Data Base Documentation - Chapter 14/17 European Union,* Center for Global Trade Analysis, Purdue University.

Lenzen, M., L. Pade & J. Munksgaard (2004). CO_2 Multipliers in Multi-region Input–Output Models, *Economic Systems Research, 16*(4), 391-412.

Linden, J.A. van der (1999). *Interdependence and Specialisation in the European Union: Intercountry Input-Output Analysis and Economic Integration*. Ph.D, Faculty of Economics, University of Groningen.

Linden, J. A. van der & J. Oosterhaven (1995). European community intercountry input-output relations: Construction method and main results for 1965-85. *Economic Systems Research, 7*(3), 249-249.

Miller, R. E. & P.D. Blair (2009). *Input-output analysis: Foundations and extensions.* Cambridge University Press.

Minguez, R., J. Oosterhaven & F. Escobedo (2009). Cell-Corrected RAS method (CRAS) for Updating or Regionalizing an Input-Output Matrix. *Journal of Regional Science* 49(2): 329–348.

Moll, S. & I. Rémond-Tiedrez (2011). CO_2 emissions induced by EU's final use of products are estimated to be 9 tonnes per capita. *Statistics in focus 22/2011*, Eurostat, Luxembourg.

Oosterhaven, J. (1981). *Interregional Input-Output Analysis and Dutch Regional Policy Problems*. Gower, Aldershot, UK.

Oosterhaven, J. (1984). A family of square and rectangular interregional input-output tables and models. *Regional Science and Urban Economics, 14*, 565-82.

Oosterhaven, J. (1995). Changing specialization and interdependency of EC-economies 1959-1975. *Australasian Journal of Regional Studies, 1*(11), 51-64.

Oosterhaven, J., D. Stelder, & S. Inomata (2008). Estimating international interindustry linkages: Non-survey simulations of the Asian-Pacific economy. *Economic Systems Research, 20*(4), 395.

Oosterhaven, J. & F. Escobedo-Cardeñoso (2011) A new method to estimate input-output tables by means of structural lags, tested on Spanish regions. *Papers in Regional Science*, forthcoming.

Puzzello L. (2011). A proportionality assumption and measurement biases in the factor content of trade, *Journal of International Economics*, forthcoming.

Roca Zamora A. (2009). *How is the internal market integration performing? Trade and foreign direct investment indicators for monitoring the state of the economic integration*, European Commission, DG Internal Market and Services: Brussels.

Rueda-Cantuche, J. M. (2011). The choice of type of Input-Output Table revisited: moving towards the use of supply-use tables in impact analysis, *Statistics and Operations Research*, 35 (1), January-June, 2011, pp. 21-38.

Rueda-Cantuche, J. M., J. Beutel, F. Neuwahl, I. Mongelli, & A. Loeschel (2009). A Symmetric Input–Output Table For EU27: Latest Progress. *Economic Systems Research, 21*(1), 59.

Schilderinck, J.H.F. (1984). *Interregional Structure of the European Community, Part II*. Research Memorandum No. 165, Department of Economics, Catholic University of Brabant, Tilburg.

Stone, R. (1961). *Input-Output and National Accounts*. Organization for European Economic Cooperation, Paris.

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

Ungar, P. & J. Heuschling (1994). The Interlinking of Economic Branches in the European Union – Consolidated Input-Output Table for 1991. *Rapid Reports, Economy and Finance*, *2*. Eurostat, Luxembourg.