
Improving the analysis of global value chains: the UNCTAD-Eora Database

Bruno Casella, Richard Bolwijn, Daniel Moran and
Keiichiro Kanemoto*

The UNCTAD-Eora Global Value Chain (GVC) database offers global coverage (189 countries and a “Rest of World” region) and a timeseries from 1990 to 2018, reporting on key GVC indicators. This paper explains the methodology for compiling the UNCTAD-Eora GVC database, including nowcasting employed in the estimation of recent years; second, it provides a comparison of the results against other value-added trade databases, with a focus on the OECD Trade in Value Added (TiVA) dataset; and lastly discusses the relevance of GVC data for the analysis of globalisation patterns, particularly at the intersection between trade, investment and development.

Keywords: trade in value added; MRIO; global value chains; complex value chains; value added in export; input-output analysis

1. Introduction

A pivotal element in the analysis of international production are global value chains (GVCs), which are fragmented and geographically dispersed production processes where different stages are located across different countries. GVCs are coordinated by multinational enterprises (MNEs) investing in productive assets worldwide and trading inputs and outputs intra-firm, at arm’s length or through their network of non-equity mode (NEM) partners. UNCTAD estimates that up to 80 per cent of global trade involves MNEs (*World Investment Report 2013*). In this respect, the analysis of GVCs is fully complementary to the analysis of FDI and international production.

* Bruno Casella and Richard Bolwijn are at the United Conference on Trade and Development. Daniel Moran and Keiichiro Kanemoto work at Eora. Correspondence with the authors may be addressed jointly to Bruno Casella (Bruno.Casella@unctad.org) and the Eora MRIO maintainers (info@worldmrio.com). The views expressed in this paper are solely those of the authors.

Recently, major analytical developments in the treatment of inter-country input-output tables have opened new avenues for the empirical research on global value chains. In particular, the availability of databases that break down trade according to the origin of its value added (“value added trade” or “value added in exports” data) enables the analysis of GVC patterns by countries and industries, at a level of granularity that was unimaginable as recent as ten years ago. The most important cross-regional value-added trade databases include the UNCTAD-Eora GVC database, the World Input-Output Database (WIOD) and the OECD’s Trade in Value Added Database (TiVA). Major regional initiatives include the Asian Multi-Region Input-Output Database from the Asian Development Bank and the South-American Input-Output Table from the Economic Commission for Latin America and the Caribbean (ECLAC). Table 1 provides an account and a comparison of the different and ongoing initiatives to map GVCs (see also Tukker and Dietzenbacher, 2013).

The UNCTAD-Eora GVC database was initially launched in the context of the analysis conducted for the *World Investment Report 2013 (WIR13)*, with its main theme “Global Value Chains: Investment and Trade for Development” (UNCTAD, 2013). Compared with alternative databases, its distinctive feature is broad geographical coverage, including virtually all countries. Owing to this comprehensive coverage the database has become the preferred reference source of value-added trade data in analysis involving developing economies (AfDB, OECD, & UNDP 2014; UNECA, 2015; UNIDO, 2016; IMF, 2015a; IMF 2015b; IMF 2016a; IMF 2016b).

Given the importance of GVC analysis in the context of globalization and development and the high demand for value-added trade data, particularly for developing countries, UNCTAD-Eora has upgraded its GVC database. This has led not only to an update of the 2013 dataset to include GVC indicators up to 2015 but also a new improved version, featuring a “nowcast” methodology to project value-added trade data from 2016 to 2018. This step addresses one of the main weaknesses of available value-added trade databases (including the WIOD, TiVA and the previous version of the UNCTAD-Eora GVC database), namely the time lag of two to three years between the most recent data and the time of the analysis. *A further update of the UNCTAD-Eora GVC database, including GVC indicators for 2016 and 2017 based on actual data, is in preparation and will be published in conjunction with this paper.*

The main outcome of the UNCTAD-Eora database is a set of basic GVC indicators, including foreign value added (foreign value embedded in a country’s exports), domestic value added (domestic value embedded in a country’s exports) and domestic value added embedded in other countries’ exports. Other important GVC indicators, such as GVC participation, can be easily computed from the three basic indicators (Koopman et al., 2014). UNCTAD-Eora GVC indicators are

Table 1. Efforts to map GVCs (status as of August 2019)

Project	Institution	Data sources	Countries	Industries	Years	Comments
UNCTAD-Eora GVC Database	UNCTAD/Eora	National Supply-Use and I-O tables, and I-O tables from Eurostat, IDE-JETRO and OECD	189	26-500 depending on the country	1990–2015 (nowcast for 2016, 2017 and 2018)	Meta database drawing together many sources and interpolating missing points to provide broad, consistent coverage
Trade in Value Added (TIVA) dataset	OECD	National I-O tables	64	34	2005–2015 (projections 2016)	Information on all OECD countries, and 27 non-member economies (including all G20 countries)
World Input-Output Database (WIOD): 2016 Release	Consortium of 11 institutions, EU funded	National Supply-Use tables	43	56	2000–2014	Based on official national account statistics; uses end-use classification to allocate flows across partners and countries
Other multi-region input-output databases						
EXIOBASE	EU-based consortium, exioibase.eu	National supply-use tables	44+5	200	1995–2013	Covers 44 countries plus five rest-of-world regions
ADB Multi-Region Input-Output Database (ADB MRIO)	Asian Development Bank	An extension of WIOD which includes 5 additional Asian economies (Bangladesh, Malaysia, Philippines, Thailand and Viet Nam)	45	35	2000, 2005–2008, 2011	The information for the 5 additional Asian countries are estimates methodically produced to assist research and analysis, not official statistics
Global Trade Analysis Project (GTAP)	Purdue University	Contributions from individual researchers and organizations	121 countries plus 20 regions	65	2004, 2007, 2011, 2014	Includes data on areas such as energy volumes, land use, carbon dioxide emissions and international migration.
South American Input-Output table	ECLAC and Institute of Applied Economic Research (IPEA) from Brazil	National I-O tables	10	40	2005	Based on official information from National Accounts

Source: UNCTAD.

publicly available at granular year-, country- and industry-level on the UNCTAD-Eora webpage.¹

The intention is to establish the UNCTAD-Eora project as a continuing project for the update and improvement of GVC data and analysis, with annual updates envisaged.

In this context, this paper has two objectives: First, it presents the analytic and methodological construction of the UNCTAD-Eora database (sections 2 and 3). Second, it compares results with other available databases, particularly the OECD TiVA, for data validation purposes (section 4). The concluding section puts the UNCTAD-Eora database in the broad context of the analysis of the trade-investment-development nexus: it shows how GVC data can provide an important perspective on some relevant trends at the intersection between these three key areas in modern globalization.

2. The analytical background of the new UNCTAD-Eora database

In this section we briefly retrace the steps that lead to the establishment of the new UNCTAD-Eora database. The first step (section 2.1) – the construction of a multiregional input-output (MRIO) dataset – is the most technically complex and computationally intensive. We present it only qualitatively; for more detail the existing literature is referenced. Once an MRIO is available, some straightforward algebraic steps allow to fit the relevant information contained in the MRIO into the framework of value-added trade and derive the key GVC indicators (section 2.2). Finally, a nowcasting procedure is implemented to project value-added trade data from the last available year onward (section 2.3). Unlike section 2.1 and section 2.2 which are essentially summaries of existing material, the treatment of nowcasting in section 2.3 is new, hence its analytical elaboration here is more detailed.

2.1. The construction of the Eora MRIO dataset

This section provides an overview of how the Eora MRIO is constructed. For a more comprehensive explanation, the primary reference paper is Lenzen et al. (2012). Some more approachable summary papers are Lenzen et al. (2013); Moran and

¹ <http://worldmrio.com/unctadgvc/>. For references to the UNCTAD-Eora database, cite this method paper as follows:
Casella, B. et al. (2019). Improving the analysis of global value chains: the UNCTAD-Eora Database, *Transnational Corporations Journal* 26(3). New York and Geneva: United Nations.

Geschke (2013); and Moran (2013). The documentation section of the Eora website (at <http://worldmrio.com>) also provides several papers and reports that present the main elements of I/O analysis.

The Eora dataset provides a multi-region input-output table at the global level to estimate value added in trade. The construction of the Eora MRIO table follows several steps.

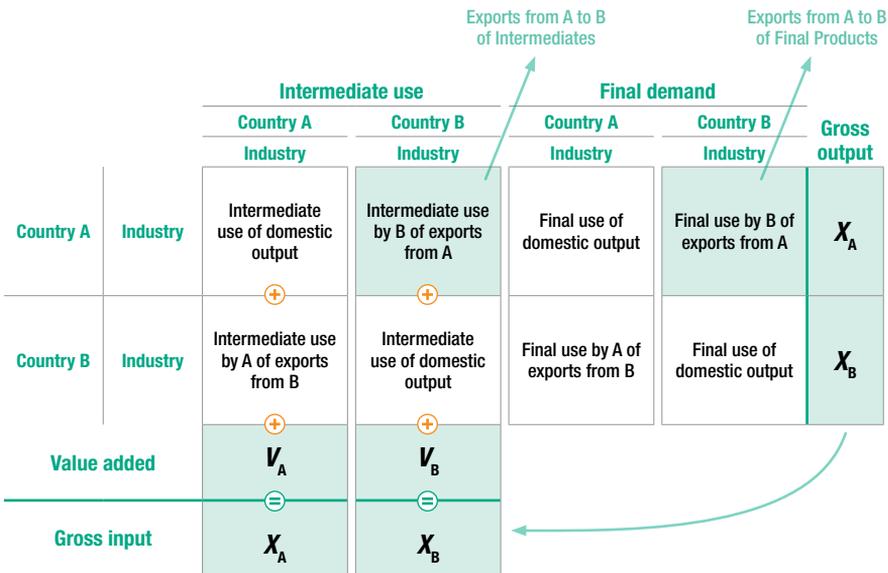
- a. The starting points are the national IO tables or supply/use tables (SUTs). National SUTs are recommended over input-output tables because they provide information on both products and industries. However, the national statistics bureaus in some countries still provide only input-output tables. A supply table provides information on products produced by each domestic industry and a “use” table indicates the use of products by industries or final users. As SUTs are only available for a limited number of countries, the remaining countries are hence represented by input-output (I/O) tables, which can be sourced from available data or compiled according to a range of assumptions. In order to avoid departures from the original raw data, EORA preserves the sectoral classification from each data provider. The complete list of raw data sources involved in preparing the IO table for each country in Eora is available at the Quality Report section of the Eora website and in the Supplementary Information of Lenzen et al. (2012).
- b. National SUTs and I/O tables are linked through international trade statistics using import tables to obtain a multi-region input-output table. At this step, an estimation procedure is used to construct so-called “off-diagonal” trade blocks, estimating flows from each export sector in each origin country (rows) to each importing sector in each destination country (columns). Trade data is most often reported by product and by producer and consumer country. However, an off-diagonal trade block in an IO table requires knowing how goods from each exporting sector are absorbed into each importing sector. Put another way, the raw data is three-dimensional, but the IO table requires four dimensions. Thus, creating the trade blocks involves several assumptions and estimation steps. The challenges and procedures used to estimate trade are presented in full in Lenzen et al. (2012).
- c. After obtaining a first estimate of an MRIO table, the resulting trade data are balanced through an industry-level balancing condition: the total output produced by each sector must equal the sum of the inputs used by that sector. This has been achieved via “constraints data”: i) Input-output tables and main aggregates data from national statistics offices; ii) Input-output compendia from Eurostat, IDE-JETRO and OECD; iii) The UN National Accounts Main Aggregates Database and official country data; iv) The UN COMTRADE and UN Service Trade international trade databases. An optimization procedure (a variant of the

RAS algorithm that can handle multiple conflicting constraints; see Lenzen et al., 2014) is set up so that the solution should be some compromise table that respects the initial estimates and also satisfies constraints with as little deviation as possible. For the optimization exercise, a standard error is estimated for each data point based on the reliability of the data. In general, larger values are taken to be more reliable than smaller values, in relative terms. Data from national statistics agencies are assumed to be more reliable than other sources. The ordering of data sources listed above largely corresponds to the data reliability assumed in assigning standard errors.

- d. The time series is constructed iteratively, by starting with an initial year estimate (year 2000), balancing it with all the starting year constraints, and taking the solution as the initial estimate for the following year, and so on. In each year, all available data for that year (GDP totals, trade data, new I/O tables, interpolated I/O table estimates, and so on) are overlaid onto the initial estimate of that year, and the table is rebalanced. The practice of using the previous-year solution as the initial estimate for the subsequent year has an effect to “smooth” timeseries data, though other constraints that introduce “jumps” will also be considered in the solution table for each year.

Figure 1 shows a simplified MRIO table, considering only one industry for two countries.

Figure 1. Structure of an MRIO Table



The rows in an MRIO table indicate the use of gross output from a particular sector in a country. The gross output X produced in country A (first row) can be used by country A itself as intermediate or as final consumption, or by country B, again as an intermediate input or final product. From here, we can retrieve a measure of gross exports from A to B, summing the intermediate and final output produced in country A and used in country B (the grey blocks in the example above).

The columns of an MRIO table provide information on the technology of production, as they indicate the amounts of intermediates needed for the production of the gross output whose use is then decomposed along the row. Hence, each column provides the domestic and foreign share of intermediates in the production of one unit of output. The first column thus shows how much domestic inputs contribute to the production of the gross output of country A (first cell, “Intermediate use of domestic output”), and how many inputs are sourced from abroad through imports (second cell, “Intermediate use by A of exports from B”). The difference between the gross output produced in each country and the sum of the (domestic and foreign) inputs necessary for production yields the value added generated in each country (V).

2.2. Deriving value-added trade from Eora MRIO

The derivation of value-added trade from the MRIO table follows the standard approach proposed by Koopman et al. (2010; 2014). Here we provide a concise description and we refer to Koopman’s paper and other reviews such as the OECD’s De Backer and Miroudot (2013) and the IMF’s Aslam et al. (2017) for the details. The IMF paper in particular explicitly uses the Eora MRIO computational framework to derive value-added trade indicators. Some other important papers addressing issues in the computation of value-added trade include Hummels et al. (2001), Johnson and Noguera (2012), Stehrer et al. (2012), Timmer et al. (2012), Wang et al. (2013, 2017a, 2017b), Los et al. (2016), Johnson and Noguera (2016), Timmer et al. (2016), Antras and de Gortari (2017), and Los and Timmer (2018).

We first establish standard IO analysis identities for an MRIO table with N countries and H industries:

$$\begin{aligned}
 x &= T + y \\
 \Leftrightarrow x &= Ax + y \\
 \Leftrightarrow (I - A)x &= y \\
 \Leftrightarrow x &= (I - A)^{-1}y = Ly
 \end{aligned} \tag{1}$$

where x is the $(NH \times 1)^2$ vector of gross outputs by countries and by industries, T is the corresponding vector of intermediate uses, y is final demand. From (1), we introduce the $(NH \times NH)$ key matrices of the GVC construction: the technological coefficient matrix A and the Leontief inverse L (Leontief, 1970).

The fundamental relationships in (1) can be applied to the “value-added trade” framework. After introducing the $(NH \times NH)$ diagonal matrices V and E , reporting respectively value-added share and exports by countries and industries, we define the matrix $(NH \times NH)$ of embodied value-added flows F as follows:

$$F = \begin{pmatrix} F^{11} & \dots & F^{1N} \\ \vdots & \ddots & \vdots \\ F^{N1} & \dots & F^{NN} \end{pmatrix} = \begin{pmatrix} V^1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & V^N \end{pmatrix} \begin{pmatrix} L^{11} & \dots & L^{1N} \\ \vdots & \ddots & \vdots \\ L^{N1} & \dots & L^{NN} \end{pmatrix} \begin{pmatrix} E^1 & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & E^N \end{pmatrix} \quad (2)$$

where F^{rs} is a $(H \times H)$ matrix showing inter-sector flows between country r and country s (domestic flows in the case that r and s are the same country). The matrix F is the key matrix of our analysis (figure 2). The matrix essentially describes how the value added contained in the exports of each country (and industry) is generated (by column) and distributed (by row) across countries. Henceforth, in order to facilitate the intuition, we will describe the elements of F (2) as if they were scalar (this is equivalent to considering an economy with only one product) rather than $(H \times H)$ matrices as in the general case. Thus, the first column of the matrix describes the value added contained in the export of country 1. This is composed of two parts:

- the term F^{11} (in the matrix multiplication we have that $F^{11} = V^1 L^{11} E^1$) denotes the *Domestic Value Added* (DVA) content of exports of country 1;
- the generic term F^{r1} (in matrix notation $F^{r1} = V^r L^{r1} E^1$) denotes the *Foreign Value Added* (FVA) content of exports of country s generated by country r (with $r \neq 1$). Recall that the production of output by country s (part of which is exported) requires inputs from other countries. In producing these inputs, the other countries also generate value added. Hence, this term represents the share of value added that has been generated in country r (V^r) and that has been imported by country 1 (L^{r1}) in order to produce its exports (E^1).

The (column) sum of domestic and foreign value added, by construction, will yield the total exports of country 1. The other columns of the F matrix replicate the

² The notation $(NH \times 1)$ refers to the dimensions of a matrix with NH (i.e. N times H) rows and 1 column (a column-vector). The same type of notation is used throughout the paper to provide the dimensions of any matrix when relevant.

exercise for the other countries. Therefore, in column 2 of the matrix we will find the term F^{22} , which denotes the DVA content of exports of country 2, as well as the generic term F^{r2} , which denotes the FVA content of exports of country 2 generated by country r , and so on. Hence, the DVA can be read on the diagonal of the matrix as the generic term F^{rr} for any country r in the dataset.

Finally, by reading the matrix along the row rather than along the column (and excluding the diagonal terms F^{rr}), we have an indication of how much of each country’s domestic value added enters as an intermediate input in the value added exported by other countries. The latter terms are what Koopman et al. (2014) call “indirect value-added exports” (DVX). Clearly, by constructing what each country contributes to all the others in terms of indirect value-added exports has to be equal at the world level to what each country sources from all the others in terms of foreign value added, that is at the world level $FVA = DVX$. The latter gives a rough, though not perfect, proxy of the double counting embedded in the gross (official) trade figures.

Figure 2. The matrix of the value-added content of trade

	Country 1	Country 2	Country 3	...	Country K	...	Country N
Country 1	F^{11}	F^{12}	F^{13}	...	F^{1K}	...	F^{1N}
Country 2	F^{21}	F^{22}	F^{23}	...	F^{2K}	...	F^{2N}
Country 3	F^{31}	F^{32}	F^{33}	...	F^{3K}	...	F^{3N}
...
Country K	F^{K1}	F^{K2}	F^{K3}	...	F^{KK}	...	F^{KN}
...
Country N	F^{N1}	F^{N2}	F^{N3}	...	F^{NK}	...	F^{NN}

2.3. Nowcasting value added trade for more recent years

Compared to the original 2013 version, the current version of the UNCTAD-Eora database (as of August 2019) includes a nowcasting procedure to extend the time horizon covered by the GVC time-series to the most recent years. Specifically, the UNCTAD-Eora GVC results are based on reported data for the years from 1990 to 2015, and are nowcasted to estimate results for 2016, 2017 and 2018. The full MRIO elaboration is available only until 2015 because of the time lag (2-3 years) of the underlying macroeconomic data.

The nowcasting is based on estimates from the IMF's World Economic Outlook (WEO), December 2017 edition (IMF, 2017). The WEO provides estimates of the annual change of GDP, imports and exports, in each country. These estimates are provided as nowcasts for recent years (2016, 2017 and 2018 for the 2017 edition) and with 2+ year predictions for selected indicators.

The UNCTAD-Eora nowcasting of GVC indicators is performed in two stages. First, the value-added contribution from each origin country is adjusted according to their (nowcasted) change in GDP. Second, for each exporting country, resulting value-added contributions are then rescaled and normalized in order to sum the WEO nowcasted values for gross exports. In other words, the WEO GDP nowcasting determines the changes in the *distribution* of a country's export among its value-added contributors, while export nowcasting affects the change in the *level* of value-added trade. In this way, nowcasting essentially provides a simple and transparent way to project GVC indicators from actual year t to a following year $t+1$, by incorporating the macroeconomic estimates from the IMF's WEO into the standard GVC setting of section 2.2.

We may provide a formal elaboration of the procedure. The mathematical treatment presented below will be more detailed than for the standard GVC calculations illustrated in the previous section (noting that the basic computation of value added in trade is presented in a number of papers already, cited in the previous section). To this end, we also develop the formulas in the most general case of N countries and H industries.

Let F then be the final GVC matrix (2) at time t containing data from the latest observed period. For each country $r = 1, 2, \dots, N$, let $(I + \partial G)_r$ and $(I + \partial E)_r$ be diagonal ($H \times H$) matrices, reporting on the diagonal the sum between the unit and the (WEO-nowcasted) annual growth rate of GDP and export respectively, say ∂g_r and ∂e_r . In principle, of course, each industry would have its own growth rates, i.e. the elements in the diagonal of the matrices should be different. However, this is not possible in the nowcasting setting as the WEO estimates are provided only at the aggregate level.

First, we define the adjusted matrix \hat{F} .

Step 1. Value-added adjustment:

$$\hat{F} = \begin{pmatrix} \hat{F}^{11} & \dots & \hat{F}^{1N} \\ \vdots & \ddots & \vdots \\ \hat{F}^{N1} & \dots & \hat{F}^{NN} \end{pmatrix} = (I + \partial G) \times F \quad (3)$$

where $(I + \partial G)$ is a $(NH \times NH)$ block diagonal matrix with matrices $(I + \partial G)_r$, ($r = 1, 2, \dots, N$) on the diagonal, while F is the $(NH \times NH)$ block diagonal matrix

defined by (2). The generic element of the $(H \times H)$ matrices \hat{F}^{rs} ($r, s = 1, 2, \dots, N$) in (3) is then given by $\hat{f}_{i,j}^{r,s} = [v_i^r l_{i,j}^{r,s} e_j^s] * (1 + \partial g_r)$ with $i, j = 1, 2, \dots, H$. In this context, consistent with the matrix notation introduced in (2), v_i^r is the value-added share of country r in the production of product i ; $l_{i,j}^{r,s}$ is the element of the Leontief inverse matrix corresponding to the countries' pair (r, s) and industries' pair (i, j) , e_j^s is the export of product j by country s and ∂g_r the GDP growth of country r .³ At time $t+1$, the value added extracted by country r at time t , represented by the generic elements $v_i^r l_{i,j}^{r,s} e_j^s$ ($s=1, 2, \dots, N$) of the matrix F in (3), is therefore adjusted to account for economic performance of country r between t and $t+1$, as reflected by the country's GDP growth, ∂g_r .

The \hat{F} matrix in (3) potentially defines a new structure of the countries' export at time $t+1$; this is denoted by a $(NH \times NH)$ block diagonal matrix \hat{E} where each component \hat{E}^s ($s=1, 2, \dots, N$) is a $(H \times H)$ matrix reporting the exports of country s as implied by (3). Otherwise stated, the diagonal elements of \hat{E} correspond to the sums of the NH columns of \hat{F} .⁴ These elements are determined by the structure of the exports at time t , by the existing production technology at time t and by the economic growth between t and $t+1$.

In the second step of the nowcasting we incorporate in the GVC estimation the WEO information on the export's growth rates by country, ∂g_s ($s = 1, 2, \dots, N$). Let \tilde{E} be the $(NH \times NH)$ export matrix, as resulting by the application of the WEO nowcast of export growth to export at time t , i.e. $\tilde{E} = E \times (I + \partial E)$ where E is the matrix of exports at time t and $(I + \partial E)$ is a diagonal block matrix with components $(I + \partial E)_s$ ($s = 1, 2, \dots, N$).

The export structure resulting from (3) does not coincide with the one implied by the WEO nowcasting, i.e. $\tilde{E} \neq \hat{E}$. Thus, we need to normalize and rescale (3) to make sure that the resulting export at time $t+1$ is consistent with nowcast provided by the WEO.

³ More specifically, when $r = s$, the element $\hat{f}_{i,j}^{r,s}$ indicates the domestic value added extracted by country r , related to the intermediate use of domestic output i necessary to meet export levels of product j ; if $s \neq r$, it indicates the foreign value added generated by country r , related to the provision of the intermediate input i necessary to meet export of product j from country s .

⁴ Formally, for each exporting country s , the $(H \times 1)$ vector of exports implied by (3), say \hat{e}_s (the vector of the diagonal element of the matrices \hat{E}^s , is defined by $\hat{e}_s = [i^T \times \hat{F}^s]^T$ where i is a unit vector $(1 \times NH)$ and \hat{F}^s is a $(NH \times H)$ representing the value-added structure of export of country s .

Analytically, this is equivalent to calculate a new matrix \tilde{F} as follows:

Step 2. Normalization and rescaling:

$$\tilde{F} = \begin{pmatrix} \tilde{F}^{11} & \dots & \tilde{F}^{1N} \\ \vdots & \ddots & \vdots \\ \tilde{F}^{N1} & \dots & \tilde{F}^{NN} \end{pmatrix} = \hat{F} \times \hat{E}^{-1} \times \tilde{E} = \hat{F} \times \hat{E}^{-1} \times E(I + \partial E) \quad (4)$$

The first product in (4) normalizes value-added exports resulting from (3), the second rescales them in order to sum aggregate exports implied by the WEO nowcasting. The generic element of the block matrices \tilde{F}^{rs} ($r, s = 1, 2, \dots, N$) is then given by

$$\tilde{f}_{i,j}^{r,s} = \frac{\hat{f}_{i,j}^{r,s}}{\hat{e}_j^s} \times \tilde{e}_j^s = \frac{\hat{f}_{i,j}^{r,s}}{\sum_{r=1}^{H,N} \hat{f}_{i,j}^{r,s}} \times e_j^s (1 + \partial e_s).$$

It is easy to verify that the value-added shares implied by the matrix \tilde{F} is the same as for \hat{F} , i.e. $\frac{\tilde{f}_{i,j}^{r,s}}{\tilde{e}_j^s} = \frac{\hat{f}_{i,j}^{r,s}}{\hat{e}_j^s}$

for any i, j, r, s . At the same time, for each exporting country s and each industry j , the sum of value added contributed by all other countries (domestic and foreign) equals the export implied by the WEO nowcasting:

$$\sum_{i,r} \tilde{f}_{i,j}^{r,s} = \tilde{e}_j^s (\sum_{i,r} \hat{f}_{i,j}^{r,s} / \hat{e}_j^s) = e_j^s (1 + \partial e_s) (\hat{e}_j^s / \hat{e}_j^s) = e_j^s (1 + \partial e_s)$$

This nowcasting approach is simplified compared to the full procedure used to compute value added in trade for years with observed data. In particular, the lack of timely information on the sectoral composition of the economy and the corresponding disaggregation between intermediate and final use, as provided by national I/O tables, does not allow constructing a sectoral detailed MRIO such as in figure 2. The most computationally intensive steps, illustrated in section 2.1, are not possible in the nowcasting setting. Instead, the inter-country, inter-sectoral structure of the economy is fully inherited from the last year, say t , for which full macroeconomic data are available. What nowcasting does is to adjust the GVC indicators at the national level at time t to account for the changes in the (relative) economic performance of countries and the expected trend in exports, assuming no change in the underlying economic structure. We also note that there is no explicit balancing step in the nowcasting procedure, since the WEO provides balanced forecasts (e.g. growth in exports from one country is 100 per cent absorbed by growth in imports from other countries).

Table 2 provides an example of the nowcasting approach using three countries with one industry.

Table 2. Numerical example illustrating the nowcasting method

Value added (VA) originating in:	GVC indicators at time t (actual)		Nowcasted growth (WEO input)*	Intermediate step		GVC indicators at time t+1 (nowcasted)	
	VA embodied in exports	VA added shares		Adjusted value added	Adjusted value added shares	VA embodied in exports	VA added shares
Country A	700	70%	9%	763	71%	750	71%
Country B	100	10%	3%	103	10%	101	10%
Country C	200	20%	1%	202	19%	199	19%
Exports from A	1 000	100%	5%	1 068	100%	1 050	100%

* Nowcasted growth (shaded column) refers to GDP growth for the first three rows and to export growth for the last row.

3. Limitations and areas for further development

There are two main sources of uncertainty in the estimation of value-added trade data and GVC indicators. The major one, discussed in section 3.1, is related to the original construction of an MRIO, requiring modelling assumptions and computational steps. This uncertainty is common to all MRIO approaches and it stems from the complexity of the estimation problem inherent to the construction of an MRIO, i.e. reconstructing the global network of bilateral trade flows across sectors and countries in the most comprehensive and granular way. A second set of uncertainties involves more specific data issues affecting the interpretation of value-added trade data and GVC indicators (section 3.2).

3.1. Common limitations related to the construction of an MRIO

The topic of MRIO construction and reliability has been extensively discussed in the MRIO literature (Wiedman et al., 2011, Tukker and Dietzenbacher, 2013, Dietzenbacher, 2013, Tukker et al., 2018). This section is a brief, non-technical overview only.

All MRIO databases are to some degree modelled. Some portions of the databases are overdetermined, with multiple, conflicting reports, while others are underdetermined and need assumptions or modelling to fill in portions of the dataset not covered by official sources. In particular the trade blocks of an MRIO are underdetermined. Trade statistics provide data as [good/service – country of origin – absorbing country] tuples, while the MRIO database structure reports data

as [good/sector of export – country of origin – absorbing good/sector – absorbing country]. This results in trade flows at the sector-to-sector level being inferred or estimated.

The modelling and interpolation approach ranges in complexity from simple linear interpolation to more complex proxy or statistical methods. In this context, there is no “correct” global MRIO table. Rather, there is variety of models that differ in how comprehensive and detailed they are and in how they treat conflicting and missing data. In view of this uncertainty, every single data point in the Eora MRIO is accompanied by an estimate of its standard deviation, reporting the extent to which it was contested, interpolated, estimated or adjusted away from its original value in order to assemble a balanced global I/O table. A large number of reliability and confidence reports are made available on the Eora website.

The several available MRIO databases are constructed by independent research teams. It should not be expected that they agree perfectly. They generally obey similar macroeconomic constraints at the national level (total GDP, total exports, imports, consumption, and value added created), though even on these basic macroeconomic totals the MRIOs do not perfectly match. There are multiple data providers for these macro statistics (the United Nations, the World Bank, national statistics agencies) and the values are not always identical across providers. The Eora website has a page that offers a comparison of the various MRIOs in terms of their reported values for these key macroeconomic totals (<http://worldmrio.com/comparison/>).

Even if the MRIOs were constructed using identical macroeconomic constraints, there remains considerable room for variation across the independent models at the sector level. The level of aggregation/disaggregation chosen is one major cause of variation. The OECD database opts to aggregate national IO tables to a relatively high degree (to 34 sectors). The WIOD database offers higher resolution (56 sectors). This means that the national IO tables have to be reclassified, aggregated or disaggregated, in order to adjust the source national tables to match the 56 sector classification. The Eora database preserves each country's national IO table in its native classification scheme. Eora's heterogenous classifications make inter-country comparison difficult and makes the MRIO slightly more complex to assemble and use, but, as major advantage, it minimally disturbs each original national IO table. The details of how the sector-level results are constructed vary substantially across the MRIOs. The effects of sectoral aggregation are well studied (Steen-Olsen et al. 2014, de Koning et al. 2015).

A significant body of work has investigated the reliability of MRIO databases using side-by-side comparison, sensitivity analysis, and using decomposition analysis to isolate sources of divergence (Lenzen et al., 2010; Wilting, 2012; Geschke et al., 2014; Moran and Wood, 2014; Wood et al., 2014; Inomata and Owen, 2014;

Owen et al., 2014; Owen et al., 2016; Steen-Olsen et al., 2016; Owen, 2017; Tukker et al., 2018; Rodrigues et al., 2018). Together, these studies indicate that the major MRIOs agree to within +/-10 per cent for most values for most larger and structurally central economies, and to within +/-30 per cent for smaller economies or economies with less comprehensive or reliable data.

3.2. Other specific issues affecting value-added trade data

In this section we discuss some issues that proved to be particularly relevant in the economic applications of GVC data and indicators, according to our experience with UNCTAD-Eora database and feedbacks received from UNCTAD-Eora users.

Re-exports / re-imports

Re-exports refers to goods imported and then re-exported with null or negligible transformation (e.g. goods that land, are warehoused and are then shipped out). The accounting of re-exports can be problematic. Different countries may account for re-exports differently. Additionally, the value of re-exports is sometimes estimated. The estimated value of re-exports can form a significant portion of trade, in particular for trade-intensive economies such as Belgium and the Netherlands. When re-exports form a large share of imports or exports, inconsistencies in how re-exports are reported in MRIOs or, whether they are excluded entirely, can drive large divergences in the calculation of value added in trade. Eora preserves re-exports. Other databases may handle re-exports differently. In the benchmark provided in the next section, we shall see that such differences in the treatment of re-exports is a major cause of divergence in results between GVC indicators as estimated by the UNCTAD Eora and the OECD TiVA databases, in particular for trade-exposed countries such as Belgium and the Netherlands.

Processing trade

Most MRIO databases and published Chinese IO tables treat export processing as structurally identical to domestic production. They do not differentiate the technical coefficients between production for exports and production for domestic use. However, in reality, production for exports often uses more foreign imports than does production intended for domestic consumption (Dietzenbacher et al. 2012). Processing exports account for 35-50 per cent of total Chinese merchandise exports (varying by year) so this homogeneity assumption affects a substantial share of the total economic activity in China. Mexico, and likely other countries, face a similar situation whereby export-led firms operate with a different mix of inputs than their peers selling to the domestic market. It is important to differentiate export processing. Chen et al. (2018) empirically studied the importance of distinguishing

export processing zones. They conclude, “[I]f China’s processing trade is undistinguished... China’s bilateral net trade in value added with some economies, such as Japan, Korea and Taiwan, would be significantly underestimated, while it would be significantly overestimated for some other economies, such as the United States”. However, official public data on processing trade for China are currently not available, making undifferentiated treatment a necessary choice.

Re-imported domestic value added

In complex value chains it is possible that value is added in a domestic sector, the intermediary good is then exported, value is added in one or more foreign countries, and the final good is then imported back into the originating country. This is called re-imported or “feedback” value added.

Investigation of “re-imported DVA”, e.g. by Koopman (2012), shows that the latter is relatively small at the world level (though it might be slightly more significant for some countries or industries than others). Koopman et al. (2012) estimate the domestic content of foreign exports that finally return home at 4 per cent of gross exports in 2004. The results computed by Stehrer (2012), using the WIOD database, indicate at the world level a range from a minimum share of 2.6 per cent in 1995 to a maximum of 3.3 per cent in 2008, with the figure for 2009 at 2.9 per cent. The OECD/WTO initiative, in turn, estimates that the re-imported DVA equals to just 0.6 per cent of world gross exports in 2009. The magnitude of these feedback effects was also investigated by Moran et al. (2017). The study concludes that re-imported value added usually comprises 2-6 per cent of value added in imports for most countries and sectors.

* * *

Following the discussion of the issues above, it is possible to identify three areas where future development would help improve the data accuracy and reliability of the database. This list is not intended as a fully-fledged research agenda for future work but rather as a partial list of issues that merit priority.

- i. Improve results agreements across MRIO databases. Other fields have inter-comparison projects or model suite projects that help implementors identify errors and improve alignment across models.
- ii. Improve sectoral detail that will offer high sector and product level resolution in the results.
- iii. Provide more consistent treatment of re-exports and processing trade.

4. Comparison between UNCTAD-Eora and other GVC databases

While there are several studies providing comparison and cross-validation of the Eora MRIO against other MRIO databases (see section 3.1), less effort has been made to directly compare the key GVC indicators across different value-added databases. Our goal in this section is to contribute to covering this gap by investigating the consistency between the UNCTAD-Eora GVC estimates and results from other credible GVC databases, particularly the OECD TiVA. In section 4.1 we present the results of a novel comparison between the UNCTAD-Eora GVC database (version 2018) and the latest OECD TiVA database (December 2018). In section 4.2, we briefly recall the findings from two previous studies that have performed similar cross-validation, IMF's paper by Aslam et al. (2017) and UNCTAD (2013b).

Overall, all these efforts confirm a general alignment of UNCTAD-Eora GVC results with the OECD TiVA at the countries' level. This is an important, and not at all obvious, achievement given that the coverage of the UNCTAD-Eora database is higher than that of the other databases (see table 1).

4.1. UNCTAD-Eora GVC Database and the OECD's TiVA (2018 versions)

We compare results from the new UNCTAD-Eora database and the OECD TiVA (2018 versions). To run the comparison, we selected one key GVC indicator, the foreign value-added share or FVA share, i.e. the share of foreign value added in total export. This, and the corresponding domestic value-added shares, is the most basic and fundamental GVC indicator. The comparison involves those years for which both datasets report actual values, a time horizon between 2005 and 2015. The reference year for most analysis is 2015, the most recent year of comparison. Country perimeter includes all 64 countries covered by the OECD TiVA, a subset of the 189 countries covered by UNCTAD-Eora.

Figure 3 shows the correlation between FVA share from UNCTAD-Eora and the OECD TiVA for 2015. High correlation (linear correlation coefficient $\rho = 0.75$) indicates an overall consistency between the results. A slope of the linear regression line close to 1 (0.85) suggests that values of FVA shares are generally similar between the two databases. The consistency between the results is substantially preserved over time, as confirmed by figure 4a plotting FVA share across countries and years. The correlation coefficient between the two sets of data is consistently above 0.7 in all years considered (figure 4b).

Figure 3. FVA shares of UNCTAD-Eora and the OECD TiVA, 2015

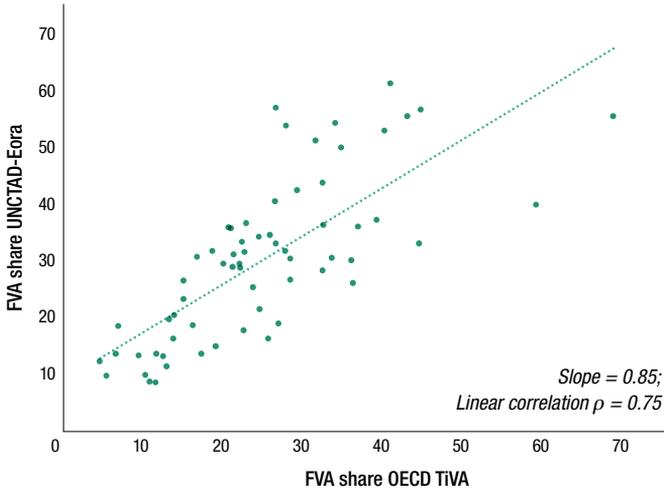


Figure 4a. FVA shares of UNCTAD-Eora and the OECD TiVA, 2005–2015

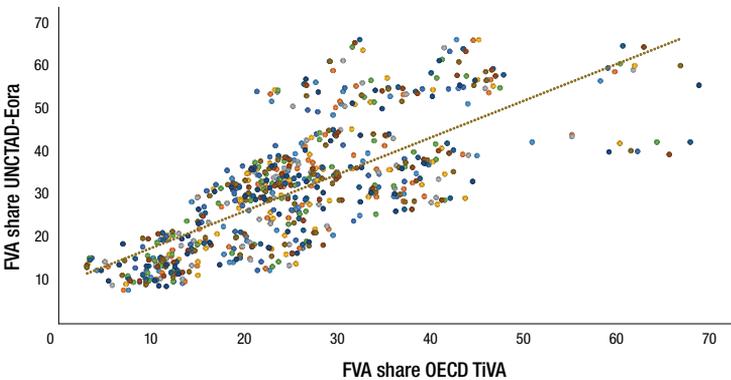


Figure 4.b. Linear correlation coefficient between UNCTAD-Eora and OECD TiVA across countries by year, 2005–2015

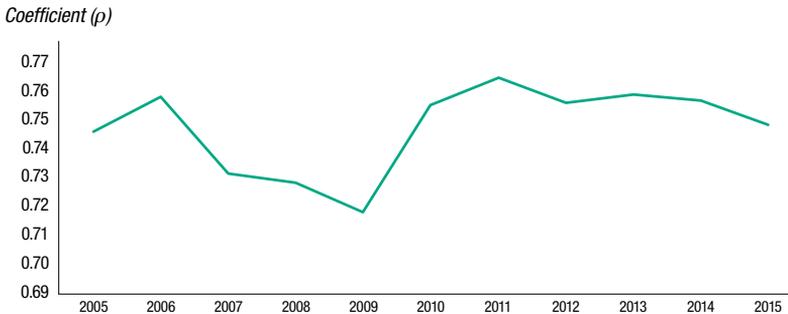
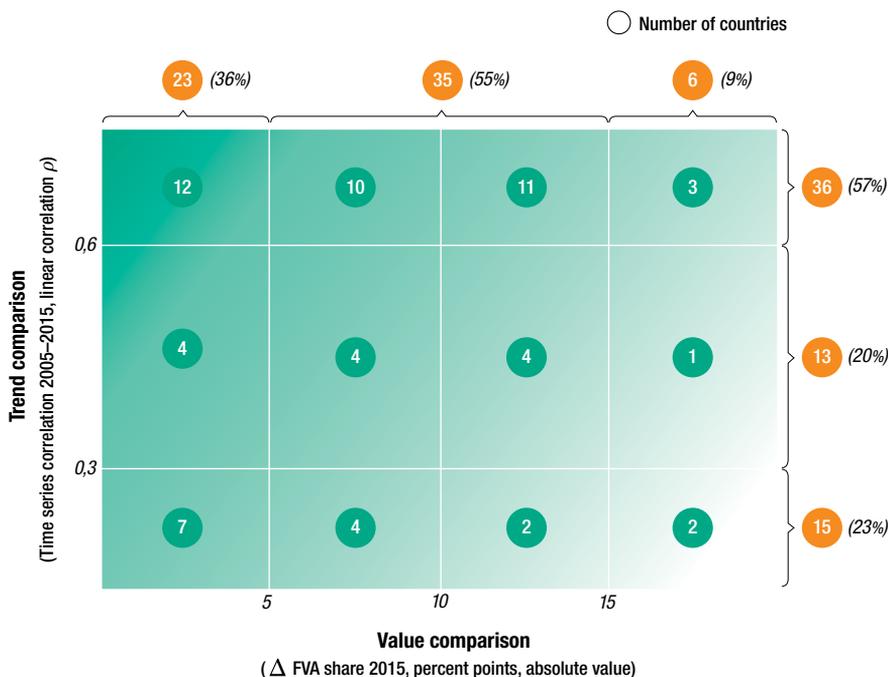


Figure 5 summarizes the results of the by-country comparison along the two critical dimensions: comparison of values (x-axis) and of trends (y-axis). Almost 60 per cent of the countries (36 out of 64) show highly consistent trends of FVA shares in the period of interest 2005–2015 ($\rho > 0.6$) and more than a third (23 countries) display similar values ($|\Delta \text{FVA share}| < 5\text{pp}$).

Figure 5. Summary of the comparison between UNCTAD-Eora and the OECD TiVA, 2005–2015

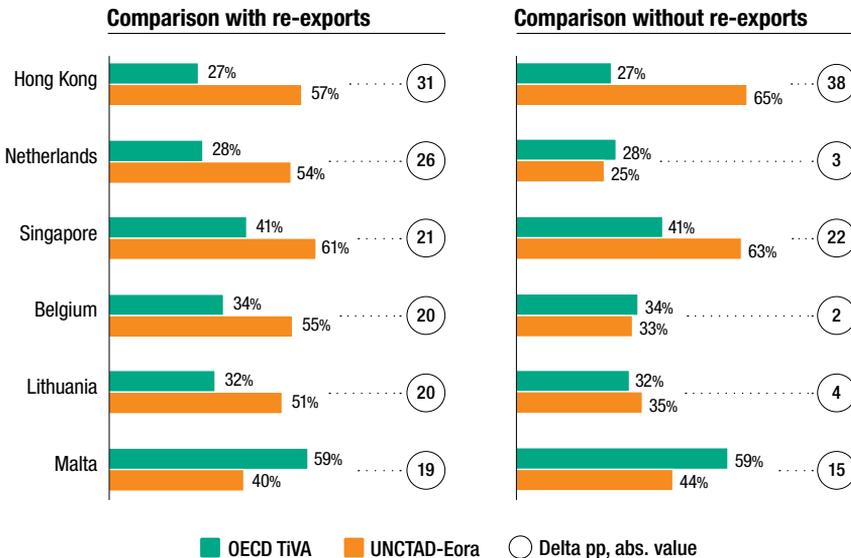


There are six countries (Hong Kong, the Netherlands, Singapore, Belgium, Lithuania and Malta) that present substantial divergence between the estimates ($|\Delta \text{FVA share}| > 15\text{pp}$). These economies, particularly Hong Kong, Netherlands, Belgium and Singapore have a large amount of imports and exports relative to their total GDP, so the challenges discussed above relating to the macro constraints of total imports and total exports, and the sector-wise attribution of value added, become especially acute. Additionally, for these countries, the difference in the treatment of re-exports between UNCTAD-Eora and the OECD TiVA (see section 3.2) may heavily affect the final estimation as high level of re-exports would amplify UNCTAD-Eora FVA share relative to the OECD TiVA. Figure 6 tests this hypothesis by comparing the two databases, both in their original form (left-hand side) and

after removing the re-export component from UNCTAD-Eora estimate. In half of the cases (the Netherlands, Belgium and Lithuania), the values of UNCTAD-Eora and the OECD TiVA substantially realign after removing re-export from the UNCTAD-Eora estimate. Hong-Kong and Singapore are somehow surprising cases as we would expect the level of re-exports to be high and relevant. These cases warrant further consideration and analysis.

More generally removing re-export from the comparison further improves the overall consistency between the UNCTAD-Eora and the OECD TiVA. For example in figure 5, the share of countries with absolute delta less than 5 percent points would increase from current 36 per cent to 58 per cent after removing the re-export component.

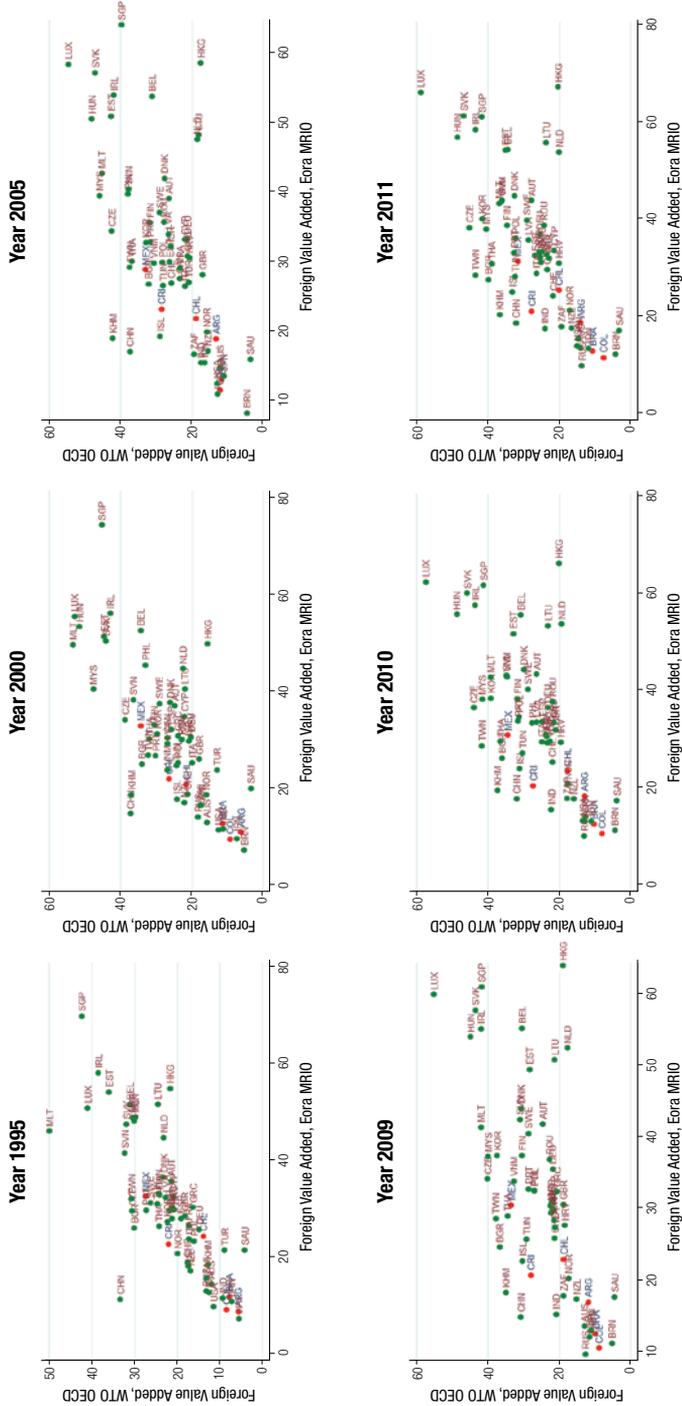
Figure 6. Comparison between FVA shares of UNCTAD-Eora and the OECD TiVA for selected (problematic) countries, with and without re-exports, 2015



4.2. Previous comparisons

The numerical comparison presented in the previous section is the most detailed cross-check of UNCTAD-Eora GVC indicators but not the only one. Here we briefly recall other two comparative analysis which generally confirm the consistency of UNCTAD-Eora with the other available GVC databases.

Figure 8. FVA shares of UNCTAD-Eora and the OECD TIVA, selected years (from Aslam et al, 2017)

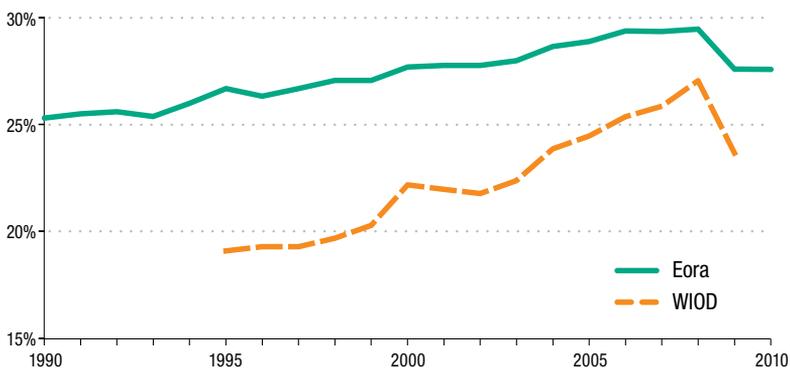


Aslam et al (2017) compare for different years the FVA shares of UNCTAD-Eora and the OECD TiVA, essentially the same exercise as figure 3 but replicated on several years. For illustrative purposes figure 8 reports some of their scatterplots, showing a substantial alignment between the two datasets similar to what we found. The authors conclude that *“Overall, the scatterplots reassure us that Eora and the OECD-WTO TiVA statistics are generally consistent with one another. Given this, we can feel somewhat more comfortable using Eora for countries for which the OECD-WTO data are not available. However, the researcher should be aware of possible problems, given the method by which the input-output table have been constructed for countries where no official supply-use tables are available. Some important country examples, such as China, Hong Kong etc. ... depending on the year, have Eora data points that are not aligned with those of the OECD-WTO”* (page 19).

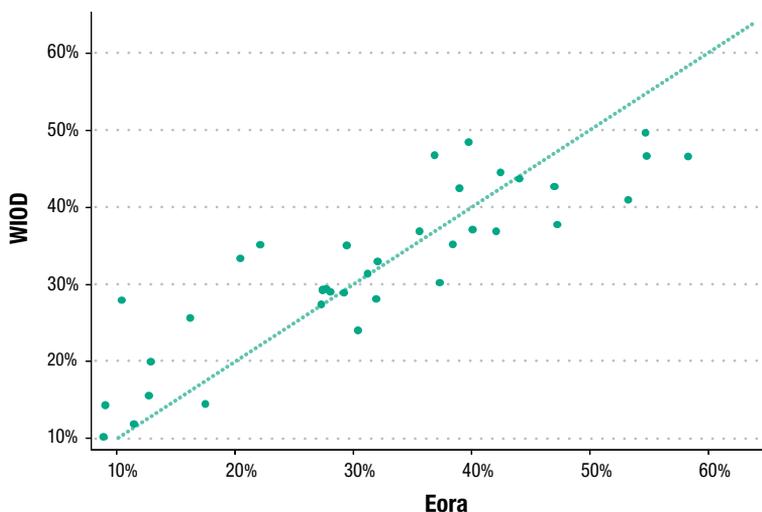
Comparison in UNCTAD (2013b), while quite limited in scope, is interesting because it uses the WIOD instead of OECD TiVA. The UNCTAD report shows that global average FVA shares estimated by UNCTAD-Eora and the WIOD are close, both in values and trends, and the difference is narrowing over time (figure 9a). Furthermore, the comparison of FVA shares at the country-level for 2009 reveals a strong correlation between data reported by UNCTAD-Eora and by the WIOD, close to 0.9, and a slope of the regression line at around 1 (figure 9b).

Figure 9. FVA shares of UNCTAD-Eora and WIOD (from UNCTAD, 2013b)

a. FVA share in exports, comparison between UNCTAD-Eora and WIOD



b. FVA share in exports by country, WIOD vs. UNCTAD-Eora, 2009



5. Concluding remarks: the importance of GVC data in the analysis of globalization

The analysis of GVCs has long occupied a central place in the analysis of trade and development. The concept gave development economists, in particular, an essential tool to examine the role of countries in the global production system and to identify opportunities for investment and growth in specific industries and value chain segments.

GVC analysis received a significant boost when data on value added in trade became available in the early part of this decade. The new data yielded many policy insights. For example, it was helpful in explaining the link between economies' openness to imports and export success; it showed the importance of services in GVCs; and it shed light on relative levels of GVC participation of, and integration between, countries and regions in the world.

The slowdown of trade growth relative to GDP growth after the global financial crisis again showed the utility of the new data as they helped to explain the factors behind the trend. At the time, GVC data could not provide all the answers, mainly because of the significant time lag inherent in most datasets. With the UNCTAD-Eora database now covering the full timespan since the financial crisis, the data show that GVCs reached an inflection point at about 2010-2012. Since then, foreign value added in exports has been stagnating after a lengthy period of continuous growth that started in 1990 (see UNCTAD, 2018, p. 22).

GVC data confirmed some important intuitions right away. A key insight was that GVCs have created an inextricable link between trade and investment. With the exchange of goods and services within the international production networks of MNEs comprising such a large part of global trade, it meant that the slowdown in global FDI flows – which today are still well below their peak level in 2007 – was a major factor behind the deceleration of global trade. The reverse is equally true; the current suite of policies designed to slow cross-border trade will have consequences for FDI. Trade and investment are two sides of the same coin – the very coin that ultimately pays for development.

The importance of GVC data as a barometer of trends in international production means the accuracy, universality and contemporaneity of the data are crucial. For these reasons, the efforts to renew and improve the UNCTAD-Eora dataset, as described in this paper, were undertaken.

The requests UNCTAD receives for GVC data are growing in number. This is in part owing to the realization among researchers that the dataset is reliable while the coverage has been expanded. The growing reliance on GVC data is also in large part the result of the current turbulence in the global policy environment for trade and investment. GVC analysis is critical to enable a serious assessment of the consequences of trade wars, including the shifting of supply chains, the effects on intra-firm trade and the potential relocation of production stages. It is also important for understanding other major global policy trends, such as the increasing reliance on regional economic cooperation, which is explained by the relatively greater importance of regional, over global, value chains.

GVC analysis is also relevant for understanding the impact of technology development on global trade and investment patterns. The digital economy and the new industrial revolution will cause important shifts in value chain-related sourcing patterns across geographies, industries and value chain segments. For policymakers, especially those in the 100+ countries that are actively pursuing industrial policies (cf. UNCTAD 2018), anticipating potential changes and identifying future opportunities for economic growth and development will be paramount.

References

- AfDB, OECD and UNDP (2014). *African Economic Outlook 2014: Global Value Chains and Africa's Industrialization*. Paris: OECD Publishing.
- Antràs, P., A. de Gortari (2017). On the Geography of Global Value Chains. *National Bureau for Economic Research, Working Paper Series No. 23456*, doi:10.3386/w23456.
- Aslam, A., N. Novta, and F. Rodrigues-Bastos (2017). Calculating Trade in Value Added, IMF Working Paper No. 17/178. Available online at <https://www.imf.org/en/Publications/WP/Issues/2017/07/31/Calculating-Trade-in-Value-Added-45114>
- Chen, Z.M., M. Lenzen, S. Ohshita, T. Wiedmann (2018). Consumption-based greenhouse gas emissions accounting with capital stock change highlights dynamics of fast-developing countries. *Nature Communications* 9, 3581.
- Chen Q., K. Zhu, P. Liu, X. Chen, K. Tian, L. Yang, C. Yang (2018). Distinguishing China's processing trade in the world input-output table and quantifying its effects. *Economic Systems Research*, 1–21, doi: 10.1080/09535314.2018.1534225.
- De Backer, K. and S. Miroudot (2013). "Mapping Global Value Chains", *OECD Trade Policy Papers*, No. 159, OECD Publishing, Paris, doi:10.1787/5k3v1trgnbr4-en.
- De Koning A, M. Bruckner, S. Lutter, R. Wood, K. Stadler and A. Tukker (2015) Effect of aggregation and disaggregation on embodied material use of products in input–output analysis *Ecological Economics* 116 pp. 289–99, doi: 10.1016/j.ecolecon.2015.05.008.
- Dietzenbacher, E., M. Lenzen, B. Los, D. Guan, M. Lahr, F. Sancho, S. Suh, C. Yang (2013). Input-Output Analysis: The Next 25 Years. *Economic Systems Research* 25, pp. 369–389.
- Dietzenbacher, E., J. Pei, C. Yang (2012). Trade, Production, Fragmentation, and China's Carbon Dioxide Emissions. *Journal of Environmental Economics and Management* 64(1). Doi: 10.1016/j.jeem.2011.12.003
- Edens B., R. Hoekstra, D. Zult, O. Lemmers, H. Wilting and R. Wu (2015) A Method to Create Carbon Footprint Estimates Consistent with National Accounts. *Economic Systems Research* pp. 1–18, doi:10.1080/09535314.2015.1048428.
- Geschke A., R. Wood, K. Kanemoto, M. Lenzen and D. Moran (2014) Investigating Alternative Approaches to Harmonise Multi-Regional Input-Output Data. *Economic Systems Research* 26 pp. 354–85, doi:10.1080/09535314.2014.937069.
- Hummels, D., J. Ishii, K.-M. Yi (2001). The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics* 54, pp. 75–96.
- IMF (International Monetary Fund) (2018). *World Economic Outlook*. IMF, Washington, DC.
- Inomata S. and A. Owen (2014) Comparative Evaluation of MRIO Databases *Economic Systems Research* 26 pp. 239–44, doi:10.1080/09535314.2014.940856.
- Johnson R.C. and G. Noguera (2016). A Portrait of Trade in Value Added over Four Decades. *National Bureau for Economic Research, Working Paper Series No. 22974*, doi:10.3386/w22974.

- Johnson R.C. and G. Noguera (2012). Fragmentation and Trade in Value Added over Four Decades. *National Bureau for Economic Research*, Working Paper Series No. 18186, doi:10.3386/w18186.
- Kitzes, J. (2013). An Introduction to Environmentally-Extended Input-Output Analysis. *Resources* 2 489–503, doi:10.3390/resources2040502.
- Koopman, R., W. Powers, Z. Wang and S.-J. Wei (2010). Give credit where credit is due: tracing value added in global production chains, *National Bureau for Economic Research*, Working Paper Series, No. 16426, doi:10.3386/w16426.
- Koopman, R., Z. Wang and S.-J. Wei (2012). Tracing Value-added and Double Counting in Gross Exports. *National Bureau for Economic Research*, Working Paper Series No. 18579, doi:10.3386/w18579.
- Koopman, R., Z. Wang, S.-J. Wei (2012). Tracing Value-added and Double Counting in Gross Exports. *National Bureau for Economic Research*, Working Paper Series No. 18579, doi:10.3386/w18579.
- Koopman, R., Z. Wang, S.-J. Wei (2008). How Much of Chinese Exports is Really Made in China? Assessing Domestic Value-Added When Processing Trade is Pervasive. *National Bureau for Economic Research*, Working Paper Series No. 14109, doi:10.3386/w14109.
- Lenzen, M., R. Wood, T. Wiedmann (2010). Uncertainty analysis for Multi-Region Input-Output models - a case study of the UK's carbon footprint. *Economic Systems Research* 22, pp. 43–63, doi: 10.1080/09535311003661226.
- Lenzen, M. and J. M. Rueda-Cantuche (2012). A note on the use of supply-use tables in impact analyses, *Statistics and Operations Research Transactions*, 36(2): pp. 139–152.
- Lenzen, M., D. Moran, A. Geschke, K. Kanemoto (2014). A Non-Sign-Preserving RAS Variant. *Economic Systems Research* 26, pp. 197–208.
- Lenzen, M., K. Kanemoto, D. Moran and A. Geschke (2012). Mapping the Structure of the World Economy, *Environmental Science & Technology*, 46(15): pp. 8374–8381.
- Lenzen, M., D. Moran, K. Kanemoto, A. Geschke (2013). Building Eora: A Global Multi-Regional Input-Output Database at High Country and Sector Resolution. *Economic Systems Research*, 25:1, pp. 20–49, doi:10.1080/09535314.2013.769938.
- Los, B., & M. Timmer (2018). *Measuring Bilateral Exports of Value Added: A Unified Framework*. Cambridge MA: NBER.
- Los, B., M.P. Timmer and G.J. de Vries (2016). Tracing Value-Added and Double Counting in Gross Exports: Comment. *American Economic Review*, 106(7), pp. 1958–1966. doi: 10.1257/aer.20140883.
- Moran, D., R. Wood, and J. F.D. Rodrigues. (2017). A Note on the Magnitude of the Feedback Effect in Multi-Region Input-Output Tables *Journal of Industrial Ecology* 22 (3). doi: 10.1111/jiec.12658.
- Moran D. and R. Wood (2014). Convergence Between the Eora, WIOD, EXIOBASE, and OpenEU's Consumption-Based Carbon Accounts *Economic Systems Research* 26 245–61 doi:10.1080/09535314.2014.935298.

- Moran, D., A. Geschke (2013). Tracing Embodied CO₂ in Trade Using High-Resolution Input-Output Tables, chapter in *Computational Intelligent Data Analysis for Sustainable Development*, T. Yu, N. Chawla, S. Simoff, Eds. (Chapman and Hall/CRC, 2013).
- Moran, D. (2013). The Eora MRIO chapter in *The Sustainability Practitioner's Guide to Multi-Regional Input-Output Analysis*, J. Murray, M. Lenzen, Eds. (Common Ground, Champagne, Illinois, 2013), pp. 66–71.
- Owen A, K. Steen-Olsen, J. Barrett, T. Wiedman and M. Lenzen (2014). A Structural Decomposition Approach to Comparing Input-Output Databases *Economic Systems Research* 26 pp. 262–83.
- Owen, A., R. Wood, J. Barrett, A. Evans. (2016). Explaining value chain differences in MRIO databases through structural path decomposition. *Economic Systems Research* 28, pp. 243–272.
- Owen, A. (2017). *Techniques for Evaluating the Differences in Multiregional Input-Output Databases A Comparative Evaluation of CO₂ Consumption-Based Accounts Calculated Using Eora, GTAP and WIOD Cham*, Switzerland, Springer International Publishing;
- Rodrigues J. F. D., D. Moran, R. Wood and P. Behrens (2018). The uncertainty of consumption-based carbon accounts. *Environmental Science & Technology*, doi:10.1021/acs.est.8b00632.
- Schaffartzik, A., M. Sachs, D. Wiedenhofer, N. Eisenmenger (2014). Environmentally Extended Input-Output Analysis.. ISSN 1726-3816. Available online at https://worldmrio.com/pdf/Schaffartzik_IntroToEEMRIO.pdf.
- Steen-Olsen K, A. Owen, E.G. Hertwich and M. Lenzen (2014). Effects of Sector Aggregation on CO₂ Multipliers in Multiregional Input-Output Analyses. *Economic Systems Research* 26.
- Steen-Olsen K., A. Owen, J. Barret, D. Guan, E. Hertwich, M. Lenzen, T. Wiedmann (2016). Accounting for value added embodied in trade and consumption: an intercomparison of global multiregional input–output databases. *Economic Systems Research* 28, doi:10.1080/09535314.2016.1141751.
- Stehrer, R., N. Foster and G. de Vries (2012). Value Added and Factors in Trade: A Comprehensive Approach, wiiw Working paper 80, Vienna.
- Södersten, C.J., R. Wood, E. G. Hertwich (2018). Endogenizing Capital in MRIO Models: The Implications for Consumption-Based Accounting. *Environmental Science & Technology*, doi:10.1021/acs.est.8b02791.
- Timmer, M., B. Los, and G. de Vries, G. (2016). The Rise of Global Manufacturing Value Chains: A New Perspective Based on the World Input-Output Database. In D. W. Jorgenson, K. Fukao, & M. P. Timmer (Eds.), *The World Economy: Growth or Stagnation?* (pp. 535-563). Cambridge, United Kingdom, Cambridge University Press.
- Timmer, M., B. Los, R. Stehrer, G. de Vries (2012). Fragmentation, Incomes and Jobs. An analysis of European competitiveness, WIOD Working Paper 9, Groningen.
- Tukker A. and E. Dietzenbacher (2013). Global Multiregional Input-Output Frameworks: An introduction and Outlook. *Economic Systems Research* 25(1) pp. 1–19.

- Tukker A., A. de Koning, A. Owen, S. Lutter, M. Bruckner, S. Giljum, K. Stadler, R. Wood, R. Hoekstra (2018). Towards Robust, Authoritative Assessments of Environmental Impacts Embodied in Trade: Current State and Recommendations. *Journal of Industrial Ecology* 22, doi:10.1111/jiec.12716.
- UNCTAD (2013a). *World Investment Report 2013: Global Value Chains: Investment and Trade for Development*. New York and Geneva: United Nations.
- UNCTAD (2013b). Global Value Chain and Development. *Working paper*. https://unctad.org/en/PublicationsLibrary/diae2013d1_en.pdf.
- UNCTAD Secretariat (2015). UNCTAD-EORA Global Value Chain Database: methodology and further research agenda. *Transnational Corporations* 21(3). https://unctad.org/en/PublicationsLibrary/diaeia2014d1_en.pdf.
- UNECA (2015). *Economic Report on Africa 2015: Industrializing Through Trade*. Addis Ababa: United Nations Economic Commission for Africa.
- UNIDO (2016). *Industrialization in Africa and Least Developed Countries: Boosting Growth, Creating Jobs, Promoting Inclusiveness and Sustainability*. Vienna: United Nations Industrial Development Organization.
- Wang, Z., S.-J. Wei and K. Zhu (2013). Quantifying International Production Sharing at the Bilateral and Sector Levels. *National Bureau for Economic Research, Working Paper Series* No. 19677, doi:10.3386/w19677.
- Wang, Z., S.-J. Wei, X. Yu and K. Zhu (2017a). Measures of Participation in Global Value Chains and Global Business Cycles. *National Bureau for Economic Research, Working Paper Series* No. 23222 (2017a), doi:10.3386/w23222.
- Wang, Z., S.-J. Wei, X. Yu and K. Zhu (2017b). Characterizing Global Value Chains: Production Length and Upstreamness. *National Bureau for Economic Research, Working Paper Series* No. 23261, doi:10.3386/w23261.
- Wiedmann, D., H. C. Wilting, M. Lenzen, S. Lutter and V. Palm (2011). Quo Vadis MRIO? Methodological, data and institutional requirements for multi-region input-output analysis. *Ecological Economics* 70, pp. 1937–1945.
- Wilting, H. C. (2012). Sensitivity and uncertainty analysis in MRIO modelling; Some empirical results with regard to the Dutch Carbon footprint. *Economic Systems Research* 24, pp. 141–171.
- Wood R., T. Hawkins, E. Hertwich and A. Tukker (2014). Harmonizing National Input-Output Tables for Consumption Based Accounting – Experiences in EXIOPOL. *Economic Systems Research* 26.
- Xing, Y. (2014). Measuring Value Added in the People's Republic of China's Exports: A Direct Approach. ADBI Working Paper 493. Tokyo: Asian Development Bank Institute. Available at: <http://www.adbi.org/working-paper/2014/08/06/6372.measuring.value.added.prc.exports/>.