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ABSTRACT

This paper aims to integrate and generalize the many attempts in the literature at tracing value added by country in international trade. We provide a conceptual framework to estimate value added that is more comprehensive than what is available in the existing literature. We fully detail the sources of value added accounting for 100 percent of gross exports, including several components of domestic value-added in exports. The decomposition of value-added exports examines both exports that are absorbed by the direct importer and those that are processed and subsequently exported to other countries. To empirically implement the framework, we construct an international database of value-added production and trade based on the GTAP database. Our results document substantial differences between major regional supply networks, with less integration between East and West Europe than within North America or Asia in 2004. Many measures show that emerging Asia differs considerably from other emerging economies. Much of Asia, including China itself, sends their exports to countries that provide final assembly on behalf of consumers in other countries. Asian countries also have relatively dispersed sourcing of imported intermediate inputs.

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1. Introduction

Worldwide trade has become increasingly fragmented, as different stages of production are now regularly performed across multiple countries. As inputs cross borders multiple times, traditional statistics on trade volume – measured in gross value terms – becomes increasingly less reliable as a gauge of value added being exported and imported. This paper aims to integrate and generalize the many attempts in the literature at tracing value added by country in international trade. We provide a conceptual framework to estimate value added that is more comprehensive than what is available in the existing literature. By design, this is an accounting exercise, and does not directly examine the causes and the consequences of global production chains. However, an accurate accounting of value added chains by source country is a necessary step toward a better understanding of all these issues.

Supply chains can be described as a system of value-added sources and destinations within a globally integrated production network.[2] An international supply chain distributes value-added shares among countries in a particular global industry. Within the supply chain, each producer purchases inputs and then adds value, which is included in the cost of the next stage of production. At each stage in the process, as goods cross an international border, the value-added trade flow is equal to the value added paid to the factors of production in the exporting country, and the final goods consumed by end users are equal to the sum of all accumulated value added in the chain. However, all official trade statistics are measured in gross terms, which include both intermediate goods and final products. Official trade flows will therefore be overstated because they "double" count the value of intermediate goods that cross international borders more than once.

Case studies of value chains in industries such as electronics, apparel, and motor vehicles have provided detailed examples of the discrepancy between gross and value-added trade values. According to a commonly cited study of the Apple iPod (Dedrick, Kraemer, and Linden, 2008), the Chinese factory gate price of an assembled iPod is $144. Of this, as little as $4 may be Chinese value added.[3] Nor is this a particularly isolated example, at least for Chinese electronics. Koopman, Wang, and Wei (2008) show that on average, foreign countries contribute

[2] Wang, Powers, and Wei (2009).

[3] The iPod exported from China contains about $100 in Japanese value added (for the hard drive, display, and battery), and about $15 of U.S. value added (for the processor, controller, and memory). Korea also makes a small contribution. China may contribute some additional value added in the $22 of unspecified parts.

80% or more of the value added embodied in Chinese exports of computers, office equipment, and telecom equipment. There are numerous other case studies of specific chains that show similar discrepancies, including Barbie dolls, Chinese hard drives, North American automobiles, and Asian apparel.

Hummels, Ishii, and Yi (2001), denoted HIY in the following discussions, provided the first general measures of vertical specialization in trade that measures foreign value added in a country's exports. This seminal paper provided key definitions and the first measures of the extent of vertical specialization in trade. While these measures have since been revised, they continue to be central to the discussion of vertical specialization in trade.[4] HIY defined measures of both direct value-added trade and indirect value-added trade that pass through third countries. Foreign content in direct exports, what HIY define as VS, has received more attention in the literature than indirect value added trade flows through third countries, or VS1 in HIY terminology. As a consequence, important suppliers like Japan, that lie upstream in global supply chains and whose intermediate exports are embodied in further intermediate exports by other countries, have sometimes received less attention than large downstream assemblers, such as China, that ship more finished products. And, in extended supply chains, where intermediates cross borders more than once, the HIY measures are no longer accurate measures of vertical trade.

Our ability to track sources and destinations of value added within specific chains has improved as detailed inter-region input output (IRIO) tables have become available for specific countries and regions. Several papers have investigated value-added trade in Asian supply chains using the Asian input-output (IO) tables produced by the Institute of Development Economies. Such papers include Koopman, Wang, and Wei (2009), Pula and Peltonen (2009), and Wang, Powers, and Wei (2009). These studies have provided a careful breakdown of the sources and destinations of value-added in Asian production networks. For specific chains, they have noted large differences in the organization and distribution of production across products (e.g., apparel, automobiles, and electronics). However, these studies' reliance on the Asian IO tables precludes them from tracking value-added to and from countries outside of Asia, although flows to the United States are included.

[4] See Chen et al. (2005) and Yi (2003) for revised estimates of the extent of vertical specialization in trade; see Daudin, Rifflart, and Schweisguth (2009), Johnson and Noguera (2009), and Wang, Powers, and Wei (2009) for refined definitions of vertical specialization in trade.

Truly global analyses have become possible recently, with the advent of global IRIO tables based on the GTAP database.[5] Such tables provide global estimates of double-counted intermediates in trade (about 25% of gross flows), and allow comparison of production networks in different regions. Global data can change our understanding of value-added trade for important countries such as the United States, which, as we show below, has an unusually large amount of its own exported value added returned to its producers and consumers after processing abroad. Though usefully global in scope, the GTAP database does not separate imported intermediate and final goods trade flows, so some important parameters have to be estimated.[6] Efforts are underway to produce more accurate and up-to-date global IRIO tables with less estimation of unknown parameters based on a compilation of single-country (or -region) IO tables and detailed bilateral trade statistics.[7]

This paper provides the first unified framework that integrates the older literature on vertical specialization with the newer literature on value added trade. It completely decomposes gross exports and connects official gross statistics to value-added measures of trade. The framework distributes all value-added in a country's exports to its original sources, and it expresses individual sources and destinations of value added at either the country-wide or industry average level. Despite the breadth of the framework, it is also quite parsimonious, expressing major global value-added flows as the product of only three matrices. This paper also provides new detailed decompositions of each country's value-added exports that highlight its upstream or downstream position in global value chains.

This paper is also related to Daudin, Rifflart, and Schweisguth (2009) and Johnson and Noguera (2009). Each of these papers highlights inaccuracies in HIY's measure of value-added exports. They analyze global value-added trade flows using an estimated IRIO table based on the GTAP database, in which they proportionally allocate gross trade flows into intermediate and final goods and distributing across users. Each shows that countries and sectors differ widely in their ratio of value added to gross trade. This paper expands upon their analysis in the following four aspects:

[5] See Daudin, Rifflart, and Schweisguth (2009), Johnson and Noguera (2009), and Bems, Johnson, and Yi (2010).
[6] See sections 3 for additional distinctions between the IO structure underlying the GTAP database and IRIO tables required for global value-added analysis.
[7] See Wang, Tsigas, Mora, Xin, and Xu (2010) for the construction of one such database. The World Input-Output Database Consortium (www.wiod.org) is producing a similar set of tables.

First, we develop a single, unified, transparent conceptual framework that incorporates all measures of value-added trade. These measures include analogues of Johnson and Noguera's ratio of value-added trade to gross trade (VAX ratio), HIY's measures of vertical specialization (both VS and VS1), and Daudin et al.'s measure of domestic value added in imports returned from abroad (VS1*).[8]

Second, we completely decompose each country's gross exports into its value-added components, thus establishing a formal relationship between value-added measures of trade and standard trade statistics. We begin by splitting gross exports into domestic value added sent abroad, domestic value added sent abroad that ultimately returns in home's imports, and foreign value added embodied in gross exports. Our decomposition ties HIY's original measures of vertical specialization (for the first time, as far as we know) with newer measures of value-added trade in a way that completely accounts for all elements of gross exports.[9]

Third, we split domestic value-added exports into four parts that allow us to more clearly distinguish each country's position and role in global value chains.[10] Domestic value-added exports are either absorbed by the importing country or exported on to third countries. The portion that is absorbed by the directly importing country includes domestic value added in: (i) final goods exports, and (ii) intermediate exports that are transformed into final goods and absorbed by the direct importer. The portion not absorbed by the direct importer (i.e., VS1) includes domestic value-added in two additional parts: (iii) intermediate inputs that are transformed into final goods and exported to a third country for consumption, and (iv) intermediate inputs that are used to produce other intermediates and sent to a third country for further processing.

Fourth, our estimated global IRIO better captures the international source and use of intermediate goods than in previous databases in two ways. First, we improve the estimates of intermediate imports by matching detailed bilateral import data to end-use classifications so as to

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[8] Other frameworks have been less complete or less fully specified. Johnson and Noguera (2009) did not examine HIY's VS1 measure. In addition, their value added decomposition is presented fully only for trade with one combined world region, and they do not specify how trade within the rest of the world is incorporated. Daudin, Rifflart, and Schweisguth (2009) computed values of VS, VS1, and VS* for multiple countries, but they calculated each term separately, and did not specify the connection between these terms and gross or value-added trade flows, which is very different from the integrated value-added trade decomposition reported in our paper.
[9] Each of these terms has been modified from its original definition, however, to correctly specify its share of value added in a multicountry framework or to account for all elements of gross trade.
[10] This provides a decomposition of the VAX ratio from Johnson and Noguera (2009).

determine the intermediate goods' share of imports in each sector for each exporter and importer.[11] The additional detail provides a substantial improvement over earlier approaches that assumed the share of intermediate goods in imports matched the share of intermediates in total absorption. Similarly, processing trade regimes can foster imports that have dramatically different (i.e., higher) intermediate content than domestic use in some countries. We explicitly account for these differences in Mexico and China, using the expanded Chinese IO table with separate accounts for processing exports from Koopman, Wang, and Wei (2008) and the 2003 Mexican IO table with separate domestic and Maquiladora accounts from Mexico's statistical agency.[12] While other studies have used a similar correction for Chinese exports, the new Mexican IO table provides improved accuracy in estimates of NAFTA trade flows by distinguishing domestic and Maquiladora production.

This paper is organized as follows. Section 2 presents key measures of vertical specialization and value-added trade in global supply chains, and it specifies the global IO model that generates these key measures. Section 3 discusses how the required global IO model can be made operational, given the limited information in current databases with linked IO tables. Section 4 applies the model to the constructed database to decompose each country's gross exports and to describe each country's participation in global value chains in terms of the composition of their value-added exports. Section 5 concludes.

2. Value Chains in Global Production Network: Concepts and Measurement

2.1 Concepts

With modern international production chains, value added embodied in exports originates in many places. Detailing these sources and measuring their contribution has been the main focus of both the vertical specialization and value-added trade literature. As noted, HIY provided the first empirical framework to measure participation in vertically specialized trade: a country can use imported intermediate inputs to produce exports, or it can export intermediate goods that are used as inputs producing goods exported by another country. HIY derived VS as a

[11] Feenstra and Jensen (2009) use a similar approach to separate final goods from intermediates in U.S. imports. They concord HS imports to end-use categories provided by the BEA. We concorded HS imports to UN Broad Economic Categories, which are more applicable to international trade flows.

[12] We integrated the Chinese and Mexican IO tables with version 7 of the GTAP database using a quadratic mathematical programming model to minimize the deviation between the resulting new data set and the original GTAP database.

measure of the value of imports embodied in a country's exports, and VS1 as a measure of the value of exported goods that are processed and further exported by other countries. However, HIY's original measures were insufficient for full analysis of supply chains. Their measure of VS1 is valid only in a special case, they did not mathematically define VS1, and these two measures do not capture all sources of value added in gross exports. This section examines each of these shortcomings, and provides a fully generalizable solution for each.[13]

Two key assumptions are needed for the HIY's measure to accurately reflect value-added trade. First, intensity in the use of imported inputs must be the same whether goods are produced for export or for domestic final demand. This assumption is violated when processing exports are pervasive due to policy incentives, as in China and Mexico.[14] The second key assumption is that all imported intermediate inputs must contain 100% foreign value added and no more than one country exports intermediates.[15] In the HIY model, a country cannot import intermediate inputs, add value, and then export semi-finished good to another country to produce final goods. Nor can a country receive intermediate imports that embody its own value added, returned after processing abroad.

These assumptions generally do not hold in today's increasingly globalized world, and the multi-country, back-and-forth nature of many current global production networks is often not well captured by the HIY measure.[16] To accurately track the sources of global value-added, a framework is needed that combines VS and VS1, and also captures the remaining sources of value added. Such a framework is given by our VAS matrix described in the next section.

Measuring value-added embodied in exports requires construction of a database detailing international production and use for all flows of value added. To precisely define such chains across many countries, the database must quantify the contribution of each country to the total value-added generated in the process of supplying final products.

[13] The first shortcoming has been addressed in the literature (Johnson and Noguera, 2009), but the others have not.
[14] Processing regimes provide incentives to use imported intermediate imports, but require all resulting products to be 100% exported. Hence, processing exports have a much greater imported intermediate input intensity than domestic products. As discussed in section 3, we follow Koopman, Wang, and Wei (2008) to re-compute domestic and foreign value added in China and Mexico, but in a multi-country global setting.
[15] This is equivalent to the assumption that the first exporting country's exports have to be 100% domestic sourced when compute VS1 in HIY framework.
[16] See Johnson and Noguera (2009) for a comparison of HIY's VS and a more generalized measure of foreign value in exports.

A global IRIO table provides sufficient information to completely slice up the value chain across all related countries at the industry average level.[17] In detail, an IRIO table contains a number of sub-matrices that specify (a) transaction flows of intermediate products and final goods within and between each country at the industry level, (b) the direct value-added in production of each industry in all countries, and (c) the gross output of each industry in all countries. In other words, the IRIO table provides the origin and destination of all transaction flows by industry. It also specifies every intermediate and/or final use for all such flows. For example, an IRIO table would describe the number of electronics components produced in Japan that were shipped to China. It would distinguish the number that were used as intermediate inputs in each Chinese sector and the number that were used in Chinese private household consumption and capital formation. The IRIO would also allow us to determine the amount of processed electronics that were then exported to the United States and used by different sectors of the U.S. economy. IRIOs exist, however, for a limited number of countries and regions. As such, we have estimated a global IRIO table based on version 7 of the GTAP database (2004). Section 3 presents the details of our database construction.

In the rest of section 2, we will illustrate how a global IO model can allocate the value added in a multi-country production chain to each participating country. We will incorporate previous measures of value added and vertical specialization into a complete decomposition of gross trade flows. To present the major concepts of our decomposition and show how they differ from earlier measures, we start with a two-country case and then extend to a world with many countries.[18]

2.2 Two-country case

Assume a two-country (home and foreign) world, in which each country produces goods in N differentiated tradable sectors. Goods in each sector can be consumed directly or used as intermediate inputs, and each country exports both intermediate and final goods to the other.

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[17] There are also product-level approaches to estimating the financial value embedded in a product and quantifying how the value is distributed among participants in the supply chain, moving from design and branding to component manufacturing to assembly to distribution and sales (Dedrick, Kraemer, and Linden, 2008).

[18] The authors are very grateful for the constructive discussion with Dr. Kei-Mu Yi at the Federal Reserve Bank of Philadelphia in developing the two- and three-country cases and the relationship between our new measures of vertical specialization and the original HIY measures.

All gross output produced by country i must be used as an intermediate good or a final good at home or abroad, or

$$X_r = A_{rr} X_r + A_{rs} X_s + Y_{rr} + Y_{rs}, \quad r,s = 1,2 \tag{1}$$

where X_r is the N×1 gross output vector of country r, Y_{rs} is the N×1 final demand vector that gives demand in country s for final goods produced in r, and A_{rs} is the N×N IO coefficient matrix, giving intermediate use in s of goods produced in r. The two-country production and trade system can be written in block matrix notation as

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Y_{11} + Y_{12} \\ Y_{21} + Y_{22} \end{bmatrix}, \tag{2}$$

and rearranging,

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} I - A_{11} & -A_{12} \\ -A_{21} & I - A_{22} \end{bmatrix}^{-1} \begin{bmatrix} Y_{11} + Y_{12} \\ Y_{21} + Y_{22} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}. \tag{3}$$

where B_{sr} denotes the N×N block Leontief inverse matrix, which is the total requirement matrix that gives the amount of gross output in producing country s required for a one-unit increase in final demand in country r. Y_i is an N×1 vector that gives global use of i's final goods. This system can be expressed succinctly as:

$$X = (I - A)^{-1} Y = BY, \tag{4}$$

where X and Y are 2N×1 matrices, and A and B are 2N×2N matrices.

Having defined the Leontief inverse matrix, we turn to measures of domestic and foreign value added, first for production, and then applied to trade. Let V_s be the 1×N direct value-added coefficient vector. Each element of V_s gives the share of direct domestic value added in total output. This is equal to one minus the intermediate input share from all countries (including domestically produced intermediates):

$$V_r = u(I - \textstyle\sum_s A_{sr}), \tag{5}$$

where u is a 1×N unity vector. To make the analysis consistent with the multiple-country discussion below, we will also define V, the 2×2N matrix of direct domestic value added for both countries,

$$V = \begin{bmatrix} V_1 & 0 \\ 0 & V_2 \end{bmatrix}. \tag{6}$$

Variations of this framework have been used in a number of recent studies of value-added trade.[19] However, none of these papers clearly illustrate how to apply this framework to completely decompose exports and capture all sources of value added. We turn to this task next.

Combining these direct value-added shares with the Leontief inverse matrices produces the 2×2N value-added share (VAS) matrix, our basic measure of value-added shares.

$$\mathrm{VAS} = VB = \begin{bmatrix} V_1 B_{11} & V_1 B_{12} \\ V_2 B_{21} & V_2 B_{22} \end{bmatrix}. \qquad (7)$$

Within VAS, each column of V_1B_{11} denotes domestic value-added share of domestic produced products in a particular sector at home. Similarly, columns of V_2B_{21} denote country 2's value-added shares for these same goods. Together, each of the first N columns in the VAS matrix includes all value added, domestic and foreign, needed to produce one additional unit of domestic products at home. The second N columns present value-added shares for production in country 2. Because all value added must be either domestic or foreign, the sum along each of the 2N columns of VAS is unity:[20]

$$V_1 B_{11} + V_2 B_{21} = V_1 B_{12} + V_2 B_{22} = u\,. \qquad (8)$$

The VAS matrix is most naturally applicable to final goods trade, because of the definition of the inverse Leontief matrix. To compare to other measures of vertical specialization that have been developed in the literature and link our measure with official trade statistics, however, we will apply the VAS matrix to exports of both final and intermediate goods.[21] Let E_{rs} be is the N×1 vector of intermediate and final exports from r to s, and $\hat{E}_{rs}$ be the N×N diagonal matrix of this export vector. For consistency with the multi-country analysis below,[22] also define

$$E_r = \sum\nolimits_{s \neq r} E_{rs} = \sum\nolimits_{s} (A_{rs} X_s + Y_{rs})\,, \qquad r,s = 1,2 \qquad (9)$$

$$E = \begin{bmatrix} E_{12} & 0 \\ 0 & E_{21} \end{bmatrix}, \text{ and} \qquad (10)$$

[19] Daudin et al. (2008), Johnson and Noguera (2009), and Wang, Powers, and Wei (2009).
[20] To show this, substitute the values of the B_{ij}s from equation (9) into equation (4). KWW (2008) show this must hold in the general case with any number of countries and sectors.
[21] Mathematically, the application to intermediates goods trade presents no problems, because value added in a product does not depend on how it is used. In other words, value-added shares in intermediate goods match the shares in final goods within the same sector.
[22] In the two-country case, all trade is bilateral trade, so E_{rs}=E_r. For clarity, we use E_{rs} instead of E_r in the two-country case, although we will generally use E_r with multiple countries.

$$\hat{E} = \begin{bmatrix} diag(E_{12}) & 0 \\ 0 & diag(E_{21}) \end{bmatrix}, \tag{11}$$

where E is a 2N×2 matrix and $\hat{E}$ is a 2N×2N diagonal matrix.

The combination of the value-added share matrix (VAS) and the export matrix produces VAS_E, our main measure of value-added trade and vertical specialization in global value chains:

$$\text{VAS\_}\hat{\text{E}} = VB\hat{E} = \begin{bmatrix} V_1 B_{11} \hat{E}_{12} & V_1 B_{12} \hat{E}_{21} \\ V_2 B_{21} \hat{E}_{12} & V_2 B_{22} \hat{E}_{21} \end{bmatrix}. \tag{12}$$

$\text{VAS\_}\hat{\text{E}}$ is a 2×2N matrix. This matrix is a disaggregated measure of value-added exports, since it expresses value added embodied in exports of each sector. This measure allows comparison to case studies of supply chains in single sectors, such as apparel, electronics, or motor vehicles. However, for simplicity, and to match our empirical focus on aggregate trade, we will focus on the aggregate version of this measure throughout the rest of this section.[23] The aggregate (2×2) measure of value-added exports is given by

$$\text{VAS\_E} = VBE = \begin{bmatrix} V_1 B_{11} E_{12} & V_1 B_{12} E_{21} \\ V_2 B_{21} E_{12} & V_2 B_{22} E_{21} \end{bmatrix}. \tag{13}$$

Although rather elementary with only two countries, VAS_E expresses the major concepts of our vertical specialization measures. Diagonal elements of VAS_E define the domestic value-added share in a unit of each country's exports. Off-diagonal elements give the shares of foreign value-added embodied in a unit of each country's exports. The off-diagonal elements allow us to improve upon HIY's two major value-added concepts: foreign value added exported directly (VS), and domestic value added exported indirectly through third countries (VS1).

In the two-country case, the explicit solutions of the four B_{ij} block matrices are not too cumbersome, and nicely illustrate the difference between our general measures and the HIY measures. Applying the algebra of the partitioned matrix inverse,[24] we have

$$\begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} = \begin{bmatrix} (I - A_{11} - A_{12}(I - A_{22})^{-1} A_{21})^{-1} & B_{11} A_{12} (I - A_{22})^{-1} \\ (I_2 - A_{22})^{-1} A_{21} B_{11} & (I - A_{22} - A_{21}(I - A_{11})^{-1} A_{12})^{-1} \end{bmatrix} \tag{14}$$

[23] All results continue to hold with full dimensionality, and can be expressed simply by replacing an export vector with the relevant diagonal matrix.
[24] See, for example, Simon and Blume (1994, 182); B_{22} follows from the symmetry of countries 1 and 2.

Therefore, gross exports can be decomposed into foreign value-added (VS) and domestic value-added (DV) as follows:

$$\mathrm{VS}=\begin{bmatrix} V_2 B_{21} E_{12} \\ V_1 B_{12} E_{21} \end{bmatrix}=\begin{bmatrix} u(A_{21}-A_{12}(I-A_{22})^{-1}A_{21})(I-A_{11}-A_{12}(I-A_{22})^{-1}A_{21})^{-1}E_{12} \\ u(A_{12}-A_{21}(I-A_{11})^{-1}A_{12})(I-A_{22}-A_{21}(I-A_{11})^{-1}A_{12})^{-1}E_{21} \end{bmatrix} \tag{15}$$

$$\mathrm{DV}=\begin{bmatrix} V_1 B_{11} E_{12} \\ V_2 B_{22} E_{21} \end{bmatrix}=\begin{bmatrix} V_1(I-A_{11}-A_{12}(I-A_{22})^{-1}A_{21})^{-1}E_{12} \\ V_2(I-A_{22}-A_{21}(I-A_{11})^{-1}A_{12})^{-1}E_{21} \end{bmatrix} \tag{16}$$

They are both 2×1 matrices.

Using the same notation, HIY's VS measure can be expressed as another 2×1 matrix:

$$\mathrm{VS\_HIY}=\begin{bmatrix} uA_{21}(I-A_{11})^{-1}E_{12} \\ uA_{12}(I-A_{22})^{-1}E_{21} \end{bmatrix}. \tag{17}$$

Comparing equations (15) and (17), we can see that the HIY's VS measure accurately captures value added in trade only when A_{12}=0 or A_{21}=0; i.e., in the case when only one country's intermediate goods are used abroad. As Johnson and Noguera (2009) also point out, whenever two or more countries export intermediate products, the HIY measures diverge from the true measures of value added in exports.

The true measure captures an important element omitted from HIY's simplified formula. For the home country, both domestic and foreign value-added differ from their true values by the adjustment term $A_{12}(I-A_{22})^{-1}A_{21}$. The term consists of the product of $A_{12}(I-A_{22})^{-1}$, which as (16) shows, represents country 1's value added embodied in country 2's exports, times A_{21}, which gives country 1's intermediate use of those goods. Thus the true measure can account for value added when a country imports its own value added. In a more general context, VAS will properly attribute foreign and domestic content to multiple countries when intermediate products cross borders in even more complicated patterns. This will become clearer when we extend the measure to three or more countries.

The second HIY measure of vertical specialization is VS1, which measures the amount of a country's value-added that is sent indirectly through third countries, or the value added in intermediate exports used to produce other countries' exports. Although this term has not been previously defined mathematically, VS1 can be specified precisely based on our measures of value-added in VAS. In a two-country world, the home country's VS1 measure can be defined as

$$\mathrm{VS1}_1=V_1 B_{12} E_{21}. \tag{18}$$

This product of three terms gives the home country's value-added in the goods it produces to generate a dollar's worth of increased production abroad times the amount of that foreign production that is then exported back home. In a two-country framework, home country's VS1 is identical to foreign country's VS in exports. This will not be true in the multi-country models that we turn to next.[25]

2.3 Three or more countries

The previous analysis can be generalized to any arbitrary number of countries. Production, value-added shares, and value-added exports are given succinctly by:

$$\begin{aligned} X &= (I-A)^{-1}Y = BY \\ VAS &= VB \\ VAS\_E &= VBE\,. \end{aligned} \tag{19}$$

With G countries and N sectors, X and Y are GN×1 vectors; A, B, and $\hat{E}$ are GN×GN matrices; V and VAS are G×GN matrices; E is a GN×G matrix; and VAS_E is a G×G matrix.

In the multiple-country case, accurately calculating value added requires adjustments for intermediate inputs that cross multiple borders. Examining a three-country case in some details is useful for two reasons: (i) it exhibits nearly all the richness of the fully general multi-country analysis, and (ii) analytical solutions remain available and continue to have intuitive explanations. For example, home's domestic value-added share in production is given by[26]

$$\begin{aligned} V_1B_{11} = V_1\{I - A_{11} - A_{12}[I - A_{22} - A_{23}(I-A_{33})^{-1}A_{32}]^{-1}[A_{21} + A_{23}(I-A_{33})^{-1}A_{31}] \\ - A_{13}[I - A_{33} - A_{32}(I-A_{22})^{-1}A_{23}]^{-1}[A_{31} + A_{32}(I-A_{22})^{-1}A_{21}]\}^{-1} \end{aligned}\,. \tag{20}$$

This includes adjustments for country 2's exports to country 3 that are subsequently exported and used in country 2 or country 1, and adjustments for country 3's exports to country 2 that are subsequently used in country 3 or country 1. Similar adjustments are made to all VS and VS1 measures. These adjustments succinctly capture value added in production chains stretching across multiple borders.

[25] But, consistent with the two-country case, VS will be measured along columns and VS1 will be measured along rows.

[26] This expression is derived by iteratively applying the expression for the inverse of a partitioned matrix (see appendix in Wang, Powers, and Wei, 2009 for the derivation).

As before, the value-added shares can be applied to gross exports to produce VAS_E. With three countries, VAS_E can be measured either with aggregate or bilateral trade. With total gross trade, VAS_E is the 3x3 matrix:

$$VAS\_E = VBE = \begin{bmatrix} V_1B_{11}E_1 & V_1B_{12}E_2 & V_1B_{13}E_3 \\ V_2B_{21}E_1 & V_2B_{22}E_2 & V_2B_{23}E_3 \\ V_3B_{31}E_1 & V_3B_{32}E_2 & V_3B_{33}E_3 \end{bmatrix}. \tag{21}$$

The distinction between VS and VS1 is much clearer with three countries than with two. The sum of off-diagonal elements *along a column* is the share of foreign value-added embodied in a unit of a particular country's exports, which is the true measure of VS. The sum of off-diagonal elements *along a row* provides information on the share of a country's value-added exports embodied as intermediate inputs in third countries' exports, which is the true measure of VS1. In mathematical notation:

$$\mathrm{DV}_{\mathrm{r}} = V_r B_{rr} E_r \,. \tag{22}$$

DV measures the total domestic value-added embodied in country *r*'s exports.

$$\mathrm{VS}_{\mathrm{r}} = \sum_{s \neq r} V_s B_{sr} E_r \,. \tag{23}$$

VS measures other countries' value-added embodied in country *r*'s exports.

$$\mathrm{VS1}_{\mathrm{r}} = \sum_{s \neq r} V_r B_{rs} E_s \,. \tag{24}$$

VS1 measures country *r*'s indirect value-added exports through third countries. This is the first explicit derivation of the VS1 measure provided in the literature.

As noted above, it is straightforward to extend equation (21) to multiple sectors. However, with multiple importers, exporters, and sectors, dimensionality becomes a problem when describing global value chains. In the results section of this paper, we have thus aggregated across industries to summarize the position of each country in global production networks.[27] To provide some comparison of supply chains for different types of goods, we split out final goods from intermediates in exports. As noted above, final goods are more naturally applicable to the derivation of value-added flows, but total gross flows (final plus intermediate)

[27] To disaggregate across industries using the notation above, replace the diagonal exports matrix E *with* matrix $\hat{E}$, the resulted value-added export matrix of size G×GN. Besides the dimensionality problem, there also data limitations that may cast doubt on the disaggregated sector results as we discussed in section 3, so we decide do not report disaggregate results in current paper but it is available upon request.

better match official trade statistics and the value-added measures already developed in the literature.

Within intermediates, we further divide those goods that are consumed by the direct importer from those goods that are processed or finished in one country and exported for consumption or further processing in another. To do this, we divided gross exports into final goods and intermediates flows as follows:

$$E_{rs} = Y_{rs} + A_{rs}X_{s} = \underbrace{Y_{rs}}_{\text{Final goods}} + \underbrace{A_{rs}X_{ss}}_{\text{Finished and consumed in } s} + \underbrace{\sum\nolimits_{s \neq r} A_{rs}X_{sr}}_{\text{export back to r}} + \underbrace{\sum\nolimits_{s \neq t} A_{rs}X_{st}}_{\text{export to third countries}}, \quad (25)$$

where X_{rs} denotes country r's output consumed in country s. Such a gross exports decomposition helps distinguish countries that lie downstream in supply chains, i.e., countries that directly supply the final demanders of their products, from those that are upstream in the supply chain, largely supplying intermediates for later incorporation into final goods. Finally, we normalize most measures of value-added trade by their corresponding gross flows, to report value-added trade as shares of gross exports.

When we combine the mathematical definition of domestic value-added (DV) in equation (22) and the export decomposition in equation (25), we will be able to decompose a country's domestic value-added (value-added exports) into four parts:

$$\mathrm{DV}_{\mathrm{rs}} = V_r B_{rr} E_{rs} = V_r B_{rr} \sum_{r \neq s} Y_{rs} + V_r B_{rr} \sum_{r \neq s} A_{rs} X_{ss} + V_r B_{rr} \sum_{r \neq s} A_{rs} X_{sr} + V_r B_{rr} \sum_{s \neq t} A_{rs} X_{st} \quad (26)$$

The first term is the value-added trade embodied in country r's final goods exports, which is consumed by countries that directly import them; the second term is the value-added embodied in country *r*'s intermediate goods used by countries to produce their own domestic final demand, which are also consumed by the direct importer; the third term is country *r*'s intermediate exports to countries producing intermediate or final goods that are then shipped back home (VS1*). The last term is the value-added embodied in country *r*'s intermediate goods used by a second country to produce intermediate or final goods for a third country (VS1).

As indicated by equation (26), the portion of DV that is absorbed by the directly importing country consists of domestic value in (i) final goods exports, and (ii) intermediate exports that transformed to final goods and absorbed by the direct importer. The portion of DV not absorbed by the direct importer (i.e., VS1) consists of (i) intermediate inputs that are transformed into final goods and exported to a third country for consumption, and (ii) intermediate inputs that are used in other intermediates and sent to a third country for further processing. These four parts of DV represent an important aspect of the position of an exporter in a value chain: e.g., far downstream with a high share of final goods, or far upstream with a high share of intermediates subsequently exported by other countries in the chain. In a similar manner, VS also can be expressed as foreign value that is exported in final products or foreign value embodied in exported intermediates.

Equation (26) makes it possible to integrate the older literature on vertical specialization with the newer literature on value added trade, thus completely decomposing gross exports and connecting official gross statistics to value-added measures of trade. The vertical specialization literature has proven that gross exports consist of domestic value added (DV) and foreign value added embodied in imported intermediate inputs (VS). Equation (26) shows that domestic value-added can be further broken down into additional components that reveal the ultimate destination of a country's exported value added. Our complete decomposition of gross exports is diagraphed in figure 1. Section 4 of this paper will report the major breakout of the value-added in a country's gross exports to the world based on this figure, providing details on the upstream or downstream position of specific countries in global value chains.

(Insert figure 1 here)

3. Database Construction

3.1 Overview

A world production chain characterizes the distribution of value-added shares among countries in a particular global industry. To precisely define such chains across many countries one needs to be able to quantify the contribution of each country to the total value-added generated in the process of supplying final products. As noted in the previous section, IRIO tables provide sufficient information to allow us to model global value-added generation at the industry average level, but these tables are not available on a global basis, and in fact are rarely available at the national or regional level. The available global IO databases, such as the GTAP Multi-Region Input-Output (MRIO) tables, do not have enough detail on the cross-border supply and use of goods to be directly applied to supply chain analysis.

To provide a workable dataset for our global value chain analysis, we constructed a global IRIO table for 2004 based on version 7 of the GTAP database as well as supplemental detailed trade data and the proportionality assumptions described below. To reflect the reality and importance of Export Processing Zones (EPZs) in developing economies and their role in global value-added trade and production network,[28] we also incorporated an expanded Chinese IO table with separate accounts for processing exports and a 2003 Mexican IO table with separate domestic and maquiladora accounts.[29] We integrated the GTAP database and the additional information with a quadratic mathematical programming model that (a) minimized the deviation of the resulting new data set from the original GTAP data, (b) ensured that supply and use balance for each sector and every country, and (c) kept all sectoral bilateral trade flows in the GTAP database constant. The new database covers 26 countries and 41 sectors and was used as the major data source of this paper.[30]

IRIO tables report imported intermediate use coefficients that specify country *r*'s use in sector *i* of imports from sector *j* from source country *s*. To estimate these coefficients, we need to (i) distinguish intermediate and final use of imports from all sources in each sector, and (ii) allocate intermediate goods from a particular country source to each sector it is used within all destination countries. We addressed the first of these deficiencies using detailed trade data and United Nation (UN) Broad Economic Categories (BEC), as described in section 3.2 No additional information is available to properly allocate intermediates of a particular sector from a specific source country to its use industries at the destination economy, however. Thus, sector *j*'s imported intermediate inputs of a particular product are initially allocated to each source country by assuming they are consistent with the aggregate source structure of that particular product.[31]

The data requirements for final goods in our analysis also exceed the detail available in MRIO databases. In particular, GTAP provides information on the allocation of final goods into

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[28] WTO reported that around 20% of developing country exports are out of EPZs while the share on the imports side is about 13% based on balance of payment statistics. In the 2000-2008 period, China alone accounted for about 67% of all reported processing exports while Mexico represents another 18 percent. See Maurer and Degain (2010) for more details.

[29] Processing regimes provide incentives to use imported intermediate inputs, provided the resulting final goods are entirely exported. Processing exports violate the assumption that exports have the same intermediate input intensity as domestic use. Failure to account for processing imports can dramatically overstate the domestic content of exports (Dean, Fung, and Wang, 2009). The source of the Chinese processing data is Koopman, Wang, and Wei (2008), and the Mexican table is from the Mexican statistical agency Instituto Nacional de Estadística, Geografía e Informática (INEGI).

[30] The country classification and its concordance with GTAP regions and sectors are given in Table 5.

[31] For example, if 20% of U.S. imported intermediate steel comes from China, then we assume that each U.S. industry using imported steel as an intermediate input obtains 20% of its imported steel from China. Such an assumption ignores the heterogeneity of imported steel from different sources. In reality, 50% of the imported steel used by the U.S. construction industry may come from China, while only 5% of the imported steel used by auto makers may be Chinese. Further, these proportions may be reversed for steel imported from Japan.

three types of final demand (private consumption, government consumption, and investment) but does not distinguish how imports from specific sources are distributed to these components. The initial allocation again assumed that final goods imports were allocated to these components consistent with the aggregate supply structures of those final goods.

After integrating the new data into GTAP with the quadratic programming model, the resulting dataset is sufficient to calculate value added generated by every country at each stage of the global value chain for each product. We next turn to the results of these calculations.

3.2 Distinguishing imports of intermediate inputs and final goods

Although the GTAP database provides bilateral trade flows, it does not distinguish the use of these goods. Our initial allocation of bilateral trade flows into intermediate and final uses is based on the UN BEC method, determined by detailed trade statistics at the 6-digit HS level from COMTRADE. This differs from the approaches in Johnson and Noguera (2009) and Daudin, Rifflart, and Schweisguth (2009). These studies also transfer the MRIO table in the GTAP database into an IRIO table. However, they do not use trade data to identify intermediate goods in each bilateral trade flow. Instead, they applied a proportion method directly to the GTAP trade data; i.e., they made an additional assumption that the proportion of intermediate to final goods is the same for domestic supplied and imported products.

The use of end-use categories to distinguish imports by use is becoming more widespread in the literature and avoids some noted deficiencies of the proportional method. Feenstra and Jensen (2009) use a similar approach to separate final goods from intermediates in U.S. imports in their recent re-estimation of the Feenstra-Hanson (1999) measure of offshoring. Dean, Fung, and Wang (2009) have shown that the proportionality assumption underestimates the share of imported goods used as intermediate inputs in China's processing trade. Nordas (2005) states that the largest industrial countries have a higher share of intermediates in their exports than in their imports, while the opposite is true for large developing countries. These results imply that the intermediate content of imports differs systematically from the intermediate content in domestic supply.

Consistent with the literature, our study shows that the proportional method may overestimate the share of intermediate goods in imports of most developed countries and underestimate the proportion of final goods in exports of many developing countries (such as

China and Vietnam). BEC method thus provides a less distorted picture of the value added distribution in global value chains.

Table 1a reports the share of intermediate goods in each country's total exports and imports by the two different methods of allocating gross trade flows into intermediate and final goods. Columns (2) and (3) show that for most developing countries, the BEC method produced a much lower intermediate share in exports. This indicates these developing countries (e.g., Vietnam, China, South Asia, Thailand, and Mexico) may export substantially more final goods than is indicated by previous value-added databases. The exceptions are the natural-resource exporting countries such as Brazil, Russia and the rest of the world—the BEC method produced higher intermediate share in their exports.

(Insert table 1a here)

The patterns for imports are more nuanced. Columns (4) and (5) show that the BEC classification also results in higher share of intermediates in some developing countries' imports (e.g., Mexico, India, Indonesia, and South Asia), indicating these developing countries may import substantially more intermediate products. At the national level, China appears to be an exception, because the BEC classification gives a lower intermediate share estimates for China's imports than the proportion method. However, when we distinguish processing and normal trade, we find that intermediate goods make up a much higher share for China's processing imports than for its normal imports (89 vs. 71%), very similar to Mexico (Table 1b). The difference at the national level between China and Mexico is due to the role of normal non-processing sectors in China is large than that in Mexico.

(Insert table 1b here)

The differences between the BEC and proportion methods at the industry level are much greater than the national aggregates. Table 2 illustrates the differences in U.S. imports (second panel) and Chinese exports (third panel) of electronic machinery. Because the proportion method assigns the intermediate share in total absorption to all foreign input sources, the second panel reports the same intermediate goods share (54% percent) for all sources. Since the BEC classification is applied to each bilateral trade flow, it allows for product composition differences from different source countries. The BEC classification identified more final products in U.S. imports from almost all East Asian developing countries as well as Brazil and Mexico, but more intermediate inputs from developed countries and natural resource exporters. Over all, the proportion method allocates 7 percentage points more U.S. electronic machinery imports into intermediate goods than the BEC classification, which may be inaccurate given that the United States has the world largest consumer electronics market.

(Insert table 2 here)

The third panel of table 2 reports Chinese exports of electronic machinery. The proportion method results in substantially more Chinese intermediate goods exports to almost all countries in our database. In total, the share of intermediate goods in Chinese electronic machinery exports is 21 percentage points higher under the proportion method than the BEC classification, which does not reflect China's position as one of the largest exporters of consumer electronics in the world.

A statistical summary of the difference in estimates of intermediate shares between the two methods for all countries and industries in the database are reported in appendix tables A2 and A3. The tables include both the simple and trade-weighted mean differences, along with their standard errors for all bilateral merchandise trade flows. At the sector level, the proportion method resulted in lower intermediate goods shares for primary and manufacturing products, but higher intermediate goods shares in consumer and capital products.

Therefore, despite its shortcomings,[32] we believe that the UN BEC classification provides a better identification of intermediates in gross trade flows than the proportion methods. It provides a better row totals for each block matrix of A_{sr} in the IO coefficient matrix A, thus improving the accuracy of the most important parameters, the IO coefficients in an IRIO model. However, it still does not solve how to properly allocate particular intermediate goods imported from a specific source country to each using industry (the coefficients in each cell of a particular row in each block matrix A_{sr} still have to be estimated by proportion assumption). This allocation is especially important to precisely estimate value-added by sources in a particular industry, although it may be less critical at the country aggregate level because total imports of intermediates from a particular source country are fixed so misallocations will be canceled out.

[32] The literature discusses that the shortcomings of the UN BEC classification, particularly its inability to properly identify dual-use products such as fuels, automobiles, and some food and agricultural products.

4. Results

4.1 Complete decomposition of gross exports

Table 3 presents a complete decomposition of each country's gross exports to the world by value-added components and the main breakdown of domestic value added. It selects key estimates of value-added exports from the VAS_E matrix, as specified in equations (22) to (26) and applied to our database of international production and trade flows (the IRIO table).

The first three columns of results decompose gross exports into three terms that integrate the vertical specialization and value-added trade literature: the value-added trade to gross trade (VAX) ratio from Johnson and Noguera (2009), VS from HIY 2001, and VS1* from Daudin et al. (2008). As described in section 2, these terms present the value added by domestic factors in the production process, the foreign value embodied in imported intermediate inputs, and domestic value-added embodied in imported goods that have returned after processing abroad. Each of these terms has been modified from its original definitions to correctly specify its share of value added in a multi-country framework. Although these elements have been independently computed based on different elements in the VAS_E matrix, they sum to exactly 100 percent of gross exports, thus verifying that the decomposition is complete. This is the first such decomposition of gross exports in a global setting.

Column (2) gives the share of value-added exports in gross exports—the VAX ratio proposed by Johnson and Noguera (2009). For example, on average, each dollar of gross exports from Australia and New Zealand incorporates 88 cents of domestic value added. This share is quite high for two types of exporters: natural resource producers (such as Australia, Brazil, Latin America, and Russia) and high-income countries, particularly the EU and Japan.

Column (3) reports the share of foreign value-added in gross exports—the VS share in HIY 2001. For example, on average, each dollar of gross exports from China includes 36 cents of foreign content. This share is high for Mexico, China, ASEAN countries and East Asia tigers, but low for industrial countries and natural resource exporters.

An important difference between domestic value-added share and VAX ratio need to be mentioned, there is a portion of gross exports not belong to a country's value-added exports but are a part of its domestic value-added generated from its production factors, which is the value-added embodied in its intermediate exports used by a foreign country producing products that shipped back to the home country (therefore cannot counted as the home country' value-added exports), used as intermediate inputs, invested or consumed there. This component of domestic value-added as a share of each country's gross exports is listed in column (4). This is called VS1* in Daudin, Rifflart, and Schweisguth (2009). For most countries, this share is low (under 1%), but it is quite high for the United States (12.4%) [33]and the EU (7.4%), and relatively high for Japan (2.9%) and the rest of the world (2.5%). The world average is 4.0%. To account for all sources of value added, our measure of VS1* includes both imported intermediates and final goods, so we report higher values than Daudin et al. (world average of 1.8%), which includes final goods only.[34]

(Insert table 3 here)

4.2 Decomposition of domestic value added in gross exports

Different regions of the world have sharply different compositions of domestic value added embodied in exports. Broadly, domestic value added in exports can be apportioned to the value in final goods, intermediate exports absorbed by the direct importer, and intermediate exports processed and exported to further countries (i.e., VS1).[35] VS1 can be further divided into value that is re-exported in final goods and value re-exported in processed intermediate goods.

Columns (5) through (8) in table 3 decompose total domestic value added in gross exports into these four components, i.e., value-added embodied in final goods exports and three types of intermediate-goods exports. This decomposition provides a more detailed look at value-added exports than has previously available in the literature, particularly Daudin, et al. Column (5) gives the share of value added incorporated in exports of final goods, relative to total gross exports, which corresponds to the first term in equation (26) divided by gross exports. Not surprisingly, natural resources exporters such as Russia have little of their value added in final goods, because these countries produce relatively few final goods.[36] Value-added embodied in final goods constitute a large share of most Asian countries' value-added exports. For example, more than half of the value-added exports comes from final products in Vietnam, South Asia,

[33] This may explain why Johnson and Noguera (2009)'s VAX ratio is much smaller than 1 minus the VS share in HIY for the United States, but very close for other countries, because they are different by definition.
[34] If only final goods are taken into account, our estimate is 1.9%, consistent with Daudin et al.
[35] Corresponding to columns 5, 6, and 7+8 in table 3.
[36] However, value added per dollar of gross exports is similar for exports of final goods and intermediate goods from these countries. See discussion below.

and processing regimes in China (as well as Mexico), indicating that these countries are located in the end of world value-added production chains.

Domestic value-added in intermediate goods exports is split out in the next three columns. Column (6) reports the share of value added embodied in exported intermediate goods that by the direct importer to produce final goods and invested or consumed (i.e., absorbed) there. This column corresponds to the second term in equation (26) divided by gross exports. All the natural resource exporters generate about half of their value-added exports through this channel. For example, about 55% of value-added exports from Russia and the rest of the world (largely oil producing countries) come from exporting intermediates directly to a destination country which uses these intermediate inputs produce final goods to satisfy their domestic demand. In contrast, most Asian economies except Indonesia have a substantially less value-added embodied in such intermediate exports (less than 25%). Columns (7) and (8) show the shares of value added embodied in exported intermediate goods that are subsequently exported as intermediate or final goods and used in a third country, which corresponds to the last terms in equation (26) divided by gross exports.

Most of East Asia countries except Vietnam and processing China produce a large share of value-added in exports via such channels. Intermediate goods sent to another country to produce intermediate or final goods for exports accounts for a high proportion of total value-added exports for much of East Asia, including Taiwan, the Philippines, Malaysia, Korea, Indonesia, Thailand, Singapore, and Japan. East Asian countries thus engage in longer production networks and are located in the middle of the production chain, providing a large share of manufactured intermediates to both advanced and emerging economies. This result is consistent with case studies that have examined supply chains for electronics (Baldwin and Evenet, 2009) and automobiles (Nag, 2007) in China.[37] Japan is an outlier among developed countries. As papers such as Dean, Lovely, and Mora (2009) have shown, a high share of Japanese exports are processed in China and are then sent as finished goods to developed countries such as the United States.

A comparison of Canada and Mexico is instructive about the differences in supply networks presented in table 3. Both countries send three-quarters or more of their exports to the neighboring United States, and both can take advantage of nearly free trade with the United

[37] See Baldwin and Evenet (2009) for disk drives, and Nag (2007) for automobiles.

States under NAFTA. Analysis of value-added trade, however, shows that these countries participate with distinctly different supply chains. Of the two countries, Canada has much higher domestic value-added share in its gross exports (71% vs. 51%). As with China, extensive processing trade in Mexico generates a low domestic value-added share of exports. Column (6) shows a major difference between the two countries' value-added exports: Mexico sends a much lower share of exports that are, at the end of the supply chain, finished and consumed in the same country (33%/53%). This implies that many Mexican goods, if finished in the United States, may not used there, but sent to a third country for further processing or final assembly and on to a different final destination. This ultimately implies that Mexican exports proceed through a more lengthy supply network than Canadian exports. Canadian firms may also be part of lengthy chains, but they are further downstream in supplying products to the United States.

The value-added decomposition contained in table 3 is quit rich, but may not be easily absorbed by a reader unfamiliar with these different value-added concepts. Figure 2 displays these components by country group, including advanced economies, Asian NICs, emerging Asia, and other emerging economies.[38] It is clear from the figure that Asian countries have much lower total domestic value added in exports than other similar regions. Asian NICs have lower domestic value added than the advanced economies, and shares in emerging Asia are lower than in other emerging countries. Despite their large overall shares, Asian countries have lower shares of value added absorbed by the direct importer than their counterparts. Among the emerging economies, Mexico and the EU accession economies appear most similar to the Asian countries. These two regions are distinguished, however, by the large share of final goods and intermediates absorbed directly by their large immediate neighbors.

(Insert figure 2 here)

Figure 3 compares these components in another way, by examining each component's share of domestic value-added exports rather than gross exports. The figure relies on a property of an equilateral triangle, that the sum of the perpendicular distance to each side is the same for all points in the triangle and is equal to the height of the triangle.[39] Because the triangle can compare only three items at a time, we collapse the two components of VS1 back into a single share. In this case, the height of the triangle is 100, because the three trade shares sum to 100

[38] Groups defined by the IMF at www.imf.org/external/pubs/ft/weo/2010/01/weodata/groups.htm#oem.
[39] See Ley (1996) for an application of this diagram (the Kolm triangle) to the provision of public goods.

percent of domestic value-added exports. Each country is plotted in the triangle with the distance to each side corresponding to the share of each component in value-added exports. For example, Russia has the lowest share of final goods in domestic value-added exports (9.5/89.1=10.6 percent), so it lies closest to the bottom edge of the triangle. Russia also has the highest share of intermediates absorbed by the direct importer (49.1/89.1=55.1 percent), so it lies the farthest from the left edge of the triangle. Regions are represented by color, with emerging and newly-industrialized Asian countries in light blue, other emerging countries in green, and advanced countries in red.

The figure shows the stark difference between Asian and non-Asian emerging economies. Emerging Asia has much lower shares of exports absorbed by the direct exporter. These countries are much more likely to be involved in longer supply chains, in which exports are processed and exported by multiple countries. The Philippines are the most extreme example of this phenomenon. Also we see that primary goods exporters, such as Russia, the rest of the world (largely the Middle East), Indonesia, and Latin America tend to have much lower shares of domestic value added in final goods than other regions. The advanced economies tend to lie in the middle of the triangle, although there are some differences. Canada, with its proximity to the United States, has relatively low exports through third countries, while a much higher share of Japan's exports go through multiple borders.

(Insert figure 3 here.)

4.3 Decomposition of foreign value added in gross exports

Columns (9) and (10) in table 3 further divide the foreign value-added share in gross exports into intermediate and final goods. These shares correspond to the sum of off-diagonal elements along each column of VAX_E matrix, given by equation (23). Most Asian developing countries (China, Vietnam, Thailand, South Asia, and the rest of East Asia), as well as Mexico and EU accession countries use substantial amounts of imported contents to produce final goods exports, while most developed countries and natural resource exporters use imported value largely in the production of intermediate exports.

Columns (11) and (12) show the domestic value-added share in exports for final goods and intermediate goods separately. While natural resource producers and highly developed countries both have high shares of domestic value added in their exports, columns (11) and (12) show substantial differences between these groups. Natural resource exporters tend to have very similar shares of value added in final and intermediate goods. Highly developed countries, however, generally have much higher domestic value added per dollar of final goods exports than per dollar of intermediate goods exports. The United States has a particularly large difference between value added embodied in final goods and the value added in intermediates. Conversely, normal Chinese and Mexican exports embody much more value added per dollar of intermediate goods than final goods. These differences are mainly caused by composition differences in these countries' exports in intermediate and final goods since we do not differentiate the value-added contents at the sector level for final and intermediate goods.

The most notable features of U.S. value-added trade appear in columns (3) and (13), which correspond to the third term in equation (26) divided by each country's total gross exports and imports respectively. The United States has by far the highest share of its own value-added exports (8.3%) that returns embodied in goods it imports. This high share certainly reflects the large U.S. market size, but it likely also reflects the U.S. role as a key supplier of value added in many advanced products that it consumes.

4.4 Position of countries within value chains: Evidence from broad sectors

Table 4 reports the broad sector content of domestic value-added (DV), foreign value-added (VS), and value-added exported indirectly through third countries (VS1). Two types of countries have high domestic value-added shares in their total exports. Countries that export much of their value added in raw materials sectors have the highest value-added shares. Countries that export much of their value added in services, including Hong Kong, the EU, and the United States, also have relatively high overall domestic value-added shares, but lower than the natural resource exporters. Conversely, countries that export most of their value added in manufacturing sectors, such as Taiwan, Mexico, and the Philippines, all have quite low domestic value-added shares in their total exports.

(Insert table 4 here)

Table 4 also reports the broad sector decomposition for VS1, value-added exported indirectly through third countries.[40] At the global level, manufacturing accounts for about one-

[40] VS1 is given by the sum of columns (4), (7), and (8) in table 3. This corresponds to the sum of off-diagonal elements along each row of VAX_E matrix, given in equation (25).

half of exports that are sent indirectly through third countries, and raw materials account for another one-third. Countries with indirect exports may be highly susceptible to global shocks (Bems, Johnson, and Yi, 2010). This may be particularly true for those with high values of indirect exports in manufacturing (e.g., the Philippines, Japan, Taiwan, and Korea). These countries suffered major production and exports downturns in 2008, even though some of their major direct export destinations (such as China) were less affected by the global slowdown.

It is difficult to find one measure that summarizes differences in vertical trade across countries. The VS1/VS ratio has been used in this regard in previous studies (Daudin et al., 2009). At global level, VS1 and VS equals each other, therefore, the average VS1/VS ratio is equal to 1. A ratio larger than 1 indicates the country lies upstream in the global value-chain, either by providing raw materials (such as Russia) or by providing manufactured intermediates (such as Japan) or both. [41] A ratio less than one means the country lies downstream in the global value-chain, using more intermediate inputs from other countries to provide final goods. Column (14) in table 4 shows that widely different countries have high VS1/VS ratios, including both emerging markets and highly developed economies. For instance, Russia, Japan, Australia and New Zealand, United States, the EU 15, the rest of the world, Brazil, the rest of Latin America, Indonesia, and South Africa all have a ratio larger than one. While South Asia, Thailand, Canada, EU accession countries, Vietnam, China, and Mexico have the lowest VS1/VS ratios (less than 0.5). Countries like Hong Kong, Korea, Taiwan, Malaysia, Philippines and EFTA have intermediate VS1/VS ratios, indicating they both use other countries' intermediate inputs to produce final products, and they provide natural or manufactured intermediate inputs in the world production chain.

Further detail on the types of goods that countries provide to value chains allows us to separate these two types of countries. Columns (15) to (17) show that countries with higher than average VS1/VS fall into one of two distinct groups. The most upstream emerging economies (e.g., Russia and Indonesia) produce primary products for global supply chains. The upstream advanced economies produce both manufactured goods and services for these chains. (Almost uniformly, countries with high VS1 in manufacturing have high VS1 in services as well.) Only a

[41] Upstream here refers to the amount of value added provided relative to the amount received. Upstream in other literatures may denote the extent of primary product production. As we will see, some countries are upstream in both senses.

few countries (Australia, Brazil, and Russia) appear upstream in both primary and non-primary products.[42]

Although the VS1/VS ratio is familiar from the literature, the specific measures of domestic value added in tables 3 and 4 are better descriptors of country's positions in global chains. First, this is true as a matter of mathematics, because the VS1/VS ratio is largely dependent on domestic value added by definition.[43] Second, the components of domestic value-added provide more nuanced vies of each country's position. For example, it can be clearly seen from table 3 that countries near large markets (e.g., Canada, the EU accession countries, and Southeast Asia) provide particularly high shares of their goods directly to their final consumer rather than through countries that process and re-export products.

As another example, figure 4 provides an alternative view of countries' positions using the domestic value added export share in table 4 (split between raw materials and other sectors) as well as foreign value-added share(including both VS and VS1*). Because these shares sum to 100 percent for each country, the triangle diagram is again appropriate. The figure clearly distinguishes the advanced economies from the raw material exporters. Most advanced countries and all of the Asian NICs have very low exports of primary materials, and appear on the left edge of the triangle (with the major advanced economies towards the bottom). Non-Asian emerging markets have very low foreign value added content in their exports, and are located towards the bottom of the diagram. Emerging Asian countries appear toward the middle.

(Insert figure 4 here)

4.5 Sources of value added in final goods exports

Table 5 details sources of value added in each country's exports of final goods. For example, 88.1% of the value added in Australia and New Zealand's final goods is sourced domestically. This share corresponds to column (11) in table 3, and is high relative to the world average.[44] Of the remaining 12% of foreign value added, table 5 shows that only the EU and the US contributes more than 2% of value each in Australia and New Zealand's final goods exports.

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[42] Note that these three regions also have a very low VS shares in column (9) of table 4.
[43] As is clear in table 3, VS1 is a component of domestic value added, and VS is close to 100 minus domestic value added for most countries. Thus the ratio must also depend largely on domestic value added. The correlation coefficient between domestic value-added exports and the VS1/VS ratio is 0.74.
[44] Australia and New Zealand have relatively high incomes and relatively large share of value added in natural resources, both of which tend to increase domestic value-added shares.

The shares illustrate some surprising contrasts across regions. Comparing Mexico and EU accession countries, for example, shows that Mexico has much lower domestic content and much higher value added from its large neighbor than the EU accession countries. This illustrates Mexico's deep integration into North American production and the influence of Mexican processing exports. This contrast also illustrates the importance of incorporating a separate IO account for Mexican processing trade into our database.[45]

(Insert Table 5 here)

While table 5 is useful to denote sources for particular countries, it can also distinguish sourcing across countries. The final column presents each country's Herfindahl Hirschman Index (HHI) for value-added shares. The EU, Japan, and the United States have the highest values, indicating high reliance on domestic sources of value-added for these highly developed regions.[46] In contrast, much of developing Asia has far lower indexes, revealing a broader (or deeper) source of international network for inputs. All countries have much more concentrated sourcing than the world average, indicating strong home and regional biases in global supply chains.

V. Conclusion and Directions for Future Work

We have developed a single, unified framework for vertical specialization and value-added trade based on a transparent conceptual framework including many countries using an international IO model. This new framework incorporates all previous measures of value-added trade in the literature and adjusts for the back-and-forth trade of intermediates across multiple borders prevalent in modern international production networks. Using this measure, we can completely decompose gross exports into its domestic and foreign content and further decompose domestic value-added exports into different value-added components that reveal a country's upstream and downstream positions in a global value chain. While the analysis of value-added trade flows in an IRIO table is naturally applicable to final goods trade, the

[45] The absence of a separate processing IO table for emerging Europe may be underestimating the share of developed EU value added in the region, particularly in sectors such as vehicles.

[46] The EU's HHI would likely drop if we better disaggregated European countries in our regions. The U.S. HHI might also drop if we disaggregated Latin America. Japan's score is unlikely to change much with further disaggregation, however, because much of Asia is included separately. We plan to revisit these scores using the full disaggregation available in the GTAP dataset.

decomposition of gross trade flows aligns our measures with official trade statistics, and provides a better comparison with existing measures of vertical specialization in the literature.

We have constructed a global IRIO table for 2004 based on version 7 of the GTAP database to empirically implement the conceptual framework. We make a refinement to the database by using the UN BEC classification method to distinguish final and intermediate goods in gross trade flows. The resulting dataset appears less distorted than the results produced under the widely used proportion method.

This paper has provided the most complete description to date of the relationship between gross trade and its value added components. It has highlighted important relationships within major regional supply networks (the EU, North America, and Asia). It has also demonstrated substantial differences between the regions, with deeper integration apparent in Asia and North America. Many measures show that countries in Emerging Asia have different roles in global supply chains than other emerging economies. Their exports pass through more borders than exports from other emerging markets. Much of Asia, including China itself, sends its exports to countries that provide final assembly on behalf of consumers in other countries. Asian countries also have relatively dispersed sourcing of imported intermediate inputs, and are less likely to be sources of raw materials. In contrast, other developing countries, which tend to lie either further upstream or further downstream in global supply chains, more commonly send their intermediates directly to the country of final consumption, and have much more concentrated sourcing networks.

The contributions of this paper lie largely in its comprehensive framework, its approach to database development, and the new detailed decomposition of value-added trade that has revealed about each country's role in global value chains. The creation of a database that encompasses detailed global trade in both gross and value-added terms, however, will allow us to move from a largely descriptive empirical exercise to analysis of fragmented trade itself in future work. In the discussion in this paper, clearly country size and proximity to large markets greatly affect the way in which countries engage in global supply chains. In future work we plan to examine the extent to which these economic forces, which have been noted and measured in gross trade for decades, apply to value-added exports.

In addition, there may be fruitful insights gained on other related topics. While this paper decomposes domestic value added (DVA) in exports for just one year, the results for overall DVA and its composition may add insights on whether a country's role in global value chains affect growth. In this single-year decomposition we see that the patterns of overall DVA in exports varies substantially among fast growing developing countries such as China, Brazil, and India. These are more similar in the sectoral composition of their DVA—with Brazil and India having much higher DVA contributions from services than China, but all have similar (and only moderate) DVA contributions from manufacturing, despite China's reputation for being predominantly a manufacturing and assembly hub. In contrast, Japan, a country with particularly high DVA in manufacturing exports, has had slow economic growth for decades. Evidence is accumulating that a country's role in global supply chains can affect the variability of trade and national income (Bems, Johnson, and Yi, 2010). Might the position in global supply chains also affect the rate of growth? We leave this for future research.

Appendix

Section 2 derives our vertical specialization measures using matrix notation applicable to any number of countries and industries. While fully generalizable, this notation does not refer to IO coefficients for any specific national or world IO accounts. This appendix provides calculations for each sub-element of the A, B, and VAS, DV, VS, and VS1 matrixes, for those perhaps more familiar with scalar sums of the coefficients themselves.

Assume there are G countries, with N industries in each country. A world IO table provides a comprehensive account of annual product and payment flows within and between countries. We use the following notation to describe the elements of the world IO table (expressed in annual values): x_i^r is gross output of industry *i* in country *r*; v_i^r is direct value added by production of industry *i* in country *r*; z_{ij}^{sr} denotes delivery of good *i* produced by country *s* and used as an intermediate by sector *j* in country *r*; and y_{ik}^{sr} denotes delivery of good *i* produced in country *s* for final use in final demand type *k* in country *r*. The number of final demand types, such as private consumption or gross capital formation, is H. The following accounting identities describe the relationship among elements of each row (*i, r*) and column (*j, s*) of the international IO table:

$$\sum_{s=1}^{G} \sum_{j=1}^{N} z_{ij}^{sr} + \sum_{s=1}^{G} \sum_{k=1}^{H} y_{ik}^{sr} = x_i^r \qquad (A.1)$$

$$\sum_{r=1}^{G}\sum_{i=1}^{N} z_{ij}^{rs} + v_j^s = x_j^s \qquad (A.2)$$

The two equations have straightforward economic interpretations. A typical row in equation (A.1) states that total gross output of commodity *i* in country *r* is equal to the sum of all deliveries to intermediate and final users in all countries (including itself) in the world. Equation (A.2) defines the value of gross output for commodity *j* in production country *s* as the sum of the values from all of its (domestic plus imported) intermediate and primary factor inputs. Equations (A.1) and (A.2) must hold for all $i, j \in$ N, $k \in$ H and $s, r \in$ G in each year.

Define $a_{ij}^{rr} = z_{ij}^{rr} / x_j^{rr}$ as the direct input coefficients of domestic products of country *r*, $a_{ij}^{sr} = z_{ij}^{sr} / x_j^{rr}$, $s \neq r$, as intermediate input/output coefficients of good *i* produced in source country *s* for use in sector j by destination country r; and $av_j^s = {}^{v_j^s}\!/\!_{x_j^s}$ as each sector j's ratio of direct value added to gross output for each producing country s. Using matrix notation, equations (A.1) and (A.2) could be re-written as equation (4):

$$X = (I - A)^{-1} Y = BY\,, \qquad \text{(A.4)}$$

where A is a GNxGN square matrix with G^2 block submatrices of size NxN. Although the analytical solution for the block matrix inverse is too cumbersome when the number of countries exceeds three, we can define each element of the block inverse matrix $B_{sr} = [b_{ji}^{sr}]$ where the superscripts s and r denote source and destination country respectively, and subscripts i and j denote the use and supply industry respectively. Let us further define $V_s = \begin{bmatrix} av_1^s & \cdots & av_j^s & \cdots & av_n^s \end{bmatrix}$ as a 1xGN vector of direct value-added.

Our basic measure of value added in a global production network is the GxGN VAS matrix

$$\text{VAS} = \begin{bmatrix} V_1 B_{11} & \ldots & V_1 B_{1G} \\ \vdots & V_s B_{ss} & \vdots \\ V_G B_{G1} & \ldots & V_G B_{GG} \end{bmatrix} = [vas_i^{sr}] = \left[\sum_{j=1}^{N} av_j^s b_{ji}^{sr} \right] \qquad \text{(A.3)}$$

The domestic value-added share in the source country's total exports is given by

$$\text{Share of } DV^s = \frac{V_s B_{ss} E^s}{uE^s} = \frac{vas_i^{ss} e_i^s}{\sum_{i=1}^{N} e_i^s} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} av_j^s b_{ji}^{ss} e_i^s}{\sum_{i=1}^{N} e_i^s} \qquad \text{(A.4)}$$

which are the diagonal elements of the VAS matrix weighted by the structure of the source country's exports. Sectoral gross exports are given by $e_i^s = \sum_{r=1}^{G} e_i^{sr}$, where $e_i^{rr} = 0$.

The foreign value-added share in the source country's total exports (VS) becomes

$$\text{Share of } VS^s = \frac{\sum_{s \neq r}^{G} V_s B_{sr} E^s}{uE^s} = \frac{\sum_{s \neq r}^{G} vas^{sr} e_i^{sr}}{\sum_{i=1}^{N} e_i^s} = \frac{\sum_{s \neq r}^{G} \sum_{i=1}^{N} \sum_{j=1}^{N} av_j^s b_{ji}^{sr} e_i^{sr}}{\sum_{i=1}^{N} e_i^s}\,. \qquad \text{(A.5)}$$

which is the sum of the off-diagonal elements of the source country column in the VAS matrix weighted by the source country's export structure.

The true measure of VS1, which is value-added embodied in exported intermediates that are processed and sent to their final destination through third countries, becomes

$$\text{Share of } VS1^s = \frac{\sum_{r \neq s}^{G} V_s B_{sr} E^r}{uE^s} = \frac{\sum_{r \neq s}^{G} vas^{sr} e_i^{sr}}{\sum_{i=1}^{N} e_i^s} = \frac{\sum_{r \neq s}^{G} \sum_{i=1}^{N} \sum_{j=1}^{N} av_j^s b_{ji}^{sr} e_i^{sr}}{\sum_{i=1}^{N} e_i^s}. \tag{A.6}$$

This share is the sum of the off-diagonal elements of the source country row in the VAS matrix weighted by the export structure of each country (excluding the source).

These measures could also be defined at disaggregate level, for each source or destination country and for each industry. For example, for a particular industry

$$\text{Share of } DV_i^s = \frac{vas_i^{ss}}{e_i^s} = \frac{\sum_{j=1}^{N} av_j^s b_{ji}^{ss} e_i^s}{e_i^s} \tag{A.7}$$

$$\text{Share of } VS_i^s = \frac{\sum_{s \neq r}^{G} vas_i^{sr}}{e_i^s} = \frac{\sum_{s \neq r}^{G} \sum_{j=1}^{N} av_j^s b_{ji}^{sr} e_i^{sr}}{e_i^s} \tag{A.8}$$

At a disaggregate level, however, VS1 may not be expressible as a share of a country's exports, since the country may not have direct exports of the particular sector or direct exports to a particular partner country. If a sector had zero direct exports but positive indirect value-added exports via third countries, the share of VS1 in exports would be infinite.

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Figure 1 Decomposition gross exports into its major value-added components

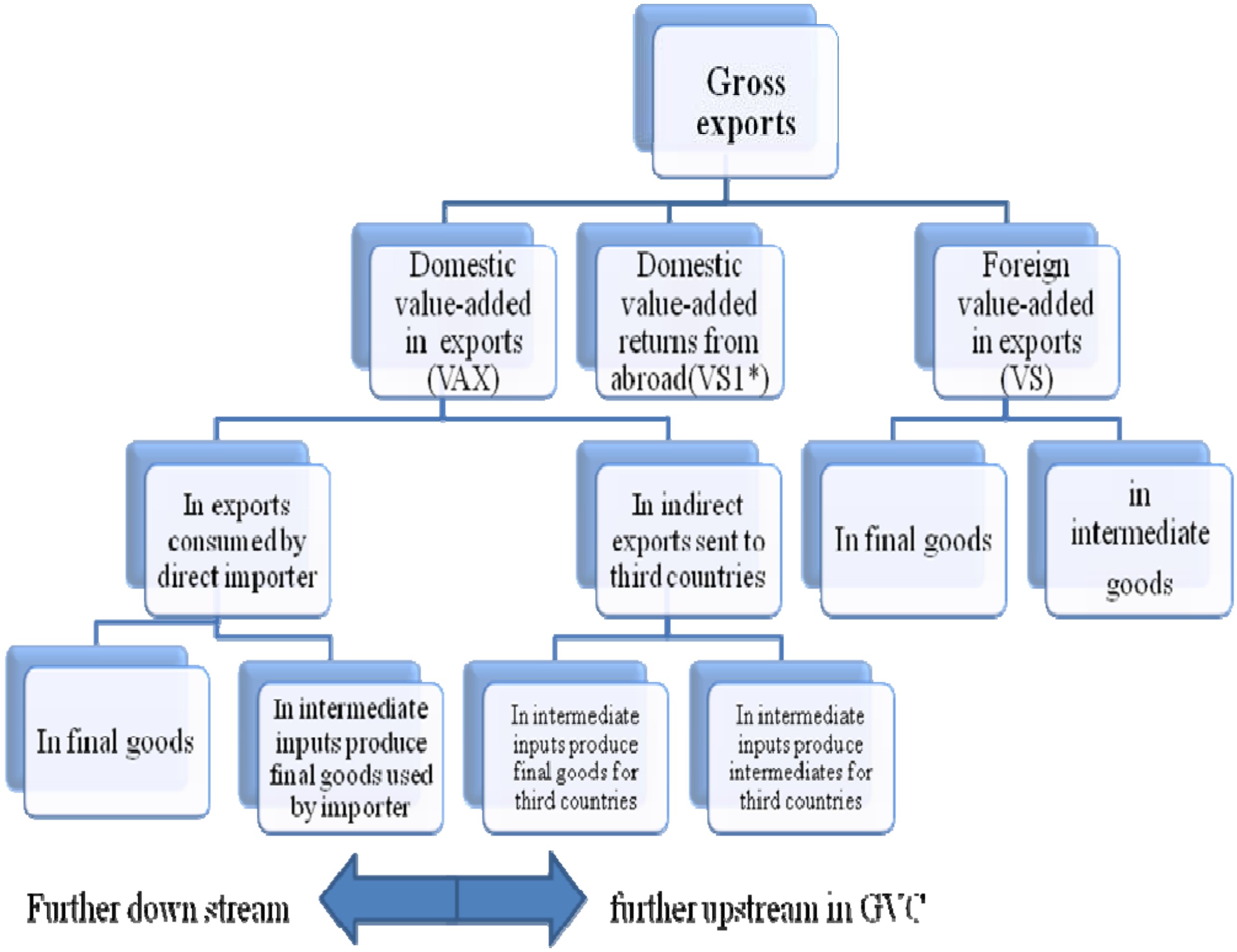


Figure 2 Composition of value-added exports, by country and region

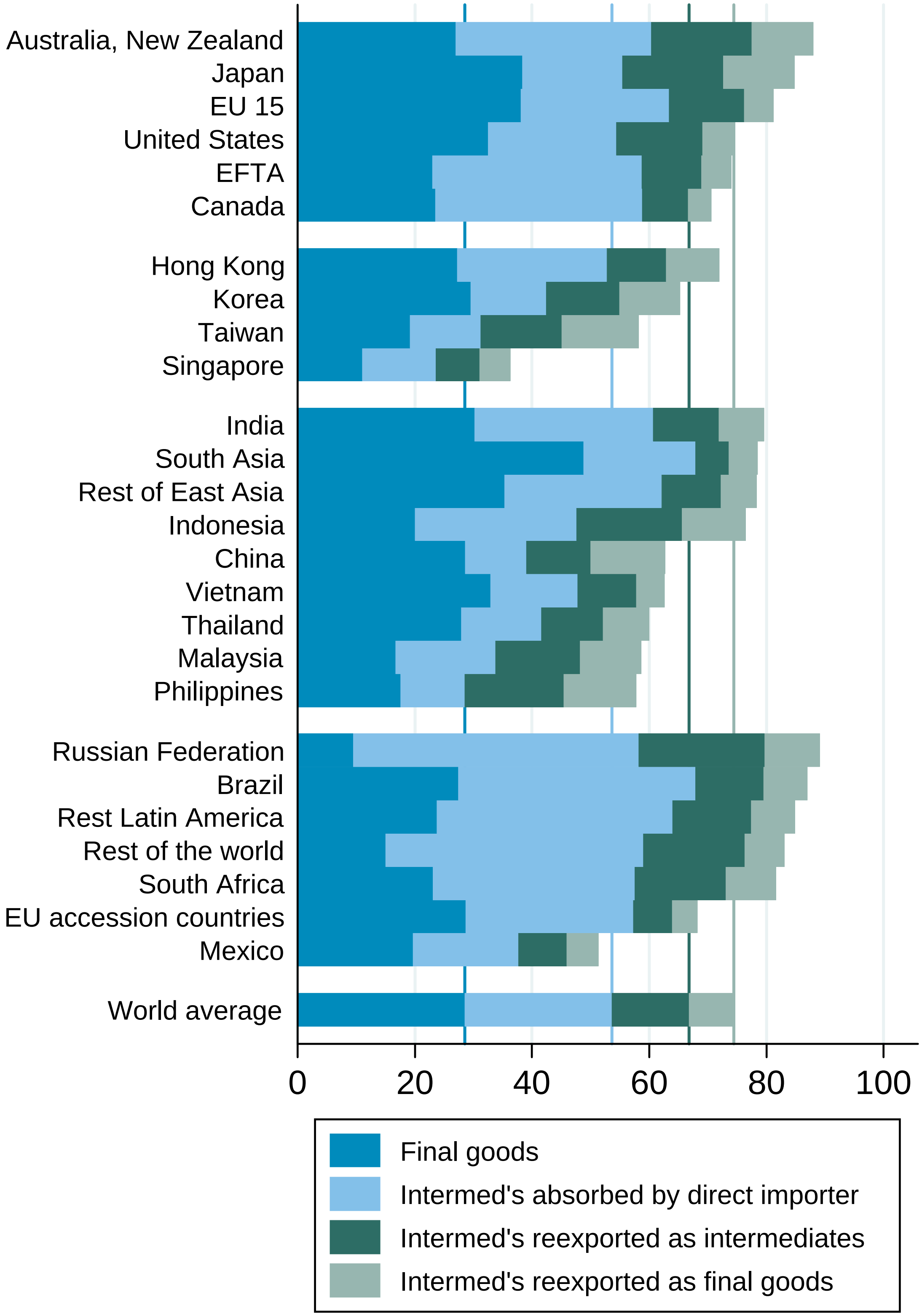
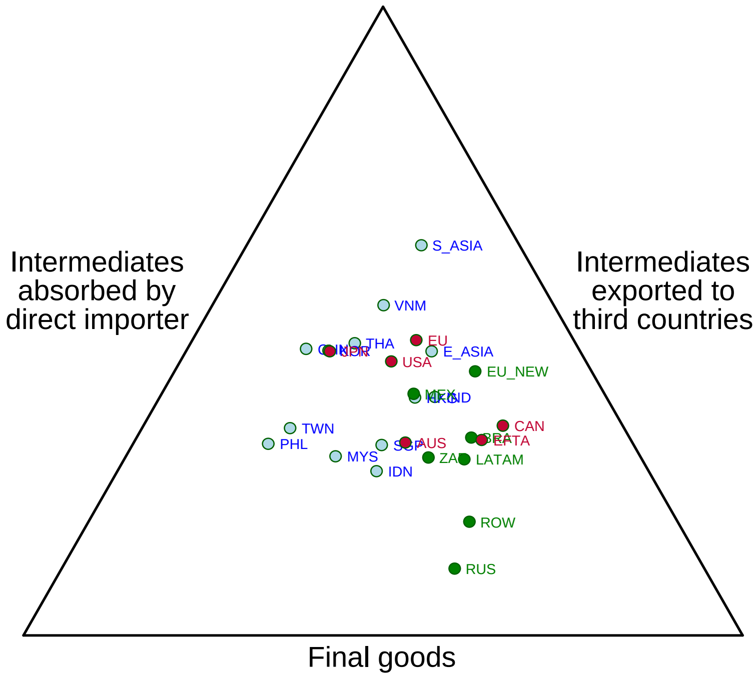
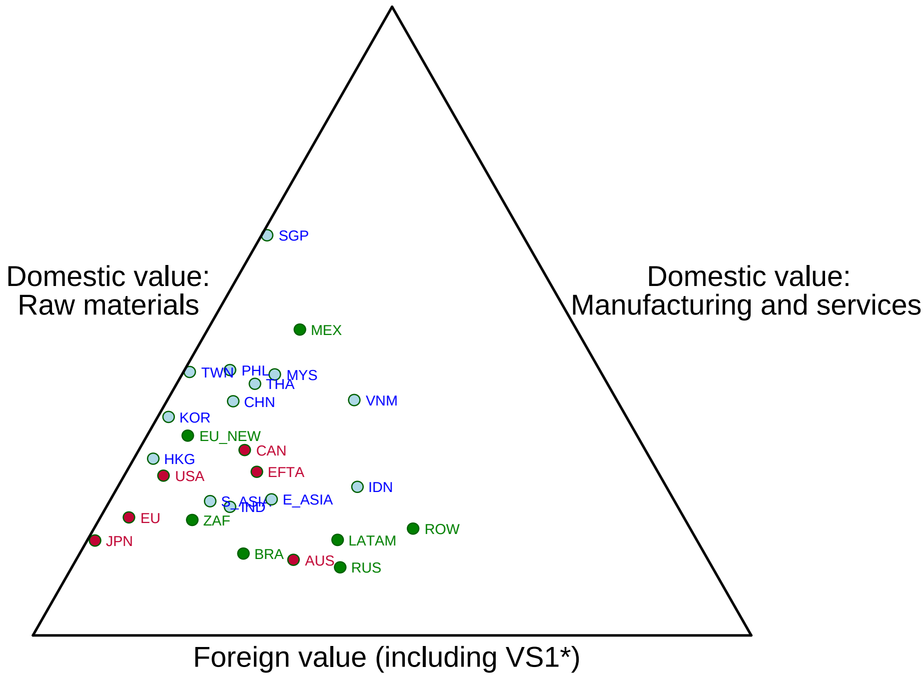


Figure 3 Intermediate and final goods, shares of value-added exports



Note: For any country, the perpendicular distance to each side gives the relevant share in domestic value-added exports. The sum of perpendicular distances for any point in the triangle is 100.

Figure 4 Domestic and foreign value-added shares of gross exports



Note: For any country, the perpendicular distance to each side gives the relevant share in gross output. The sum of perpendicular distances for any point in the triangle is 100.

Table 1a Distinguishing imports of intermediate inputs from final goods—Proportion and BEC methods, 2004, in percent of gross trade

Country	Share of intermediates in exports		Share of intermediates in imports		Share of Value-added in Gross exports	
	Proportion	BEC	Proportion	BEC	Proportion	BEC
	(2)	(3)	(4)	(5)	(6)	(7)
Australia, New Zealand	71.7	69.4	56	50.2	87.1	88
Brazil	63.5	68.7	67.4	67.1	86.8	87
Canada	61	63.7	63	60.4	70	70.5
China	54.6	43.1	82.6	77.4	69.2	62.8
EU accession countries	58.2	57.9	66.9	64	67.4	68.3
EU 15	60.4	57.2	62.8	61.1	80.7	81.1
Hong Kong	63.4	62.6	61.3	60.5	71.9	71.9
Indonesia	70.5	70.8	65.5	71	78.4	76.5
India	59.2	63.5	75.8	81.9	80.9	79.6
Japan	60.4	56.7	64.2	61.9	85.3	84.9
Korea	63.7	57.5	81.2	76.6	63.5	65.2
Mexico	55.7	52.4	63.1	74.6	72.6	51.3
Malaysia	67.5	70.4	73.5	72.1	58.4	58.6
Philippines	62	71.6	75.1	74.8	57.6	57.8
Latin America & Carib.	69.9	71.9	55.8	55.7	84.9	84.9
EFTA	71.2	66.7	65.6	61.8	73.4	74
Rest of the world	79.2	81.1	49.6	51.2	83.2	83
Russian Federation	82.8	88.8	46.4	42.3	88.6	89.1
Singapore	67.3	72.1	80.9	79.6	36	36.3
South Asia	47.1	36.5	56.2	60.6	78.6	78.6
Thailand	61.8	54.9	75.3	75.6	60.1	60
Taiwan	67.9	68.4	75.4	72.6	57.3	58.2
United States	61.4	63.2	57.2	54.7	77.2	74.6
Vietnam	55.8	42.7	72.9	72.1	62.6	62.6
Rest of East Asia	57.8	51.5	68.4	64.5	77.4	78.2
South Africa	71	71.5	65.1	61	80.7	81.6
World	63.7	62.1	63.7	62.1	75.6	74.4

Source: Author estimates based on version 7 GTAP database and UN BEC classification.

Table 1b Distinguishing imports of intermediate inputs from final goods—Normal and processing trade in China and Mexico, 2004, in billions of dollars

Country	Gross exports	Share of intermediates in exports	Gross imports	Share of intermediates in imports	Share of Value-added in Gross exports
China normal	335	49.0	364	70.9	105.5
China processing	336	37.1	205	89.0	20.2
Total	671	43.1	569	77.4	62.8
Mexico normal	64	73.5	94	61.0	92.7
Mexico processing	127	41.8	89	89.1	30.7
Total	191	52.4	183	63.1	51.3

Source: Authors estimates by combine version 7 GTAP database and China's 2002 IO table from Koopman, Wang and Wei and Mexico's 2003 IO table from Instituto Nacional de Estadística, Geografía e Informática (INEGI).

Table 2 Distinguishing imports of intermediate inputs from final goods—Difference between the proportion and BEC methods in electronic machinery trade, China and the United States, 2004

	US electronic machinery imports				China electronic machinery exports			
Country	Proportion	BEC	Difference	Value[a]	Proportion	BEC	Difference	Value[a]
Australia & New Zealand	54.2	61.7	-7.5	176	36.7	12.8	23.9	2,882
Brazil	54.2	34.0	20.2	556	46.6	0.0	46.6	872
Canada	54.2	67.9	-13.7	7,242	46.8	21.6	25.2	2,255
China	54.2	33.5	20.8	57,357				
EU 12	54.2	57.5	-3.3	1,950	61.1	71.3	-10.3	3,281
EU 15	54.2	66.3	-12.1	11,455	52.9	43.8	9.1	46,018
Hong Kong	54.2	41.4	12.8	348	54.0	1.3	52.7	5,382
Indonesia	54.2	34.9	19.3	1,765	30.3	0.0	30.3	897
India	54.2	86.2	-32.0	145	14.7	0.0	14.7	1,530
Japan	54.2	57.5	-3.3	23,364	46.2	13.0	33.3	20,088
Korea	54.2	42.4	11.8	18,718	70.2	20.3	49.9	7,857
Mexico	54.2	41.7	12.5	25,737	73.3	54.4	18.9	4,698
Malaysia	54.2	49.2	5.0	21,035	73.1	0.1	72.9	4,205
Philippines	54.2	82.2	-28.0	3,245	79.3	21.6	57.7	1,772
Rest of America	54.2	93.9	-39.6	734	44.5	41.0	3.5	1,409
Rest of High Income countries	54.2	60.8	-6.6	409	72.5	77.4	-4.8	395
REST OF THE WORLD	54.2	66.5	-12.3	1,503	32.2	6.7	25.5	3,824
Russian Federation	54.2	86.1	-31.8	17	56.1	95.7	-39.6	538
Singapore	54.2	52.5	1.8	7,678	89.2	93.0	-3.8	5,904
South Asia	54.2	90.9	-36.7	11	31.3	16.2	15.1	338
Thailand	54.2	30.4	23.8	4,787	82.1	64.0	18.0	2,081
Taiwan	54.2	62.4	-8.2	13,175	91.5	91.7	-0.3	5,085
United States of America					54.2	33.5	20.8	57,357
Viet Nam	54.2	24.8	29.4	78	82.0	80.9	1.2	197
Rest of east asia	54.2	67.0	-12.8	26	63.6	49.0	14.6	311
South Africa	54.2	75.3	-21.1	17	31.6	12.8	18.8	410
World	54.2	47.1	7.1	201,526	56.1	35.2	20.9	179,587

[a] Value of trade (not difference), in millions of 2004 U.S. dollars.

Table 3 Decomposition of each country's gross exports

Country	Total		Value added that returns to source as a % of gross exports	Channels of domestic value-added in exports (share of each value added component in total gross exports)				Share of foreign value-added in gross exports %		Domestic value-added share %		Value added that returns to source as a % of gross imports
	Domestic value-added = (5)+(6) +(7)+(8)	Foreign value-added = (9)+(10)		Exported final goods	Direct exports of intermed to produce final goods and consume there	Exports of intermed to third country producing intermediate goods for another dest	Exports of intermed to third country producing final goods for another dest.	Exports of final goods	Exports of intermmed goods	Domestic value-added in final goods exports	Domestic value-added in intermediate exports	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Australia, New Zealand	88.0	11.5	0.6	27.0	33.6	16.9	10.5	3.7	7.8	88.1	87.9	0.5
Brazil	87.0	12.7	0.3	27.4	40.7	11.5	7.5	3.9	8.7	87.4	86.9	0.4
Canada	70.5	28.1	1.3	23.5	36.2	6.9	4.0	12.8	15.3	64.8	73.8	1.4
China	62.8	35.7	0.8	36.5	14.6	6.8	4.9	20.5	15.2	64.1	61.1	0.9
EU accession countries	68.3	30.8	1.0	28.7	29.2	6.0	4.3	13.4	17.4	68.2	68.3	0.9
EU 15	81.1	11.4	7.4	38.1	29.6	8.5	5.0	4.8	6.7	88.9	75.3	7.2
Hong Kong	71.9	27.5	0.6	27.2	25.8	9.8	9.1	10.2	17.3	72.7	71.5	0.7
Indonesia	76.5	22.9	0.6	20.0	28.1	17.5	10.9	9.2	13.7	68.5	79.8	0.7
India	79.6	20.1	0.4	30.2	30.8	10.9	7.7	6.4	13.7	82.6	77.9	0.3
Japan	84.9	12.2	2.9	38.4	18.5	15.7	12.2	4.8	7.4	88.8	81.9	3.4
Korea	65.2	33.9	0.9	29.5	13.5	11.8	10.4	13.1	20.8	69.3	62.2	1.1
Mexico	51.3	48.0	0.4	21.6	20.3	6.0	3.6	26.0	22.0	45.3	56.8	0.4
Malaysia	58.6	40.5	0.9	16.7	17.7	13.7	10.4	12.9	27.6	56.5	59.5	1.4
Philippines	57.8	41.9	0.4	17.6	11.1	16.6	12.4	10.8	31.0	61.9	56.1	0.4
Rest Latin America	84.9	14.4	0.7	23.8	40.6	12.9	7.5	4.3	10.1	84.6	84.9	0.8
EFTA	74.0	25.2	0.8	23.0	36.3	9.7	5.1	10.3	15.0	69.1	76.4	0.9
Rest of the world	83.0	14.6	2.5	15.0	45.6	15.6	6.8	3.9	10.7	79.2	83.8	2.7
Russian Federation	89.1	10.2	0.7	9.5	49.1	21.1	9.4	1.6	8.5	85.3	89.6	0.9
Singapore	36.3	63.2	0.6	11.0	13.1	7.0	5.2	17.0	46.2	39.3	35.1	0.6
South Asia	78.6	21.3	0.1	48.8	19.2	5.6	4.9	14.6	6.7	76.9	81.4	0.1
Thailand	60.0	39.7	0.3	27.9	14.0	10.2	7.9	17.2	22.5	61.9	58.4	0.4
Taiwan	58.2	41.1	0.8	19.2	12.6	13.3	13.1	12.4	28.6	60.7	57.0	1.0
United States	74.6	12.9	12.4	32.5	27.6	9.0	5.5	4.3	8.7	88.4	66.7	8.3
Vietnam	62.6	37.0	0.4	32.9	15.3	9.6	4.8	24.4	12.6	57.5	69.5	0.4
Rest of East Asia	78.2	21.7	0.1	35.3	26.9	10.0	6.1	13.3	8.4	72.6	83.5	0.2
South Africa	81.6	18.2	0.2	23.1	34.5	15.4	8.5	5.3	12.8	81.3	81.7	0.2
World average	74.4	21.5	4.0	29.2	27.7	10.7	6.8	8.7	12.8	77.1	72.7	4.0

Source: Author's estimates.

Note: a. Columns (2) + (3)+(4) =100; b. Columns (4)+(7) +(8) = HIY VS1. C. Column (4) equals the third term in equation (24) divided by a country's gross exports; Column (5) equals the first term in equation (24) divided by a country's gross exports; column (6)+(7) equals the second term in equation (24) divided by a country's gross exports; column (8) equals the last term in equation (24) divided by a country's gross exports and sum of column (5) to (8) equals column (2). Column (13) equals the third term in equation (24) divided by the country's final goods imports. Column (11) are the first term in equation (24) divided by a country's final goods exports, while column (12) are the sum of the second, third, and last term in equation (24) divided by a country's intermediate exports.

Table 4 Decomposition of value-added exports from major sectors, share of gross exports

Country/Region	DV: Sector generating domestic value-added				VS: Sector contents of embodied foreign value-added				VS1: sector souces of value-added in intermediates exported via third countries				VS1/VS ratio			
	Raw materials	Manu-facturing	Services	Total	Raw materials	Manu-facturing	Services	Total	Raw materials	Manu-facturing	Services	Total	Total	Raw materials	Manu-facturing	Services
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Australia, New Zealand	30.3	21.1	36.5	88	3.6	5.6	2.3	11.5	9.8	8.7	9.4	27.9	2.4	0.86	0.76	0.82
Brazil	22.8	37.7	26.5	87	2.9	9	0.8	12.7	4.7	8.6	6	19.2	1.5	0.37	0.68	0.47
Canada	14.8	32.1	23.6	70.5	2.2	24.5	1.4	28.1	2.9	5.6	3.8	12.2	0.4	0.10	0.20	0.13
China	9.3	37.5	16	62.8	1	33.8	0.8	35.7	1.6	7.6	3	12.2	0.3	0.05	0.21	0.08
EU accession	5.7	35.7	26.8	68.3	1.2	26.7	2.9	30.8	0.8	6.2	4.3	11.4	0.4	0.03	0.20	0.14
EU 15	4	34.9	42.2	81.1	0.5	9.3	1.6	11.4	0.9	9.8	10.2	20.9	1.8	0.08	0.86	0.89
Hong Kong	2.7	11.7	57.5	71.9	0.1	11.3	16	27.5	1.3	5.8	12.4	19.5	0.7	0.05	0.21	0.45
Indonesia	33.4	28.4	14.7	76.5	1.8	19.8	1.3	22.9	13.8	10.5	4.7	29	1.3	0.60	0.46	0.21
India	17.2	35.2	27.2	79.6	1	16.5	2.6	20.1	4.3	8.9	5.8	18.9	0.9	0.21	0.44	0.29
Japan	1.1	49.9	34	84.9	0.1	11.6	0.6	12.2	0.3	18.8	11.7	30.8	2.5	0.03	1.53	0.96
Korea	1.5	45.3	18.5	65.2	0.2	32	1.6	33.9	0.4	17	5.8	23.2	0.7	0.01	0.50	0.17
Mexico	12.8	33.9	4.7	51.3	5.6	41.7	0.6	48	2.4	6.5	0.6	9.6	0.2	0.05	0.14	0.01
Malaysia	13	32.2	13.4	58.6	2.3	36.2	1.9	40.5	4.5	15.7	4.9	25	0.6	0.11	0.39	0.12
Philippines	6.4	38.5	12.8	57.8	1.2	38.8	1.8	41.9	1.6	21.8	5.9	29.4	0.7	0.04	0.52	0.14
Latin Am. And Carib.	34.8	24.2	25.9	84.9	4.5	7.6	2.3	14.4	8	7.7	5.5	21.2	1.5	0.55	0.53	0.38
EFTA	18.2	26.4	29.4	74	2.1	20.6	2.6	25.2	4.8	5.5	5.2	15.5	0.6	0.19	0.22	0.21
Rest of the world	44.5	16.3	22.2	83	5.1	7.7	1.8	14.6	15.6	4.3	5	24.9	1.7	1.07	0.29	0.34
Russian Federation	37.4	23	28.7	89.1	2.8	6.4	1	10.2	13.2	8.9	9.1	31.2	3.1	1.30	0.87	0.90
Singapore	0.8	17.7	17.8	36.3	1.1	54.1	7.9	63.2	0.1	8.5	4.1	12.8	0.2	0.00	0.13	0.07
South Asia	14	30.8	33.8	78.6	1.3	18	2.1	21.3	1.8	3.8	5	10.7	0.5	0.09	0.18	0.24
Thailand	10.9	31	18.1	60	2.5	34.3	2.9	39.7	2.2	11.4	4.9	18.5	0.5	0.06	0.29	0.12
Taiwan	0.9	37	20.2	58.2	0.4	39.7	1	41.1	0.2	18.7	8.2	27.1	0.7	0.01	0.46	0.20
United States	5.5	32.4	36.7	74.6	0.6	10.7	1.7	12.9	1.7	13.9	11.4	27	2.1	0.13	1.07	0.88
Vietnam	26.1	27.3	9.2	62.6	7	27.1	3	37	8.2	4.4	2.2	14.8	0.4	0.22	0.12	0.06
Rest of East Asia	22.4	22.2	33.7	78.2	3	13.1	5.5	21.7	6.7	3.2	6.3	16.2	0.7	0.31	0.15	0.29
South Africa	13	31.2	37.4	81.6	3.3	13.1	1.8	18.2	3.4	11.8	9	24.2	1.3	0.19	0.65	0.50
Average	12.4	32.6	29.4	74.4	1.6	18	1.9	21.5	3.6	10.3	7.6	21.5	1	0.17	0.48	0.35

Source: Author's estimates.

Table 5 Sources of value-added in final goods exports

Country/Region	AUS	BRA	CAN	CHN	EU access	EU	HKG	IDN	IND	JPN	KOR	MEX	MYS	PHL	Latin Am.	EFTA	ROW	RUS	SGP	South Asia	THA	TWN	USA	VNM	Rest E. Asia	ZAF	HHI[a]
Australia, NZL	88.1	0.1	0.2	0.8	0.1	3.1	0.2	0.3	0.1	1.0	0.3	0.1	0.4	0.1	0.2	0.2	1.3	0.1	0.2	0.0	0.2	0.3	2.1	0.2	0.1	0.1	77.7
Brazil	0.1	87.4	0.2	0.4	0.1	3.6	0.1	0.1	0.1	0.6	0.3	0.1	0.1	0.0	1.6	0.2	1.3	0.2	0.1	0.0	0.1	0.1	2.8	0.0	0.0	0.1	76.7
Canada	0.3	0.4	64.8	1.3	0.2	3.9	0.2	0.1	0.2	1.7	0.4	0.6	0.2	0.1	0.9	0.4	1.0	0.2	0.1	0.0	0.1	0.4	22.5	0.0	0.0	0.1	47.2
China	0.8	0.4	0.4	64.1	0.2	4.2	1.7	0.6	0.4	7.9	3.8	0.2	1.6	0.5	0.6	0.3	2.2	0.6	0.6	0.1	0.9	4.0	3.7	0.1	0.1	0.2	42.4
EU accession	0.2	0.2	0.2	1.1	68.2	20.1	0.1	0.1	0.2	1.3	0.5	0.1	0.3	0.1	0.4	0.7	2.3	1.4	0.2	0.1	0.1	0.4	1.8	0.0	0.0	0.1	50.7
EU 15	0.2	0.2	0.3	0.9	1.1	88.9	0.2	0.1	0.2	1.0	0.2	0.1	0.2	0.1	0.4	0.9	1.6	0.6	0.2	0.0	0.1	0.2	2.1	0.0	0.0	0.2	79.1
Hong Kong	1.1	0.1	0.4	1.8	0.2	5.4	72.7	0.5	0.7	4.6	1.6	0.1	0.7	0.3	0.4	0.4	2.2	0.3	0.4	0.2	0.5	1.8	3.2	0.1	0.1	0.2	53.6
Indonesia	1.6	0.3	0.5	2.3	0.2	5.4	0.3	68.5	0.7	4.8	2.1	0.1	1.2	0.3	0.5	0.4	3.2	0.3	1.7	0.1	0.8	1.2	3.3	0.2	0.1	0.2	47.8
India	1.1	0.2	0.2	1.2	0.2	3.9	0.2	0.3	82.6	0.7	0.4	0.1	0.4	0.0	0.3	0.7	4.4	0.4	0.2	0.2	0.2	0.3	1.4	0.0	0.1	0.5	68.6
Japan	0.5	0.1	0.2	1.1	0.1	1.8	0.2	0.4	0.1	88.8	0.7	0.1	0.3	0.2	0.3	0.2	1.5	0.2	0.1	0.0	0.3	0.5	2.1	0.1	0.0	0.1	79.0
Korea	1.1	0.3	0.4	2.5	0.2	4.1	0.5	0.6	0.2	7.1	69.3	0.1	0.6	0.3	0.7	0.4	3.4	0.6	0.4	0.1	0.3	1.1	5.3	0.1	0.1	0.2	49.2
Mexico	0.2	0.5	1.3	2.0	0.3	4.4	0.1	0.1	0.2	2.7	1.1	45.3	0.4	0.2	1.4	0.3	1.0	0.2	0.2	0.1	0.2	0.6	37.1	0.0	0.0	0.1	34.7
Malaysia	1.2	0.3	0.5	2.9	0.4	8.0	0.4	1.5	0.5	7.6	2.2	0.2	56.5	1.1	0.7	0.4	2.4	0.4	1.9	0.1	1.6	2.0	6.6	0.2	0.1	0.3	33.9
Philippines	0.7	0.3	0.4	3.6	0.2	4.8	0.4	1.0	0.4	9.0	2.7	0.1	1.3	61.9	0.5	0.5	2.7	0.4	0.8	0.1	0.9	2.8	4.2	0.1	0.0	0.1	40.0
Latin Am.	0.1	1.3	0.5	0.6	0.2	3.5	0.1	0.1	0.1	0.6	0.4	0.4	0.1	0.0	84.6	0.2	1.0	0.3	0.1	0.1	0.1	0.2	5.1	0.0	0.0	0.1	72.1
EFTA	0.2	0.2	0.4	0.7	0.8	19.7	0.2	0.1	0.2	0.9	0.2	0.2	0.1	0.1	0.6	69.1	1.8	0.7	0.1	0.0	0.2	0.2	3.1	0.0	0.0	0.2	51.8
Rest of world	0.3	0.3	0.2	1.0	0.8	9.1	0.1	0.2	0.6	0.9	0.6	0.1	0.2	0.0	0.4	0.6	79.2	1.5	0.1	0.2	0.2	0.3	2.2	0.0	0.0	0.5	63.7
Russian Fed.	0.1	0.3	0.1	0.6	0.8	6.2	0.1	0.1	0.1	0.5	0.4	0.0	0.2	0.0	0.3	0.3	3.3	85.3	0.1	0.0	0.1	0.1	0.9	0.0	0.0	0.1	73.2
Singapore	1.1	0.3	0.7	4.7	0.7	13.1	0.8	2.2	0.8	8.7	2.5	0.3	4.6	1.3	0.7	0.8	3.2	0.5	39.3	0.1	1.3	3.0	8.8	0.2	0.1	0.2	19.5
South Asia	0.7	0.2	0.2	3.6	0.2	3.4	0.3	0.6	1.7	1.3	1.3	0.0	0.5	0.0	0.3	0.3	3.6	0.3	0.3	76.9	0.6	1.3	1.8	0.1	0.1	0.1	59.7
Thailand	1.4	0.5	0.4	2.8	0.3	5.3	0.5	0.9	0.6	8.6	1.4	0.2	1.9	0.4	0.6	0.5	4.1	0.6	0.8	0.1	61.9	1.3	4.0	0.2	0.5	0.3	39.9
Taiwan	1.1	0.4	0.5	3.8	0.2	4.6	0.3	0.8	0.3	9.5	2.4	0.2	1.0	0.6	0.9	0.4	4.0	1.0	0.4	0.0	0.5	60.7	5.5	0.1	0.0	0.7	38.7
United States	0.1	0.2	1.5	0.8	0.1	2.8	0.1	0.1	0.1	1.3	0.4	0.8	0.2	0.1	0.6	0.2	1.2	0.2	0.1	0.0	0.1	0.3	88.4	0.0	0.0	0.1	78.2
Vietnam	1.0	0.3	0.4	6.2	0.2	4.7	0.4	1.2	0.9	4.0	4.0	0.1	1.3	0.2	0.8	0.6	4.6	0.8	0.9	0.3	1.9	4.5	2.8	57.5	0.4	0.2	34.6
Rest of E. Asia	0.5	0.4	0.3	5.5	0.2	4.0	1.0	0.5	0.5	1.9	1.4	0.1	0.8	0.1	0.3	0.2	1.7	0.5	0.7	0.2	1.9	2.2	2.1	0.4	72.6	0.1	53.5
South Africa	0.5	0.4	0.2	0.8	0.3	6.9	0.1	0.2	0.3	1.5	0.3	0.1	0.2	0.0	0.4	0.3	3.9	0.2	0.1	0.1	0.2	0.3	1.5	0.0	0.0	81.3	66.7
Average	1.6	1.3	3.1	9.5	3.1	24.8	1.5	0.9	1.3	11.0	3.9	1.6	1.4	0.5	2.3	2.5	5.5	1.1	0.8	0.7	1.5	2.4	16.2	0.4	0.4	0.7	11.9

[a] Herfindahl-Hirschman Index divided by 100.

Appendix Table A1 Countries in database and corresponding GTAP regions

Country or region	Corresponding GTAP regions
Australia, New Zealand	Australia, New Zealand
Brazil	Brazil
Canada	Canada
China	China
China normal	N/A
China processing	N/A
EU accession	Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia
EU 15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK
Hong Kong	Hong Kong
Indonesia	Indonesia
India	India
Japan	Japan
Korea	Korea
Mexico	Mexico
Mexico normal	N/A
Mexico processing	N/A
Malaysia	Malaysia
Philippines	Philippines
Latin America and the Caribbean	Argentina, Bolivia, Caribbean, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Nicaragua, Panama, Paraguay, Peru, Rest of Central America, Rest of North America, Rest of South America, Uruguay, Venezuela
EFTA	Switzerland, Norway, Rest of EFTA
Rest of world	Albania, Armenia, Azerbaijan, Belarus, Botswana, Central Africa, Croatia, Egypt, Ethiopia, Georgia, Iran, Islamic Republic of, Kazakhstan, Kyrgyztan, Madagascar, Malawi, Mauritius, Morocco, Mozambique, Nigeria, Rest of Eastern Africa, Rest of E. Europe, Rest of Europe, Rest of Former Soviet Union, Rest of North Africa, Rest of Oceania, Rest of South African Customs Union, Rest of Western Africa, Rest of Western Asia, Senegal, South Central Africa, Tanzania, Tunisia, Turkey, Uganda, Ukraine, Zambia, Zimbabwe
Russian Federation	Russian Federation
Singapore	Singapore
South Asia	Bangladesh, Pakistan, Rest of South Asia, Sri Lanka
Thailand	Thailand
Taiwan	Taiwan
United States	United States
Vietnam	Vietnam
Rest of East Asia	Cambodia, Laos, Myanmar, Rest of East Asia, Rest of Southeast Asia, South Africa
South Africa	South Africa

Appendix Table A2 Distinguishing imports of intermediate inputs from final goods—The difference between the proportion and BEC methods, by country, 2004, in percent

Country	Exports					Imports				
	N	Simple average		Weighted Average		N	Simple average		Weighted Average	
		MEAN	STD	MEAN	STD		MEAN	STD	MEAN	STD
Australia & New Zealand	650	-5.9	29.3	3.3	19.9	640	-2.6	26.1	7.4	17.6
Brazil	629	-6.9	34.1	-5.6	27.4	632	0.9	37.2	-1.6	17.2
Canada	649	-3.5	29.1	-2.9	14.4	639	3.7	27.6	3.3	13.0
China	650	7.8	28.2	12.5	19.2	644	3.9	24.4	5.8	12.8
EU 12	650	3.6	31.7	0.9	17.2	642	2.4	28.9	3.7	11.9
EU 15	650	1.0	23.0	4.2	12.9	646	1.2	25.6	2.6	15.9
Hong Kong	632	-0.9	35.4	3.1	17.9	637	-0.8	33.1	0.8	27.4
Indonesia	650	-0.6	30.6	-0.2	21.3	640	4.2	33.5	-7.0	21.7
India	648	-2.0	31.4	-5.0	23.2	637	-20.8	39.4	-7.4	23.3
Japan	625	-4.4	26.5	4.1	13.5	644	1.7	30.4	2.8	19.3
Korea	620	-2.5	27.3	6.8	18.9	642	2.5	27.1	5.6	21.9
Mexico	634	4.1	38.2	3.6	16.2	633	-12.5	44.2	-12.5	26.4
Malaysia	638	0.0	30.9	-2.9	15.6	640	0.2	26.8	2.2	23.8
Philippines	610	-3.8	31.7	-10.0	21.7	643	1.3	32.1	0.6	19.6
Rest of America	650	-4.2	33.6	-2.7	23.3	642	-1.6	29.2	0.3	18.1
Rest of High Income countries	649	2.7	32.1	6.2	15.4	635	2.3	36.5	5.3	21.7
Rest of the world	650	-2.9	26.0	-2.1	13.9	650	-4.1	25.5	-2.0	15.9
Russian Federation	650	-4.1	35.0	-6.5	13.7	635	-0.8	34.9	5.9	17.4
Singapore	619	-1.3	28.4	-5.9	17.3	643	-1.8	27.1	1.8	13.5
South Asia	647	-0.6	36.1	13.3	22.7	636	-10.6	31.7	-5.1	21.6
Thailand	647	3.9	31.8	8.1	20.8	644	0.8	28.1	-0.2	14.6
Taiwan	618	-4.7	28.1	-0.5	18.5	643	-1.2	26.2	3.2	13.1
United States of America	650	-2.6	23.3	-2.3	16.3	644	4.0	27.8	3.0	16.1
Viet Nam	650	4.9	35.7	14.8	26.1	633	3.6	29.4	1.2	20.6
Rest of East Asia	650	4.5	35.9	10.6	25.6	645	1.7	30.5	5.3	21.5
South Africa	629	-7.2	30.9	-0.3	18.8	635	-2.6	32.1	4.8	16.5
World	16,644	-1.0	31.4	2.1	17.4	16,644	-1.0	31.4	2.1	17.4

Appendix Table A3 Distinguishing imports of intermediate inputs from final goods—The difference between the proportion and BEC methods, by sector, 2004, percent

Sector	N	MIN	MAX	Simple average		Weighted Average	
				MEAN	STD	MEAN	STD
Crop production	650	-72.4	96.0	-1.5	31.5	-1.3	26.1
Animal husbandry	650	-80.3	93.5	-12.8	32.8	-7.1	22.8
Forestry	650	-97.1	100.0	-13.4	27.3	-15.7	22.4
Fishing	650	-98.9	98.8	9.4	46.0	45.6	31.4
Coal	518	-30.0	100.0	18.0	40.8	-1.7	3.4
Oil and gas	540	-7.6	100.0	38.7	48.9	-1.6	3.0
Minerals nec	647	-88.2	100.0	-3.8	18.1	-2.2	7.3
Meat and Dairy products	650	-88.8	82.7	-6.0	40.3	21.7	23.3
Food products nec	650	-90.1	63.2	6.8	29.9	9.5	26.2
Beverages and tobacco products	650	-88.7	90.3	12.2	36.2	22.3	24.1
Textiles	650	-73.4	65.7	-7.4	25.8	4.9	26.3
Wearing apparel	650	-89.4	79.8	8.5	26.1	8.8	10.9
Leather products	650	-87.3	91.7	-6.8	33.8	5.6	21.0
Wood products	650	-65.2	84.4	3.8	23.0	6.6	23.1
Paper products publishing	650	-35.2	79.4	-1.3	18.9	-0.6	13.8
Petroleum coal products	642	-44.6	98.5	-13.4	20.6	-17.3	10.4
Chemical rubber plastic products	650	-32.3	58.2	-1.1	13.4	0.0	10.1
Mineral products nec	650	-70.4	91.9	-2.0	16.3	-1.5	15.1
Ferrous metals	649	-92.1	80.1	-6.7	19.1	-4.5	15.3
Metals nec	648	-88.1	100.0	-7.9	20.8	-4.9	14.1
Metal products	650	-42.6	74.5	-2.5	16.7	-1.4	10.5
Motor vehicles and parts	650	-97.9	81.1	-16.3	36.0	2.1	16.9
Transport equipment nec	650	-95.3	89.8	-6.6	37.7	9.9	22.0
Electronic equipment	650	-79.0	72.9	-3.1	24.9	1.7	17.5
Machinery and equipment nec	650	-67.3	70.2	4.0	20.0	6.7	14.1
Manufactures nec	650	-77.5	75.7	-3.1	29.3	-5.8	26.7

Figure A1 Database construction: MRIO to IRIO table

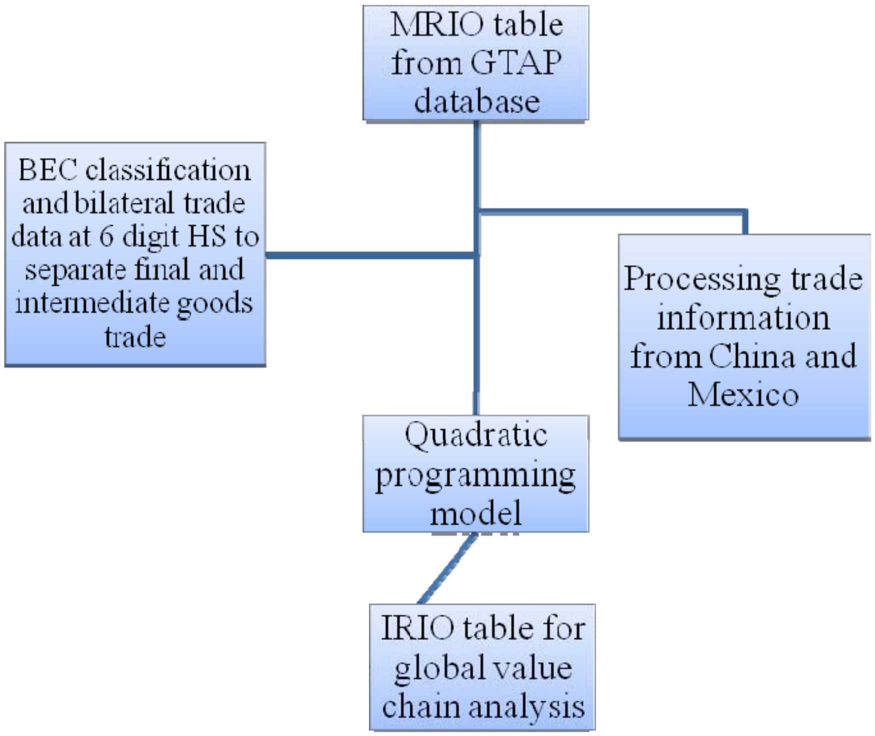


Figure A2 Share of intermediate goods in bilateral gross trade Flows: histogram-Difference between Proportion and BEC methods