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Making Global Value Chain Research More Accessible

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Abstract

Global value chains research has generated a resurgence in Leontief-style input-output analysis, since the introduction of publicly available international input-output (IIO) tables. This paper is designed to clearly present Leontief concepts and applications for international economists who may be largely unaware of these techniques. We present an overview of the structure of IIO tables and related analysis of the sources of value flowing through global production networks. We also provide the methodology to calculate flows to and from specific sectors and regions, with results and code for several examples.

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1. Introduction

The analysis of which countries contribute value to products that are traded in global production networks has important economic implications. The role that a country's firms play in these networks can alter the effects of trade policy and the transmission of global supply and demand shocks. International input-output (IIO) tables can identify the sources and destinations of value that flows through global value chains (GVCs), and identifies the roles countries and industries play in global supply chains and the sources of competitiveness (OECD-WTO, 2012). The analysis of GVCs with IIO tables began with Belke and Wang (2005) and Daudin et al. (2006), and the number of studies has grown markedly as IIO tables have become more widely available. Current analyses rely on international data sources such as the World Input-Output Database (WIOD), the UNCTAD Eora GVC database, the OECD Trade in Value Added (TiVA) database, the Institute of Developing Economies (IDE-JETRO) Asian Input-Output tables, as well as the extensions of Global Trade Analysis Project (GTAP) data.

Although the analytical techniques underpinning these studies were pioneered by Leontief in the 1940s, these techniques have been mainly applied to national accounts but have seen little use in international economics.[2] One aim of this paper is to bridge the gap between the fields of national accounts statistics and international trade. This paper also demonstrates the flexibility of GVC analysis with several examples quantifying how upstream countries and sectors supply value to downstream users in other countries. These examples extend and generalize the approaches in recent papers such as Johnson and Noguera (2012), Stehrer (2012), Lenzen et al. (2013), and OECD (2013) that measure value embodied in flows of final goods and services.

This paper is organized as follows. Section 2 provides an overview of the GVC methodology used to measure value-added flows. Section 3 compares the IIO databases currently used in the literature. Section 4 provides five examples of the connection between specific upstream sources and downstream destinations of value, with estimates based on the WIOD tables for 2009. Section 5 concludes. Appendix A provides STATA and SAS code for each of the examples in section 4.

2. Methodology

The measures discussed in this paper are based on IIO tables, which trace the international sources of value added embodied in goods and services produced throughout the world. They are derived from (i) individual countries' national account statistics (supply-use tables or input-output tables) integrated with (ii) bilateral trade data and (iii) information or assumptions about the sourcing of international intermediate inputs by using industries. Figure 1 provides the structure of a general IIO table with 2 countries and N sectors.

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[2] CGE models and economic geography models also make use of IO tables to describe upstream-downstream relationships, though require less information on the sourcing of international inputs. The literature on outsourcing includes the sourcing of international inputs, but does not use input-output tables. Trefler and Zhu (2010) is a rare exception that incorporates both concepts.

FIGURE 1 A two-country IIO table

			Intermediate use		Final Use		Total use
			Country 1 $1 \cdots N$	Country 2 $1 \cdots N$	Country 1	Country 2	
Supply	Country 1	1 ⋮ N	1's use of its own inputs	2's use of inputs from 1	1's use of its own final goods	2's use of final goods from 1	1's total output
	Country 2	1 ⋮ N	1's use of inputs from 2	2's use of its own inputs	1's use of final goods from 2	2's use of its own final goods	2's total output
	Value added		1's value added	2's value added			
	Total supply		1's total output	2's total output			

Source: Powers (2012)

As discussed in Powers (2012), rows in the table indicate how and where products are used. For example, the top row indicates global use of product 1 produced in country 1, including intermediate inputs used by each industry and final good demanded in each country. The leftmost column indicates the total inputs from country 1 and country 2, plus value-added in country 1, that must be supplied to produce the total output of product 1 in country 1. Value added consists of value generated by primary factors, and is equal to compensation of workers plus payments to capital.[3] Both rows and columns sum to the value of total output, since the sum of all uses of a product must equal the value of all inputs (including value added) in that product.

As indicated in figure 1, all output must be used as an intermediate or final good at home or abroad. Hence, production in a general IIO table with G countries and N sectors is given by

$$X = AX + F, \tag{1}$$

where X is the GNx1 vector of gross output, consisting of stacked vectors of gross output for each country. The N×1 vector X_i denotes gross output of country i in each sector:

$$X = \begin{bmatrix} X_1 \\ \vdots \\ X_G \end{bmatrix}$$

The GN×GN matrix A provides the direct intermediate input-output coefficients, where A_{ij} denotes the N×N matrix giving direct use of inputs supplied by each sector of country i in each sector of country j.

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[3] As well as taxes on production and imports, less subsidies.

$$A = \begin{bmatrix} A_{11} & \cdots & A_{1G} \\ \vdots & \ddots & \vdots \\ A_{G1} & \cdots & A_{GG} \end{bmatrix}$$

Final demand is given by the GN×1 matrix F, which gives world demand for final goods. The N×1 vector F_i denotes the value of final goods produced in country i.

$$F = \begin{bmatrix} F_1 \\ \vdots \\ F_G \end{bmatrix}$$

The examples in section 4 will disaggregate F into final goods supplied to specific destinations, where $F_i = \sum_j F_{ij}$. Further, $F_{ij} = D_{ij} + E_{ij}$, or

$$\begin{bmatrix} F_{11} & \cdots & \cdots & F_{11} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ F_{G1} & \cdots & \cdots & F_{GG} \end{bmatrix} = \begin{bmatrix} D_{11} & 0 & \cdots & 0 \\ 0 & D_{22} & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & D_{GG} \end{bmatrix} + \begin{bmatrix} 0 & E_{12} & \cdots & E_{1G} \\ E_{21} & 0 & & \vdots \\ \vdots & & \ddots & E_{G-1G} \\ E_{G1} & \cdots & E_{GG-1} & 0 \end{bmatrix}, \qquad (2)$$

where D_{ii} is the N×1 vector of final goods and services produced and consumed domestically, and E_{ij} denotes the N×1 vector of final goods and services produced in i and exported to (and consumed in) country j.

We can express equation (1) as

$$X = (I - A)^{-1}F = BF, \qquad (3)$$

where B is the GN×GN "Leontief inverse" matrix. Elements of this matrix express the total output, used both directly and indirectly, required to produce \$1 of final goods and services. As with the direct coefficient matrix A, the Leontief inverse matrix B is composed of N×N submatrixes B_{ij} that denote the value of output used in each sector of country i to produce final goods in each sector of country j.

IIO analysis traces the flow of value added from the source sector to the final consumer. Value added is described by V, the 1×GN vector giving the amount of value contributed directly by primary factors per dollar of output. The 1×N vector V_i gives value-added in the sectors of country i.

$$V = [V_1 \quad \cdots \quad V_G]$$

Premultiplying equation (3) by V produces global GDP, a scalar, which implicitly includes all flows of value from source sectors to final consumers.

$$VX = VBF \qquad (4)$$

Section 4 slices these global flows of value into progressively more detailed examples, but first we provide information on the available databases used for IIO analysis in the literature.

3. Available IIO databases

Currently, the most widely used IIO tables are produced by WIOD, the OECD-WTO, Eora MRIO, and IDE-JETRO. Several research teams have also extended the GTAP database for use in IIO analysis. Datasets differ in their method of construction and data sources. For example, some tables are based on input-output tables contributed by individual researchers, others are based on official input-output tables, and yet others are based on official supply-use tables. The method and information available to allocate imported intermediate inputs to using sectors also differ by source. Datasets also differ in their coverage of countries, sectors, and years. Table 1 summarizes the four major IIO databases, including three papers based on GTAP. For an analysis of the extent to which the underlying coefficients differ among datasets, see Degain et al. (2013) and UNCTAD (2013a).

TABLE 1 Global IIO databases

Database	Data sources	Countries/regions	Sectors	Years
World Input-Output Database (WIOD)	National supply-use tables	40	35	1995-2009
OECD-WTO TiVA database	National input-output tables	58 plus China processing trade	37	1995, 2000, 2005, 2008, 2009
UNCTAD-Eora GVC Database	National and regional supply-use and I-O tables plus estimates from UN sources	187	25	1990-2010
GTAP	I-O tables submitted by GTAP members			
• Daudin et al. (2011)		66 or 113	55	1997, 2001, 2004
• Johnson and Noguera (2012)		94	57	2004
• Koopman, Wang, and Wei (2013)		26	41	2004

WIOD

Funded by the European Commission from 2009 to 2012, the WIOD Project developed the WIOD tables for the analysis of the dynamic interrelatedness of countries and industries. The WIOD database includes 27 EU members and 13 other major economies. It covers 35 sectors and all years from 1995 to 2009. Timmer (2012) provides more information on the contents, sources, and methods of the database. WIOD was the first freely available IIO database, and is available for download at www.wiod.org.

OECD-WTO TiVA database

The OECD and WTO jointly developed an IIO database to understand international trade in the context of global production networks and to identify the sources of competitiveness. The latest version was released in May and June 2013. The OECD TiVA database includes IIO tables for 58 countries and 37 sectors. It includes the years covered by the OECD national input-output tables (1995, 2000, and 2005) plus extensions to 2008 and 2009. To better estimate value added in Chinese production and trade, the database includes additional input-output tables for three types of economic activity in China: processing trade, ordinary trade, and domestic-only enterprises. The WTO and OECD describe their IIO and TiVA measures in WTO-

OECD (2012). Although the database is not publicly distributed, TiVA measures based on the IIO tables are available at www.stats.oecd.org.

UNCTAD-Eora GVC database

UNCTAD and Eora MRIO have produced an IIO with a developing country perspective, including the most countries in any IIO table to date. The underlying Eora MRIO database provides a time series of input-output tables with matching environmental and social satellite accounts for 187 countries for 1990–2011. Eora includes data at a very detailed level for many countries (at the level provided by national statistical offices). Standard IIO calculations require a balanced table, however; hence, the UNCTAD-Eora GVC database contains only 25 harmonized sectors. Although UNCTAD-Eora has the most extensive country coverage of any IIO table, input-output tables for many of these countries are not available and have been estimated from the UN System of National Accounts and other more aggregated data. Lenzen et al. (2013) describes the construction of the underlying Eora database, and UNCTAD (2013a, 2013b) describe the related UNCTAD-Eora database.

GTAP database

As GTAP predates the other IIO tables, it was the source of the original GVC studies in the literature such as Daudin et al. (2006), Johnson and Noguera (2012), and Koopman et al. (2011). As GTAP does not contain information on the use of imported intermediate inputs by sector, researchers have applied various versions of the proportionality assumption to estimate such use. The latest GTAP version (v. 8) has both 2004 and 2007 data, with 57 sectors and 129 countries or regions. Early studies relied on GTAP v. 7, with 2004 data, and GTAP v. 6, with 2001 data; these versions also have 57 sectors but include fewer countries. In general, GTAP-based GVC studies have not included the full dimensionality of the GTAP dataset. For those interested in constructing an IIO table from GTAP, Gehlhar, Tsigas, and Wang (2012) provides a detailed example.

4. Examples

This section provides selected examples that show the different ways to implement the GVC analysis in order to obtain more granular value flows. Generally, we are interested in value added flows in a specific sector in specific countries for a specific final demand (i.e. automotive sector in the United States, electronic exports from China, etc.). To that end, we can modify the components of equation (6) and (7), mainly V and F (D and E), so that only the value added flows which we are interested in are calculated and reflected in the result. For each example, we provide the calculated values from the WIOD IIO table for 2009.

4.1. Calculation of each country's GDP

As with global GDP, we can calculate each country's GDP as the total contribution from factors in all of its sectors to final goods and services consumed in all destinations (both at home and abroad), as shown in equation (5). By shaping the value-added matrix in the appropriate way, we can calculate all countries' GDPs simultaneously. Each row of the G×GN value-added matrix

in equation (5) contains a single country's 1×N V_i vector, with zeros in all other elements.[4] Although it is not necessary to calculate GDP in this manner (GDP can be determined directly from value added in the IIO table), this calculation provides a useful check of GVC concepts and a foundation for the further disaggregation presented below.

$$
\begin{bmatrix} GDP_1 \\ \vdots \\ \vdots \\ GDP_G \end{bmatrix} = \begin{bmatrix} V_1 & 0 & \cdots & 0 \\ 0 & V_2 & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & V_G \end{bmatrix} \begin{bmatrix} B_{11} & \cdots & \cdots & B_{1G} \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ B_{G1} & \cdots & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} F_1 \\ \vdots \\ \vdots \\ F_G \end{bmatrix}
\tag{5}
$$

Table 2 provides the GDP for each country in the 2009 WIOD table estimated with equation (5).

TABLE 2 GDP, billion U.S. dollars

Country	GDP	Country	GDP
Australia	983.3	Italy	2,015.6
Austria	367.7	Japan	4,934.6
Belgium	456.0	Korea	820.1
Bulgaria	42.9	Lithuania	34.5
Brazil	1,503.0	Luxembourg	51.0
Canada	1,290.6	Latvia	24.6
China	5,065.3	Mexico	865.9
Cyprus	21.8	Malta	7.6
Czech Republic	185.5	Netherlands	765.6
Germany	3,167.4	Poland	414.0
Denmark	286.7	Portugal	220.6
Spain	1,427.7	Romania	155.9
Estonia	17.8	Russia	1,137.5
Finland	224.1	Slovak Republic	86.3
France	2,532.4	Slovenia	46.3
Great Britain	2,111.8	Sweden	381.3
Greece	307.1	Turkey	586.6
Hungary	120.2	Taiwan	370.8
Indonesia	566.5	USA	14,174.5
India	1,351.7	Rest of World	7,502.1
Ireland	215.6	World[a]	56,840.3

Source: WIOD, 2009.

[a] Calculated with equation (4).

4.2. Canadian value added in U.S. final goods and services imports from the world

GVC analysis can estimate the value added generated in one country that is absorbed in final goods imported into another country. This value may travel directly or take a circuitous route through multiple sectors and across multiple borders. The example in equation (6) estimates the amount of Canadian value added that is absorbed in U.S. imports of final goods from all countries. This example uses a 1×GN value-added matrix, the standard GN×GN Leontief inverse matrix, and a GN×1 vector of all countries' exports to the United States. In the value-added

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[4] Note this is not the GN×GN diagonalized V matrix, which if inserted into equation (5) would produce the value added generated in each sector for each country.

matrix, all elements other than the 1×N subvector of Canadian value added are replaced with zeros.

$$[0 \ \ldots \ 0 \ \ V_{CAN} \ \ 0 \ \ldots \ 0] \begin{bmatrix} B_{11} & \cdots & B_{1G} \\ \vdots & \ddots & \vdots \\ B_{G1} & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} E_{1 \ USA} \\ \vdots \\ E_{G \ USA} \end{bmatrix} \tag{6}$$

The approach of all examples in this paper is to employ the standard, full Leontief inverse matrix, while adjusting the value-added and final demand matrices to reflect the desired source and destination sectors. Other calculations will produce the same results, however. Equation (6') presents an alternative calculation for this value-added flow which replaces non-Canadian rows of the B matrix with zeroes. This approach is taken in the code provided for Koopman et al. (2013), for example.

$$[V_1 \ \cdots \ V_G] \begin{bmatrix} 0 & \cdots & 0 \\ \vdots & & \vdots \\ 0 & \cdots & 0 \\ B_{CAN \ 1} & \cdots & B_{CAN \ G} \\ 0 & \cdots & 0 \\ \vdots & & \vdots \\ 0 & \cdots & 0 \end{bmatrix} \begin{bmatrix} E_{1 \ USA} \\ \vdots \\ E_{G \ USA} \end{bmatrix} \tag{6'}$$

Based on WIOD data, value added from Canada accounted for \$60.7 billion (8.0%) of the \$758.8 billion of final goods and services imported by the United States in 2009.

4.3. Canadian value added in U.S. final demand

A related estimate is the value added generated in one country that is absorbed in final goods consumed in another country. As in the previous example, value could be embodied in final goods that are imported directly or indirectly after processing in third countries. In addition, value may be embodied in imported intermediate inputs that are processed into final goods and consumed in the destination country. Hence, this calculation includes foreign value in final goods from both imported and domestic sources.

Equation (7) estimates the value added by Canada in all final goods consumed in the United States, including those it produces domestically with Canadian intermediate inputs. This example uses a 1×GN value-added matrix, the standard GN×GN Leontief inverse matrix, and a GN×1 vector of final demand.

$$[0 \ \ldots \ 0 \ \ V_{CAN} \ \ 0 \ \ldots \ 0] \begin{bmatrix} B_{11} & \cdots & B_{1G} \\ \vdots & \ddots & \vdots \\ B_{G1} & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} F_{1 \ USA} \\ \vdots \\ F_{G \ USA} \end{bmatrix} \tag{7}$$

Based on WIOD data, value added from Canada accounted for \$161.3 billion (1.1%) of the \$14,491.8 billion of final goods and services consumed by the United States in 2009.

4.4. The Canada-U.S. value-added trade balance

Many studies have estimated bilateral trade balances in value-added terms (see USITC, 2011, WTO and IDE-JETRO, 2011, and Johnson and Noguera, 2012). Although the balance of trade in standard ("gross") terms depends on values that are *shipped* between the two countries, the balance of trade in value-added terms depends on the values that are *consumed* in the two countries.[5] Equation (8) provides the Canada-U.S. trade balance in value-added terms, which consists of equation (7) and its converse.

$$TB_{CAN\ US} =$$

$$[0 \ \dots \ 0 \ V_{CAN} \ 0 \ \dots \ 0] \begin{bmatrix} B_{11} & \cdots & B_{1G} \\ \vdots & \ddots & \vdots \\ B_{G1} & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} F_{1\ USA} \\ \vdots \\ F_{G\ USA} \end{bmatrix} -$$

$$[0 \ \dots \ 0 \ V_{USA} \ 0 \ \dots \ 0] \begin{bmatrix} B_{11} & \cdots & B_{1G} \\ \vdots & \ddots & \vdots \\ B_{G1} & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} F_{1\ CAN} \\ \vdots \\ F_{G\ CAN} \end{bmatrix} \qquad (8)$$

Based on WIOD data, the 2009 value-added trade balance between Canada and the United States is $32.0 billion—representing a trade surplus for Canada and deficit for the United States. This value is smaller than the 45.5 billion gross bilateral trade balance. For each country, domestic value added consumed in the other country accounts for about 70% of total gross exports.[6] Hence, the value added trade balance is also about 70% of the total trade balance.

4.5. Mexican value added in U.S. transport equipment exports to the world

GVC calculations can also determine the value added contained in exports of final goods and services from specific sectors. When examining sectoral value added flows, it is important to distinguish between (i) value created by factors in a specific sector that may be exported through multiple downstream sectors, and (ii) value exported from a specific sector that may include value created in multiple upstream sectors.

Equation (9) provides an example of the second of these types of flows of value added. Production of transport equipment uses inputs from multiple sectors, such as business and professional services, fabricated metal, electronics, and parts from the transportation equipment sector itself. Production is also tightly integrated in North America, with value flowing through multiple countries, particularly for motor vehicles.[7] For example, U.S. companies may add value to motor vehicle parts, which are sent to Mexico for further processing, sent back to the United States for final assembly, and subsequently exported as finished automobiles to Canada. In these supply chains, each country's value potentially crosses borders multiple times before ultimately residing in a finished product. Equation (9) calculates

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[5] Value added in exports of intermediate goods that are not consumed in the receiving country are part of gross trade balances but do not enter into the value-added trade balance calculation.

[6] This share is unusually low for the United States, reflecting substantial Canadian value added returning home in these exports; the U.S. value-added-to-gross-trade ratio is about 90% with countries outside of North America.

[7] WIOD does not distinguish motor vehicles from the wider transportation equipment sector. To focus on motor vehicles specifically, we would need to use tables such as those from the WTO-OECD, which have not yet been publicly released.

Mexican value in U.S. exports of finished transport equipment, capturing all value from Mexican sectors, which may have crossed borders multiple times due to the back-and-forth nature of production in the sector.

As in previous examples, equation (9) uses a 1×GN value-added matrix, including value for only a single country, and the standard GN×GN Leontief inverse matrix. Unlike previous examples, the GN×1 export vector contains only a single nonzero element.

$$[0 \cdots 0 \ V_{MEX} \ 0 \cdots 0] \begin{bmatrix} B_{11} & \cdots & B_{1G} \\ \vdots & \ddots & \vdots \\ B_{G1} & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} 0 \\ \vdots \\ 0 \\ E_{USA}^{transport} \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad (9)$$

The N×1 vector $E_{USA}^{transport}$ includes only U.S. exports of transportation equipment to the world.

$$E_{USA}^{transport} = \begin{bmatrix} 0 \\ \vdots \\ 0 \\ e_{USA}^{transport} \\ 0 \\ \vdots \\ 0 \end{bmatrix}$$

Based on WIOD data, in 2009 the United States exported $83.9 billion of final products in the transport equipment sector, in which value added by Mexico accounted for only $1.5 billion (1.8%). In the reciprocal calculation, in 2009 Mexico exported $27.5 billion of finished transport equipment, in which value added by the United States accounted for $3.7 billion (13.4%), a substantially higher share of the total.

4.6. Value added by the EU27 service sectors in U.S imports from the world

Services trade in GVCs is attracting increasing attention, as services can be substantial inputs into goods trade as well as trade in other services. For example, Miroudot and Rouzet (2013) report that in the OECD, services contributed over 30% of the total value added in manufactured goods, and Timmer et al. (2012) estimate that in the EU, 50% of jobs in manufacturing GVCs are outside the manufacturing sector.

Equation (10) presents an example that estimates the value created by productive factors in services sectors that is embodied in trade, whether directly or indirectly. It identifies the value added generated in services sectors from all 27 EU countries that is ultimately embodied in U.S. imports. A similar method could be used to determine value created in goods sectors.

Unlike previous examples, equation (10) uses a 1×GN value-added matrix that includes value from only service sectors in EU countries. However, it still uses the standard GN×GN Leontief inverse matrix, and a GN×1 vector of all countries' exports to the United States.

$$[0 \ \dots \ 0 \ V_{EU1}^{services} \ \dots \ V_{EU27}^{services} \ 0 \ \dots \ 0] \begin{bmatrix} B_{11} & \cdots & B_{1G} \\ \vdots & \ddots & \vdots \\ B_{G1} & \cdots & B_{GG} \end{bmatrix} \begin{bmatrix} E_{1\,USA} \\ \vdots \\ E_{G\,USA} \end{bmatrix}, \qquad (10)$$

where the 1×N vector $V_{EUi}^{services}, i \in 1 \dots 27$, for each EU country includes nonzero elements only in the S services sectors.

$$V_{EUi}^{services} = [0 \ \dots \ 0 \ v_{EUi}^{services\,1} \ v_{EUi}^{services\,2} \ \dots \ V_{EUi}^{services\,S}]$$

Based on the WIOD table, in 2009 the EU services sectors contributed $24,189.2 billion in value to overall world production, and of that, $83.4 billion was captured in U.S. imports.

5. Conclusion

This note extends the usefulness of the publically available IIO tables and provides examples that illustrate a variety of value added flows. By modifying to the value added and final demand vectors in the value added calculations, we can estimate the contribution of specific countries and industries, and trace value to specific destination countries and sectors. The changes allow us to make granular observations of contributions to country and global production. And as IIO tables grow and evolve, so too, shall the flows that this analysis is able to calculate. Because the basis of the calculation is simple matrix multiplication, implementation only requires statistical packages that have methods of handling matrices. We hope that this will increase the accessibility of GVC analysis and spur further research in the area of trade in value added.

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Appendix

This appendix provides STATA and SAS code for the examples given above. The following code assumes that the V, A, and F matrices have been created as separate data files.

A.1 Calculation of global GDP

This section provides code for the calculation of global GDP in equation (4).

Stata Code

```
* In each file, Australia (aus) is the first country and the Rest of the World (row) represents country G.
* The V and A dta files each contain GN number of variables, one for each country and sector
*    (identified by variable names), which are to be converted into a matrix
version 13.1
use "V.dta", replace
mkmat aus_sec1-row_sec35, matrix(V)
use "A.dta", replace
mkmat aus_sec1-row_sec35, matrix(A)
* The F dta file contains G variables, one for each country's final demand;
*   they are combined into a vector of world final demand which is then converted into a matrix
use "F.dta", replace
egen double totalfinaluse = rowtotal(ausfinaluse-rowfinaluse)
mkmat totalfinaluse, matrix(F)
* Run the value chain equation
local isize = rowsof(A)
matrix B= inv(I(`isize')-A)
matrix Wgdp = V*B*F
clear
* Create a dataset from the matrix Wgdp (which is held in memory)
svmat double Wgdp
```

SAS Code

```
Proc iml;
Use A;
Read all var _all_ into A;
Use V;
Read all var _all_ into V;
Use F;
Read all var _all_ into F;
isize=I(nrow(A));
B= inv(isize-A);
WorldGDP=V*B*F;
Create worldgdp from WorldGDP;
Append from WorldGDP; /*create dataset from the matrix worldGDP*/
Quit;
```

A.2 Calculation of each country's GDP

This section provides code for the calculation of each country's GDP in equation (5).

Stata Code

* In each file, Australia (aus) is the first country and the Rest of the World (row) represents country G,
*   and there are 35 sectors.
* The V and A .dta files each contain GN number of variables, one for each country and sector,
*   which are to be converted into a matrix.

```
use "V.dta", replace
mkmat aus_sec1-row_sec35, matrix(V)
use "A.dta", replace
mkmat aus_sec1-row_sec35, matrix(A)
```

* The F .dta file contains G variables, one for each country's final demand;
*   they are combined into a vector of world final demand which is then converted into a matrix.

```
use "F.dta", replace
egen double totalfinaluse = rowtotal(ausfinaluse-rowfinaluse)
mkmat totalfinaluse, matrix(F)
```

* This code works to reshape V so that there is one row for each country.
* The dimension of the following diagonal matrix is 1435x1435,
*   which is the product of 35 countries and 41 sectors

```
matrix diagV = diag(V)
svmat double diagV
collapse (sum) diagV1-diagV1435, by (country)
mkmat diagV1-diagV1435, matrix(V2)
keep country
```

* Run the value chain equation

```
local isize = rowsof(A)
matrix B= inv(I(`isize')-A)
matrix country_gdp = V2*B*F
clear
```
* Create a dataset from the matrix country_gdp (which is held in memory)
```
svmat double country_gdp
```

SAS Code

```
Proc iml;
Use A;
Read all var _all_ into A;
Use V;
Read all var _all_ into V;
Use F;
Read all var _all_ into F;
isize=I(nrow(A));
B= inv(isize-A);
V1=diag(V);
do i = 1 to 1435 by 35;
   j = i+34;
rows = i:j;
```

```
Vctr=V1[rows,];
temp=Vctr[+,];
V2=V2//temp;
end;
ctrGDP=V2*B*F;
Create countrygdp from ctrGDP;
Append from ctrGDP; /*create dataset from the matrix ctrGDP*/
Quit;
```

A.3 Canadian value added in U.S. final goods and services imports from the world

This section provides code for the calculation of Canadian value added in U.S. final goods and services imports from the world represented by equation (6).

Stata Code

* In each file, Australia (aus) is the first country and the Rest of the World (row) represents country G,
*   and there are 35 sectors.
* The V dta file contains GN number of variables, one for each country and sector (identified by
*   variable names), which need to be modified to have non-Canadian values replaced with zeroes

```
use "V.dta", replace
foreach va of varlist aus_sec1-row_sec35 {
    replace `va'=0 if substr("`va'",1,3)!= "can"
}
mkmat aus_sec1-row_sec35, matrix(V_CAN)
```

* The A dta file contains GN number of variables, one for each country and sector,
*   which are to be converted into a matrix

```
use "A.dta", replace
mkmat aus_sec1-row_sec35, matrix(A)
```

* The F dta file contains G variables, one for each country's final demand;
*   here, only US final demand is required

```
use "F.dta", replace
gen double E_USA = usafinaluse
```
* Domestic consumption must be zeroed out, as it is not an import
```
replace E_USA=0 if country=="USA"
mkmat E_USA, matrix(E_USA)
```

* Run the value chain equation
```
local isize = rowsof(A)
matrix B= inv(I(`isize')-A)
matrix CAN_VA = V_CAN*B*E_USA
clear
```
* Create a variable from the matrix CAN_VA which can be now saved in a dataset
```
svmat double CAN_VA
```

SAS Code

```
proc iml;
```

```
use V2; /*please see V2 calculation in Example A.2*/
read all var _all_ into V2;
use B;
read all var _all_ into B;
use F;
read all var _all_ into F;

/*keep Canada V matrix*/
Vcan=V2[6,];

/*keep U.S. final demand*/
E_USA=F[,40];

/* get rid of U.S. domestic consumption of final goods*/
rows=1366:1400;
E_USA[rows,]=0;

/*calculate Canada value added in US global imports*/
V_CAN=Vcan*B*E_USA;

create V_CAN from V_CAN;
append from V_CAN;
quit;
```

A.4 Canadian value added in U.S. final demand and the Canada-U.S. trade balance in value-added terms

This section provides code for the calculation of Canadian value added in U.S. final demand and U.S. value added in Canadian final demand, as shown in equations (7) and (8).

Stata Code

```
* In each file, Australia (aus) is the first country and the Rest of the World (row) represents country G,
*   and there are 35 sectors.
* Step 1, set up the matrices for Canada's value added in the U.S.
* The V dta file contains GN number of variables, one for each country and sector (identified by
*   variable names), which need to be modified to have non-Canadian values replaced with zeroes
use "V.dta", replace
foreach va of varlist aus_sec1-row_sec35 {
    replace `va'=0 if substr("`va'",1,3)!= "can"
}
mkmat aus_sec1-row_sec35, matrix(V_CAN)

* The A dta file contains GN number of variables, one for each country and sector,
*   which are to be converted into a matrix
use "A.dta", replace
mkmat aus_sec1-row_sec35, matrix(A)

* The F dta file contains G variables, one for each country's final demand;
```

```
*   here, only US final demand is required
use "F.dta", replace
mkmat usafinaluse, matrix(F_USA)

* Step 2, set up the matrices for USA's value added in Canada
* Set up a value added vector with only US value added coefficients
use "V.dta", replace
foreach va of varlist aus_sec1-row_sec35 {
    replace `va'=0 if substr("`va'",1,3)!= "usa"
}
mkmat aus_sec1-row_sec35, matrix(V_USA)
* Set up a final demand vector for Canada
use "F.dta", replace
mkmat canfinaluse, matrix(F_CAN)

* Run the value chain equation
local isize = rowsof(A)
matrix B= inv(I(`isize')-A)
* Example 4.3 result
* Value added by Canada to the U.S.
matrix CAN_VA = V_CAN*B*F_USA
* Value added by the U.S. to Canada
matrix USA_VA = V_USA*B*F_CAN

clear
* Create variables from the matrices CAN_VA and USA_VA which can be now saved in a dataset
svmat double CAN_VA
svmat double USA_VA
```

SAS Code

```
proc iml;
use V2;  /*please see V2 calculation in Example A.2*/
read all var _all_ into V2;
use B;
read all var _all_ into B;
use F;
read all var _all_ into F;

/*step 1: calculate value added from Canada in U.S. final demand*/
/*keep Canada V matrix*/
Vcan=V2[6,];
/*Keep US final demand*/
F_USA=F[,40];
/* Example 4.3 result */
/*calculate Canada value added in US final demand*/
V_CAN=Vcan*B*F_USA;

/*step 2: calculate value added from U.S. in Canada final demand*/
/*keep US V matrix*/
```

```
Vusa=V2[40,];
/*keep Canada final demand*/
F_CAN=F[,6];
/*calculate US value added in Canada final demand*/
V_USA=Vusa*B*F_CAN;

create V_can from V_CAN;
append from V_CAN;
create V_USA from V_USA;
append from V_USA;
quit;
```

A.5 Mexican value added in U.S. transport equipment exports to the world

This section provides code for the calculation of Mexican value added in U.S. transport equipment to the world given by equation (9).

Stata Code

* In each file, Australia (aus) is the first country and the Rest of the World (row) represents country G,
*   and there are 35 sectors.
* The V dta file contains GN number of variables, one for each country and sector (identified by
*   variable names), which need to be modified to have non-Mexican values replaced with zeroes
```
use "V.dta", replace
foreach va of varlist aus_sec1-row_sec35 {
    replace `va'=0 if substr("`va'",1,3)!= "mex"
}
mkmat aus_sec1-row_sec35, matrix(V_MEX)
```

* The A dta file contains GN number of variables, one for each country and sector,
*   which are to be converted into a matrix
```
use "A.dta", replace
mkmat aus_sec1-row_sec35, matrix(A)
```

* The F dta file contains G variables, one for each country's final demand;
*   they are combined into a vector of world final demand
```
use "F.dta", replace
egen double totalfinaluse = rowtotal(ausfinaluse-rowfinaluse)
```
* US final demand is removed from world final demand to determine U.S. exports
```
gen double E_USA_worldtrans=totalfinaluse-usafinaluse
```

* The vector focuses on only the U.S. as a source of goods, all other sources are replaced with zero
```
replace E_USA_worldtrans=0 if country!="USA"
```
* The vector must only contain data for the transport equipment sector (c15),
*   all other sectors are `replaced with zero`
```
replace E_USA_worldtrans=0 if sector!="c15"
mkmat E_USA_worldtrans, matrix(E_USA_worldtrans)
```

* Run the value chain equation
```
local isize = rowsof(A)
matrix B= inv(I(`isize')-A)
```

```
matrix MEX_VA_in_transport = V_MEX*B*E_USA_worldtrans
clear
```
* Creates a variable from the matrix MEX_VA_in_transport which can be now saved in a dataset
```
svmat double MEX_VA_in_transport
```

SAS Code

```
proc iml;
use V2; /*please see V2 calculation in Example A.2*/
read all var _all_ into V2;
use B;
read all var _all_ into B;
use F;
read all var _all_ into F;

/*keep Mexico V matrix*/
Vmex=V2[28,]; /*Mexico is corresponding to row 28*/

/* US as the supplier of transport equipment to the world's final demand is corresponding to row 1358.
We will keep only this row's value in F matrix*/

rows=1:1379;
F[rows,]=0;
rows=1381:1435;
F[rows,]=0;

/*we will exclude U.S. domestic final demand. U.S. as the user of final demand is corresponding to
Column 40*/
F[,40]=0;
E_USA=F[,+];

/*calculate Mexico value added in US transport equipment exports*/
V_mex=Vmex*B*E_USA;

create V_mex from V_mex;
append from V_mex;
quit;
```

A.6 Value added by the EU27 service sectors in U.S. global imports.

This section provides code for the calculation of value added by service sectors in the EU27 to U.S. global imports, as shown in equation (10).

Stata Code

* In each file, Australia (aus) is the first country and the Rest of the World (row) represents country G,
*   and there are 35 sectors.
* The V dta file contains GN number of variables, one for each country and sector (identified by
*   variable names), which need to be modified to have non-EU27 values replaced with zeroes
```
use "V.dta", replace
```

```
* Transpose the data to make it easier to work with
xpose, clear varname promote
* Identify EU countries
gen EU_flag=0
foreach v in AUT BEL BGR CYP CZE DEU DNK ESP EST FIN FRA GBR GRC HUN
IRL ITA LTU LUX LVA MLT NLD POL PRT ROM SVK SVN SWE {
      replace EU_flag=1 if substr(_varname,1,3)==lower("`v'")
}
* Identify services sectors
gen services_flag=0
foreach v in c17 c18 c19 c20 c21 c22 c23 c24 c25 c26 c27 c28 c29 c30
c31 c32 c33 c34 c35 {
      replace services_flag=1 if substr(_varname,4,3)=="`v'"
}
* Create a new VA vector only containing EU service sector values as non-zero
gen double EU_services_VA=0
replace EU_services_VA=v1 if EU_flag==1 & services_flag==1
keep _varname EU_services_VA
* Re-transpose the adjusted value added vector
xpose, clear promote
* Convert the value added vector to a matrix
mkmat ausc1-rowc35, matrix(V_EU_serv)

* The A dta file contains GN number of variables, one for each country and sector,
*   which are to be converted into a matrix
use "A.dta", replace
mkmat aus_sec1-row_sec35, matrix(A)

* The F dta file contains G variables, one for each country's final demand;
*   for this example, only U.S. final demand is needed
use "F.dta", replace
gen double E_USA=usafinaluse
* Domestic consumption must be zeroed out, as it is not an import
replace E_USA=0 if country=="USA"
mkmat E_USA, matrix(E_USA)

* Run the value chain equation
local isize = rowsof(A)
matrix B= inv(I(`isize')-A)
matrix EU27services_VA_in_imports = V_EU_serve*B*E_USA
clear
* Creates a variable from the matrix EU27services_VA_in_imports which can be now saved in a dataset
svmat double EU27services_VA_in_imports
```

SAS Code

```
proc iml;
use V2; /*please see V2 calculation in Example A.2*/
read all var _all_ into V2;
use B;
read all var _all_ into B;
```

```
use F;
read all var _all_ into F;

/*keep EU27 V matrix and replace other countries' value added share with 0*/
V2[1,]=0;
V2[5,]=0;
V2[6,]=0;
V2[7,]=0;
V2[19,]=0;
V2[20,]=0;
V2[23,]=0;
V2[24,]=0;
V2[28,]=0;
V2[34,]=0;
rows=38:41;
V2[rows,]=0;
V_EU=V2[+,];

/*keep value added share in EU27 service sector only, service sectors include c17-c35*/
do i = 1 to 1435 by 35;
   k=i+15;
cols = i:k;
V_EU[,cols]=0;
end;

/*modify F to keep US imports. U.S. as the consumer-importer is reflected on column 40 */
E_USA=F[,40];

/*modify F to exclude US final demand from domestic source*/
rows=1366:1400;
E_USA[rows,]=0;

/*calculate EU27 service value added in US imports*/
V_EU27=V_EU*B*E_USA;

create V_EU27 from V_EU27;
append from V_EU27;
quit;
```