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Abstract

This paper presents a new conceptual framework to measure sources of value-added trade by country in global production networks. With a parsimonious decomposition of gross exports that eliminates "double counting", it integrates all previous measures of vertical specialization and value-added trade in the literature. We apply the framework to the most recent appropriate data (2004). Among emerging markets, East Asian countries are the most globally integrated. Among major developed economies, the US is the most integrated in some aspects, and Japan in others. These regional differences also affect exporters' trade costs.

JEL Classification: F1, F2

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1. Introduction

Worldwide trade has become increasingly fragmented, as different stages of production are now regularly performed in different countries. As inputs cross borders multiple times, traditional statistics on trade values—measured in gross terms—become increasingly less reliable as a gauge of value contributed by any particular country. This paper integrates and generalizes the many attempts in the literature at tracing value added by country in international trade. We provide a conceptual framework that is more comprehensive than other measures in the 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. 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. 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. The conceptual and empirical shortcomings of gross trade statistics, as well as their inconsistency with SNA accounting standards, has long been recognized by the economic profession.[1] The comprehensive framework presented in this paper will allow people to measure trade in value-added terms that are still consistent with currently available official gross trade statistics, thus improving our understanding of the nature of cross-border trade in today's increasingly integrated world.

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. 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.[2] Nor is this a particularly isolated example, at least for Chinese electronics. Koopman, Wang, and Wei (2008) show that on average, foreign countries contribute 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 iPhones, Barbie dolls, Chinese hard drives, North American automobiles, and Asian apparel.

[1] See, for example, Leamer et al. (2006).

[2] 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.

Hummels, Ishii, and Yi (2001), denoted HIY in the following discussions, provided the first general measures of vertical specialization in trade that quantify foreign value added in a country's exports. While these measures have since been revised, they continue to be central to the discussion of vertical specialization in trade.[3] 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. More importantly, 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-regional 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 in Japan. Such papers include Koopman, Wang, and Wei (2009), Pula and Peltonen (2009), and Wang, Powers, and Wei (2009). These studies 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 in general, with the exception of flows to and from the United States.

Truly global analyses have become possible only recently, with the advent of global IRIO tables based on the GTAP database.[4] 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. For example, an unusually high share of U.S. value added is first exported to producers in other countries and then 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.[5] 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.[6]

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3 See Chen et al. (2005) and Yi (2003) for revised estimates of the extent of vertical specialization in trade; see Daudin, Rifflart, and Schweisguth (2010), Johnson and Noguera (2010), and Wang, Powers, and Wei (2009) for refined definitions of vertical specialization in trade.

4 See Daudin, Rifflart, and Schweisguth (2010), Johnson and Noguera (2010), and Bems, Johnson, and Yi (2010).

5 See section 3 for additional distinctions between the IO structure underlying the GTAP database and IRIO tables required for global value-added analysis.

6 See Wang, Tsigas, Mora, Li, 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.

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 related to Daudin, Rifflart, and Schweisguth (2010) and Johnson and Noguera (2010). Each 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 distribute 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 five aspects:

First, we develop a single, unified, transparent conceptual framework that incorporates all measures of value-added trade. Our framework ties HIY's original measures of vertical specialization with newer measures of value-added trade in a way that completely accounts for all elements of gross exports.[7] Each measure has been modified from its original definition, however, to correctly specify value added in a multi-country framework or to avoid omitting elements of gross trade.

Second, we completely decompose each country's gross exports into value-added components, thus establishing a formal relationship between value-added measures of trade and official trade statistics.

Third, we split domestic value-added exports into several parts that allow us to more clearly distinguish each country's role in global value chains. The results distinguish the extent to which countries export final goods and services, intermediate inputs that are assembled into final goods in the direct importing country, and intermediate inputs exported to other countries for further processing.

Fourth, our estimated global IRIO better captures the international source and use of intermediate goods than in previous databases. We improve the estimates of intermediate goods in bilateral trade by examining the end-use classification (intermediate or final) of detailed import statistics.[8] The additional detail provides a substantial improvement over earlier approaches that assumed the share

[7] Other frameworks have been less complete or less fully specified. For example, Johnson and Noguera (2010) did not examine HIY's measure of indirect trade through third countries. 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 (2010) compute measures for multiple countries, but they calculate each measure separately, and do not specify the connection between these terms and gross trade flows.

[8] 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 concord HS imports to UN Broad Economic Categories, which are more applicable to international trade flows.

of intermediate goods in imports matched the share of intermediates in total absorption. In addition, we incorporate IO tables that account for processing trade in China and Mexico, the two major users of such regimes in the developing world.[9] 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.

Finally, we measure trade costs in the presence of vertical specialization, showing that global production fragmentation dramatically amplifies trade costs for some countries. These effects may have a significant impact on the volume of world trade, in a manner consistent with the theoretical predictions in Yi (2003, 2010).

This paper is organized as follows. Section 2 presents key measures of 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 compare regional participation in global value chains and the impact on trade costs. 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 locations. 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 inputs that are used by another country to produce exports. However, HIY's original measures were insufficient for full analysis of supply chains. Their measure of foreign value in direct exports is valid only in a special case; they did not mathematically define their measure of indirect value-added exports through third countries; and these two measures do not capture all sources of value added in gross exports and imports. This section examines the first shortcoming, and section 2.2 provides a fully generalizable solution for each.[10]

HIY's measures are valid in a special case that generally will not hold with the multi-country, back-and-forth nature of current global production networks. Two key assumptions are needed for the HIY

9 Processing trade regimes can foster imports that have dramatically higher intermediate content than domestic use in some countries. See the discussion in section 3.2

10 Johnson and Noguera (2010) address the first of these shortcomings. They contrast HIY's measure of foreign content in exports to a more generalized measure.

measure to accurately reflect value-added trade. First, all imported intermediate inputs must contain 100% foreign value added and no more than one country can export intermediate. In the HIY model, a country cannot import intermediate inputs, add value, and then export semi-finished goods to another country to produce final goods. Nor can a country receive intermediate imports that embody its own value added, returned after processing abroad. Second, 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 raise the imported intermediate content of exports relative to domestic use, as in China and Mexico.

To accurately track the sources of value added, a framework is needed that incorporates and generalizes both HIY measures, and also captures the remaining sources of value added. To precisely define production 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. A global IRIO model provides a convenient mathematical tool to completely slice up the value chain across all related countries at the industry average level.[11] Section 2.2 illustrates how a global IRIO model can allocate the value added to each participating country using a block matrix formulation, which provides substantial clarity relative to other approaches in the literature. To present the major concepts of our decomposition and show how they differ from earlier measures, we start with a two-country case.

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.

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

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

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 as an IRIO model in block matrix notation

11 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).

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Y_{11} + Y_{12} \\ Y_{21} + Y_{22} \end{bmatrix} \quad (2)$$

and rearranging,

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

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:

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

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):

$$V_r = u(I - \sum_s A_{sr}) \quad (5)$$

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

$$V = \begin{bmatrix} V_1 & 0 \\ 0 & V_2 \end{bmatrix} \quad (6)$$

Variations of this framework have been used in a number of recent studies. However, none of these papers uses the block matrix inverse as their mathematical tool and works out a complete tracing of 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.

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

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. 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:[12]

$$V_1 B_{11} + V_2 B_{21} = V_1 B_{12} + V_2 B_{22} = u \tag{8}$$

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 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.[13] Let E_{rs} be the N×1 vector of gross exports from r to s. For consistency with the multi-country analysis below, also define

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

$$E = \begin{bmatrix} E_1 & 0 \\ 0 & E_2 \end{bmatrix}, \text{ and} \tag{10}$$

$$\hat{E} = \begin{bmatrix} diag(E_1) & 0 \\ 0 & diag(E_2) \end{bmatrix}, \tag{11}$$

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

The combination of the value-added share matrix and the export matrix produces the 2×2N matrix $\mathrm{VAS\_\hat{E}}$, our sectoral measure of value-added trade in global value chains:

$$\mathrm{VAS\_\hat{E}} = VB\hat{E} = \begin{bmatrix} V_1 B_{11} \hat{E}_1 & V_1 B_{12} \hat{E}_2 \\ V_2 B_{21} \hat{E}_1 & V_2 B_{22} \hat{E}_2 \end{bmatrix} \tag{12}$$

This matrix is a disaggregated measure of value-added exports, since it expresses value added embodied in exports of each sector. It is important to note that this measure captures all domestic

12 Koopman, Wang, and Wei (2008) show this must hold in the general case with any number of countries and sectors.

13 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.

value-added contributions to each sector's exports. For example, in the electronics sector, $\mathrm{VAS\_}\hat{\mathrm{E}}$ includes value added in the electronics sector itself as well as value added in all inputs from all other sectors (such as glass, rubber, transportation, and design) used to produce electronics for export by the source country. Such an approach aligns well with case studies of supply chains of specific sectors and products, as in the iPod example cited earlier. As an alternative, one could instead measure the value added produced by the factors of production in a specific sector and then embodied in gross exports by all sectors. This would include, for example, the value added by the electronics sector and then incorporated into gross exports of computers, consumer appliances, automobiles, etc.[14]

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. The aggregate (2×2) measure of value-added exports is given by

$$\mathrm{VAS\_E} = VBE = \begin{bmatrix} V_1 B_{11} E_1 & V_1 B_{12} E_2 \\ V_2 B_{21} E_1 & V_2 B_{22} E_2 \end{bmatrix} \tag{13}$$

This aggregate measure is equal to the sum across sectors of either sectoral measure.

Although rather elementary with only two countries, VAS_E expresses the major concepts of our new value-added trade 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 demonstrate that HIY's vertical specialization concepts are only special cases of our new value-added trade measure, because all measures can be solved for explicitly.

In the two-country case, the explicit solutions of the four B_{rs} block matrices are not overly cumbersome, and nicely illustrate that the HIY measures hold only in a special case of our new general measures. Applying the algebra of the partitioned matrix inverse,[15] we have

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

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

14 Conceptually, one could measure the value added generated in a single sector and exported by any other sector by replacing *V* in the equations above with a diagonal *V* matrix. As discussed in section 3, however, limitations in intermediate use coefficients in current IRIO databases would introduce unknown, and possibly large, bias into such estimates.

15 See, for example, Simon and Blume (1994, 182); B_{22} follows from the symmetry of countries 1 and 2.

$$\mathrm{VS} = \begin{bmatrix} V_2 B_{21} E_1 \\ V_1 B_{12} E_2 \end{bmatrix} = \begin{bmatrix} u(A_{21} - A_{12}(I - A_{22})^{-1} A_{21})(I - A_{11} - A_{12}(I - A_{22})^{-1} A_{21})^{-1} E_1 \\ u(A_{12} - A_{21}(I - A_{11})^{-1} A_{12})(I - A_{22} - A_{21}(I - A_{11})^{-1} A_{12})^{-1} E_2 \end{bmatrix} \quad (15)$$

$$\mathrm{DV} = \begin{bmatrix} V_1 B_{11} E_1 \\ V_2 B_{22} E_2 \end{bmatrix} = \begin{bmatrix} V_1 (I - A_{11} - A_{12}(I - A_{22})^{-1} A_{21})^{-1} E_1 \\ V_2 (I - A_{22} - A_{21}(I - A_{11})^{-1} A_{12})^{-1} E_2 \end{bmatrix} \quad (16)$$

They are both 2×1 matrices.

Using the same notation, HIY's measure of foreign value added can be expressed as another 2×1 matrix:

$$\mathrm{VS\_HIY} = \begin{bmatrix} uA_{21}(I - A_{11})^{-1} E_1 \\ uA_{12}(I - A_{22})^{-1} E_2 \end{bmatrix} \quad (17)$$

Comparing equations (15) and (17), we can see that HIY's measure accurately captures foreign value added in direct exports 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 (2010) also point out, whenever two or more countries export intermediate products, the HIY measure diverges from the true measure of foreign value added in gross exports.

Our new measure captures an important element omitted from the HIY formula. For the home country, both domestic and foreign value added differ from their true values by the adjustment term $A_{12}(I - A_{22})^{-1} A_{21}$. Thus our new measure can account for value added when a country imports its own value added which has been exported but returned home after processing abroad. In a more general context, VAS_E 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 details domestic value in inputs exported indirectly to third countries. Although this term has not been previously defined mathematically, it can be specified precisely in our framework. In a two-country world, the home country's indirect value-added exports can be defined (again following the HIY notation) as

$$\mathrm{VS1}_1 = V_1 B_{12} E_2 \,. \quad (18)$$

In a two-country framework, the home country's VS1 is identical to the foreign country's VS. This will not be true in the multi-country models that we turn to next.[16]

[16] But, consistent with the two-country case, foreign value in direct exports will be measured along columns, while indirect exports through third countries will be measured along rows.

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:

$$X = (I - A)^{-1} Y = BY$$
$$VAS = VB$$
$$VAS\_E = VBE \ . \qquad (19)$$

With G countries and N sectors, X and Y are GN×1 vectors; A and B 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. While we focus on the aggregate measures across both sectors and trading partners, all results continue to hold with full dimensionality and can be expressed simply by replacing the relevant weighting 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 detail 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[17]

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

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 value-added trade measures to capture value added in production chains stretching across multiple borders.

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:

$$VAS\_E = VBE = \begin{bmatrix} V_1 B_{11} E_1 & V_1 B_{12} E_2 & V_1 B_{13} E_3 \\ V_2 B_{21} E_1 & V_2 B_{22} E_2 & V_2 B_{23} E_3 \\ V_3 B_{31} E_1 & V_3 B_{32} E_2 & V_3 B_{33} E_3 \end{bmatrix}. \qquad (21)$$

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17 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 other explicit results).

The distinction between direct and indirect value-added trade measures is much clearer with three countries than with two. The sum of off-diagonal elements *along a column* is the true measure of foreign value added embodied in a particular country's direct exports:

$$\mathrm{VS}_{\mathrm{r}} = \sum_{s \neq r} V_s B_{sr} E_r \tag{22}$$

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 the third country's exports. This is the first explicit derivation of this measure provided in the literature:

$$\mathrm{VS1}_{\mathrm{r}} = \sum_{s \neq r} V_r B_{rs} E_s \quad . \tag{23}$$

The diagonal terms measure domestic value added in direct exports:

$$\mathrm{DV}_{\mathrm{r}} = V_r B_{rr} E_r \tag{24}$$

Equation (8) shows that columns of the VAS matrix sum to unity, so the sum of domestic and foreign value added must account for all gross exports, ensuring that value-added trade flows sum to official trade flows:

$$\mathrm{DV}_r + \mathrm{VS}_r = E_r \tag{25}$$

As noted above, it is straightforward to extend this framework to multiple sectors or destinations. 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 when reporting value-added trade flows.[18] To further examine each country's role in global chains, however, we have extended the framework to encompass generalized versions of other recent measures in the literature.

2.3 Extension to Other Measures

Section 2.2 fully characterized direct and indirect value-added trade, but the framework can be easily extended to more recent measures in the value-added trade literature, such as the concept of "reflected" exports examined by both Daudin, Rifflart, and Schweisguth (2010) and Johnson and

18 To disaggregate across industries using the notation above, replace the diagonal exports E with $\hat{E}$, the value-added export matrix of size G×GN. Besides the dimensionality problem, there also are data limitations that may bias the disaggregated sector results as we discuss in section 3, so we do not report disaggregate results in the current paper but they are available upon request.

Noguera (2010). Such exports return home in goods after processing or finishing abroad.[19] This measure turns out to be sizable for some large advanced economies.

To do this, we divide gross exports into final goods and intermediates. Within intermediate, we further divide those goods that are consumed by the direct importer from those goods that are processed and exported for consumption or further processing in a third country:

$$E_{rs} = Y_{rs} + A_{rs}X_s = \underbrace{Y_{rs}}_{\substack{\text{Final goods} \\ \text{exported to } s}} + \underbrace{A_{rs}X_{ss}}_{\substack{\text{Intermediates finished} \\ \text{and consumed in } s}} + \underbrace{A_{rs}X_{sr}}_{\substack{\text{Processed and} \\ \text{exported back to } r}} + \underbrace{\sum\nolimits_{t \neq r,s} A_{rs}X_{st}}_{\substack{\text{Processed and exported} \\ \text{to third countries}}} \qquad (26)$$

where X_{rs} denotes country r's output consumed in country s. Note that the third and fourth terms may include both intermediates and final goods.

When we combine the mathematical definition of domestic value-added (DV) in equation (22) and the export decomposition in equation (26), and sum over all trading partners, we decompose a country's domestic value-added exports to the world into four parts:

$$\mathrm{DV_r} = V_r B_{rr} E_r = V_r B_{rr} \sum_{s \neq r} Y_{rs} + V_r B_{rr} \sum_{s \neq r} A_{rs} X_{ss} + V_r B_{rr} \sum_{s \neq r} A_{rs} X_{sr} + V_r B_{rr} \sum_{s \neq r} \sum_{t \neq r,s} A_{rs} X_{st} \qquad (27)$$

Each of these terms corresponds to one of the four terms in equation (26), but now measures only the domestic value-added embodied in the relevant trade flows. Such a gross exports decomposition helps distinguish countries that lie downstream in supply chains (i.e., countries that provide value directly to the final demanders of their products), from those that are upstream, largely supplying intermediates for later incorporation into final goods. In a similar manner, foreign value in exports can also be divided into value embodied in final goods and intermediate inputs.

The combination of equations (25) and (27) integrates the older literature on vertical specialization with the newer literature on value-added trade, while ensuring that measured value-added flows account for all gross exports. The vertical specialization literature emphasized that gross exports contain two sources of value added, domestic and foreign. Equation (27) 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, and the source of its imports.[20] In particular, the last term corresponds to indirect exports through third countries, which was discussed extensively above. And the third term corresponds to "reflected" exports, though there are important differences across papers. For example, while we report domestic value added that returns to its source, Johnson and Noguera report the value of reflected gross exports. Daudin, Rifflart, and Schweisguth include only

[19] Daudin, Rifflart, and Schweisguth refer to this measure as VS1*.

[20] Since equation (26) decomposes all bilateral exports from country s to country r, it also decomposes all imports that country r received from country s simultaneously.

final goods in their measure, whereas we include final and intermediate goods. Only the measure reported in this paper is internally consistent with the other reported measures of value-added flows.

Our complete decomposition of gross exports and imports is diagrammed in figures 1a and 1b.[21] Section 4 of this paper will report these components of value added in each country's gross trade to the world, providing details on the upstream or downstream position of specific countries in global value chains. Because value-added flows sum to gross flows for each country, for convenience we normalize value-added trade flows by their corresponding gross flows, to report value-added trade as shares of gross trade.

3. Database Construction

3.1 Overview

Empirically measuring value added embodied in gross trade flows requires construction of a database detailing international production and use for all flows of value added. The database should contain 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. Only an IRIO table is able to provide such detailed information. It specifies the origin and destination of all transaction flows by industry as well as 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 table 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. However, 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 and value-added trade analysis.

To provide a workable dataset for our global value chain analysis and compute our new measures of value-added trade, we constructed a global IRIO table for 2004 based on version 7 of the GTAP database as well as supplemental detailed trade data from UN COMTRADE, and two additional IO tables for major processing regimes. We integrated the GTAP database and the additional information with a quadratic mathematical programming model that (a) minimized the deviation of the resulting new dataset 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

21 To be consistent with other descriptions in the literature, we have included "reflected" exports in the top row, instead of with the domestic components.

paper.[22] 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 sector in the database.

3.2 Accounting for Major Export Processing Zones

The WTO reports that about 20% of developing country exports come from Export Processing Zones (EPZs). Such processing regimes provide incentives to use imported intermediate inputs, provided that the resulting final goods are entirely exported. Processing regimes can thus dramatically increase the imported content of exports relative to domestic use. Failure to account for processing imports can dramatically overstate the domestic content of exports (Koopman, Wang, and Wei, 2008; and Dean, Fung, and Wang, 2008).

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, we incorporated an expanded Chinese IO table with separate accounts for processing exports and a 2003 Mexican IO table with separate domestic and Maquiladora accounts. China and Mexico are the two largest users of export processing regimes in the developing world, and together account for about 85% of worldwide processing exports.[23] 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, relaxing their assumption that all imports into China are 100% foreign value added. The Mexican table is from the Mexican statistical agency Instituto Nacional de Estadística, Geografía e Informática (INEGI).

3.3 Distinguishing Imports of Intermediate Inputs and Final Goods

IRIO tables require imported intermediate use data that specify country r's use in sector i of imports from sector j from source country s. To estimate these inter-industry and inter-country intermediate flows, 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 in which it is used within all destination countries. We addressed the first task by concording detailed trade data to end-use categories (final and intermediate) using UN Broad Economic Categories (BEC), as described below. 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.[24]

22 See Appendix table A1 for countries included in each region and their concordance to GTAP regions.

23 During 2000-2008, China alone accounted for about 67% of all reported processing exports in the world while Mexico represents another 18% (Maurer and Degain, 2010). Similarly, based on IMF BOP statistics provided by Andreas Maurer, we estimate that China and Mexico together accounted for about 80% of goods for processing in the world in 2005 and 2007.

24 For example, if 20% of U.S. imported intermediate steel comes from China, then we assume that each U.S. industry obtains 20% of its imported steel from China. Such an assumption ignores the heterogeneity of imported steel from different sources. It is possible that 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.

Although the GTAP database provides bilateral trade flows, it does not distinguish whether goods are used as intermediates or final goods. Our initial allocation of bilateral trade flows into intermediate and final uses is based on the UN BEC method applied to detailed trade statistics at the 6-digit HS level from COMTRADE. This differs from the approaches in Johnson and Noguera (2010) and Daudin, Rifflart, and Schweisguth (2010), which 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 apply a proportion method directly to the GTAP trade data; i.e., they assume that the proportion of intermediate to final goods is the same for domestic supply 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). The end-use method thus provides a less distorted picture of the value added distribution in global value chains.

Table 1 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 end-use method produces a lower intermediate share in exports. Developing countries (particularly Vietnam, China, South Asia, and Thailand) export substantially more final goods than is domestically supplied in their major export markets. The exceptions are the natural-resource exporting countries such as Brazil, Russia and the rest of the world—the end-use method produces higher intermediate shares in their exports.

The differences between the end-use and proportion methods at the industry level are much greater than the national aggregates. Table 2 reports the estimated share of intermediate goods in electronic machinery imports by the United States and Japan. Because the proportion method assigns the intermediate share in total absorption to all foreign input sources, the results show that the same intermediate goods share (54.2% for U.S. and 46.2% for Japan) from all source countries. Since the end-use classification is applied to each bilateral trade flow, it allows for product composition differences from different source countries. The end-use classification identifies 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. Most of the largest suppliers to the U.S. market export a substantially higher share of final goods than is supplied in the U.S. domestically. The proportional method likely understates the share of final goods imported into the United States, the world's largest demander of consumer electronics. The results for Japan are in the opposite direction: the proportion methods likely underestimate the share of intermediates in imports, given Japan's role as a major global electronics supplier.

Therefore, despite its shortcomings,[25] the UN BEC classification appears to provide a better identification of intermediates in gross trade flows than the proportion method. It provides a better row total control 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 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 for a particular industry, although it is less critical for the country aggregates reported here because total imports of intermediates from a particular source country are fixed by observed data, so misallocations will likely cancel out.

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. It selects key estimates of value-added exports, as specified in equations (22) to (27) and diagramed in figure 1a as applied to our IRIO database.

The first three columns decompose gross exports into three terms that integrate the vertical specialization and value-added trade literature. As described in section 2, these terms present the share of export value generated by domestic factors in the production process (column 2), the share of export value composed of imported intermediate inputs (column 3), and the share composed of imported inputs that originated at home (column 4).[26] These shares are presented graphically in figure 2. 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. To reiterate the connection of these terms to the existing literature: column (2) corresponds to the value-added exports to gross exports ratio (VAX) from Johnson and Noguera (2010); column (3) corresponds to

[25] 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.

[26] Column (4) equals the third term in equation (27) divided by a country's gross exports. Column (2) equals the first term in equation (25) minus column (4) divided by a country's gross exports. Column (3) equals the second term of equation (25) divided by a country's gross exports.

VS1* from Daudin, Rifflart, and Schweisguth (2010); column (4) corresponds to VS from HIY; and the sum of columns (4), (7), and (8) corresponds to VS1 from HIY.[27]

The table and figure show that there are major differences in the extent of integration across different regions of the world.[28] Among developing countries, emerging East Asia has some of the lowest domestic value-added shares in exports. For example, for each dollar of Chinese exports in 2004, Chinese factors contributed only 62.8 cents, plus an additional 0.8 cents from imported intermediate inputs that were originally generated in China.[29] Other East Asian countries have even lower shares of domestic value in their exports. Only Mexico has lower domestic content in its exports, reflecting its very tight integration into North American production networks. South Asian countries, such as India, have higher shares of domestic value in their exports, indicating their lower integration into global supply chains (on average across all goods and services). Among all emerging markets, the natural resource exporters, such as Russia, have the highest domestic value shares in their exports.

Advanced economies generally have high shares of domestic value in their exports. Among major advanced economies, the United States has a lower domestic value-added share than Japan or the EU.[30] It uses substantially more imported intermediate inputs in its exports, though much of these imported inputs initially originated in the United States. The United States has by far the world's highest share of such "reflected" intermediate inputs in its exports (12.4%), reflecting both its size and the technological sophistication of its exports and consumption. Looking at the regional trading partners of these major economies (e.g. Mexico, Canada, EU accession countries, and EFTA), North America appears more tightly integrated into regional chains than the EU.

Although Japan does not rank as highly as the United States measured by foreign content in exports (our generalized measure of VS), Japan is the most integrated major economy as a supplier of inputs to exporters in other countries. The sum of columns (4), (7), and (8) provide a generalized version of HIY's indirect vertical specialization measure VS1. For Japan, 30.8% of its gross exports are exported indirectly to third countries. The United States also ranks high by this measure (26.9%), with the EU considerably lower (20.9%). The high Japanese ranking on this measure is consistent with papers such as Dean, Lovely, and Mora (2009), which note that a high share of Japanese exports is processed in China and then sent as finished goods to developed countries such as the United States.

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27 As noted in section 2, each of these terms has been generalized in our specification. In addition, our measure of reflected intermediate inputs in column (4) differs by definition from similar measures in the literature. Our measure of reflected value includes both imported intermediates and final goods, so the world average in column (4) of 4.0% is higher than the 1.8% average in Daudin, Rifflart, and Schweisguth, which includes final goods only. If only final goods are taken into account, our estimate would be a quite similar 1.9%. Johnson and Noguera's "reflexion" is a bilateral measure applied to exports and not value added, so no direct comparison is possible.

28 Country groupings follow IMF regions (www.imf.org/external/pubs/ft/weo/2010/01/weodata/groups.htm#oem).

29 This estimate is higher than initial estimates of Chinese value added in exports, but consistent with estimates based on the most recent Chinese IO table. For example, Koopman, Wang, and Wei (2008) estimated domestic value-added share of 54% using a 2002 China benchmark IO table. In contrast, Koopman, Wang, and Wei (2011) uses the National Bureau of Statistics 2007 benchmark IO table—the same one employed in the current paper—to estimate that domestic value added composed 60.6% of Chinese gross exports.

30 "EU" refers throughout to the first 15 members of the EU; "EU Accession countries" refers to the next 12 members to join.

4.2 Decomposition of Domestic Value Added in Exports

Different regions of the world have sharply different compositions of domestic value added embodied in exports. Table 3 further decomposes domestic value added by destination and type of good to match the breakdown in figure 1a. These are expressed as shares of each country's total gross exports, so columns (5) through (8) sum to the share of domestic value-added in exports given in column (2).[31] This decomposition provides a more detailed look at domestic value-added exports than has been previously available in the literature. It shows large difference in value-added components across regions, indicating a substantial regional difference in the role and participation that countries played in global production networks.

Among emerging markets, natural resource exporters such as Russia and Indonesia export little of their domestic value added in final goods. These countries also tend to have high shares of domestic value added absorbed by the direct importer, such as Russian exports of energy products absorbed by Europe, or Brazilian exports of primary products absorbed by the United States.

Emerging East Asia stands out with very low domestic value added in those intermediates that are absorbed by the direct importer. Instead, these countries generally export substantial domestic value added in intermediate products that are subsequently re-exported to third countries. Although re-exports to third countries are the smallest of these four components on average for the entire world, they represent much larger shares of exported domestic value added in East Asia and the so called Asian Newly Industrialized Countries (NICs). These East Asian economies are thus integrated into longer supply chains than other developing countries 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 single-sector case studies that have examined Asian supply chains for products such as electronics and automobiles.[32]

Mexico and the EU accession countries appear most similar to East Asia economies among other emerging countries measured by their large share of foreign value added in gross exports. They are distinguished from East Asia countries, however, by their large share of value-added exports absorbed directly by their large immediate neighbors. Low income Asian countries (the rest of South and East Asian countries) as well as processing zones in China and Mexico have a very high share of value-added exports coming from direct exported final products, indicating that these economies are located in the end of the global value chain.

As noted above, the United States has lower domestic value added in exports than Japan or the EU. The domestic value-added decomposition shows that this is largely driven by a lower share of domestic content in final goods. The three largest advanced economies also have a relatively high

[31] Column (5) equals the first term in equation (27) divided by a country's gross exports; column (6) equals the second term in equation (27) divided by a country's gross exports; columns (7) plus (8) equals the last term in equation (27) divided by a country's gross exports.

[32] For example, see Baldwin (2008) for disk drives and Nag et al. (2007) for automobiles.

share of domestic value added embodied in their direct final goods exports in addition to their high share of indirect value-added exports through the third counties we discussed earlier, indicating these economies are located in both upstream and downstream activities in the global production chain, consistent with the so called "smiling curve" phenomena found in the business economics literature.

Columns (9) and (10) in table 3 divide foreign value added in gross exports into intermediate and final goods. 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.

4.3 Decomposition of Gross Imports

The same value-added flows used to decompose gross exports can be rearranged to examine gross imports, as shown earlier in figure 1b. Just as the export decomposition examines goods and services that embody *domestic* value added, the import decomposition sheds light on goods and services produced with *foreign* value added. Table 4 presents the import decomposition given in figure 1b. As with exports, columns (2) through (4) present the major components, which are computed independently and account for 100% of gross imports. Column (2) reports the share of value added in gross imports generated in the country that directly exported the goods and services, while column (3) reports the share generated in countries further upstream in the supply chain. Column (4) reports the share of value added in gross imports initially generated at home. As with exports, there are also substantial regional differences in the value-added components of imports.

Emerging Asia again exhibits its integration into a longer supply chain: every country in the region has lower than average value added from the direct exporter and higher than average value added from countries further upstream. Other emerging economies exhibit exactly the opposite pattern. Each of the three major advanced economies has a higher than average value share from countries other than the direct exporter, although the source of the remaining value added differs. Japan, like its Asian neighbors, gets a more than average share (though just slightly) of value from other upstream countries. The United States and Europe, however, generate a large share (over 30%) of their own upstream value.

Columns (5) through (8) further decompose direct value-added imports from the direct source country, including terms representing final goods and services imports (column 5), and intermediate imports used for the following: production for home consumption (column 6), production for re-exports to other countries as final goods (column 7), and production for re-exports as intermediates for further processing (column 8).[33] For all emerging East Asian countries, direct imports of final goods make up a very low share of gross imports. Intermediate imports consumed at home are also quite low for

[33] The value added embodied in direct final goods imports and total direct intermediate goods exports are obtained using each source country's domestic value-added share in output multiplied by its intermediate and final goods exports to the home country. The later exactly equals the sum of columns (6), (7), and (8), which are computed independently.

these countries.[34] These countries instead transfer much of the value of their direct imports into goods and services re-exported to third countries. This is another indication that these economies located in a longer production chain than other economies. Asian NICs exhibit similar patterns, though Hong Kong has a higher share of final goods imports than other countries in the region. Mexico is the only non-Asian country to exhibit similar patterns in the use of value added in its direct imports. Other emerging markets and the developed economies are integrated into global networks in a quite different manner, with above average imports of final goods or intermediate inputs consumed at home (or both).

The most notable feature of U.S. value-added imports appears in columns (4). The United States has by far the highest share of its own value-added exports embodied in its imports (8.3% of its gross imports and 12.4% of its gross exports—see column (4) of table 3). These high shares certainly reflect the large U.S. market size, but likely also reflect the U.S. role as a key supplier of value added in many advanced products that it consumes. We look into the source structure of returned value added in some detail next.

4.4 Domestic Value Added that Returns Home after Processing Abroad

For each of these three countries, table 5 reports the share represented by domestic value that has returned from abroad in the bilateral gross imports of final goods from each of the listed source countries (in columns 2, 4, and 6). It also reports the weight that each source country contributes to the returned domestic value-added totals (in columns 3, 5, and 7).

Each of these economies exhibits different patterns of integration into global supply chains. The United States contributes the highest share (10.0%) of its own value added to its imports of final goods. One-quarter of U.S. imports from Canada consist of value added from the United States itself, and a huge 40% of U.S. final good imports from Mexico consist of its own value added. These two countries account for three quarters of all U.S. value added returned from abroad. However, although the United States has the world's highest share of its own value added return from abroad, it does so largely through regional North American supply chains.[35] The EU contributes a lower share (7.8%) of value to its own imports. This returning value, however, is less concentrated among trading partners. It received about 50% of such value from its European neighbors, and moderate shares of its own value from many more countries than the United States, with moderate returned value shares from much of Asia (over 5% from Vietnam, Hong Kong, Indonesia, Thailand, and Malaysia), and especially the "rest of the world" region (14.3%). Japan imports the lowest share of its own value, at 4.3%. The vast majority of its returned value comes from Asia, and China alone accounts for 58.5% of the total.

[34] The use of imported intermediate inputs in Malaysia is not because the age of its IO table in the GTAP database makes results unreliable. India and Hong Kong also have outdated IO tables, which may explain some of the differences these countries exhibit from their regional counterparts in table 4.

[35] We also traced the returning value added one step further upstream for the United States, by computing the share of U.S. value added in other countries' exports of intermediate inputs to Canada and Mexico (which then return to the United States). The results indicate most U.S. inputs that return home after assembly and finishing in North America travel through very short supply chains. Over 96% of the returned U.S. value from Canada and Mexico was exported directly to those countries, so relatively a very small share of this value travels through third countries.

Thus Japan, like the United States, largely receives its own value through regional supply chains, though through a more diverse set of partners.

It is also interesting to note that value traveling through East Asia appears to be less affected by distance than for non-Asian countries. For example, the share of domestic value added returned from Asian NICs is about 5% for the United States, EU, and Japan. This pattern is quite different from non-Asian countries, which generally only account for moderate shares of returned value to the major economies if they are close geographically. This provides additional evidence for the special position of East Asian economies in global production networks.

4.5 Magnification of Trade Costs from Multi-Stage Production

As noted by Yi (2003, 2010), multi-stage production magnifies the effects of trade costs on world trade. Yi (2010) has formally demonstrated that there are two separate magnification forces. The first exists because goods that cross national barriers multiple times incur tariffs and transportation costs multiple times. The second exists because tariffs are applied to gross imports, but value added by the direct exporter may be only a fraction of this amount. Different participation in global networks affects the extent to which different countries and regions are affected by such cost magnification.[36] However, Yi (2003) does not actually measure the magnification of tariffs, though it is important to his simulations exercise. Using data for the United States and Canada, Yi (2010) illustrated how multi-stage production could magnify trade cost in a two-country case. Thus, earlier studies have not reported how the magnification effect differs by exporter in a multi-country setting.

With our estimates of the sources of value added in exports, combined with additional data on bilateral tariff rates and international transportation margins in the GTAP database, we are able to examine such trade cost magnification experienced by major countries in the entire world in 2004. Results are reported below. Table 6 reports our illustrative calculation of the first magnification force in columns (2) through (5). Column (2) reports trade-weighted average trade costs as a share of each country's final goods exports to the world, which we use for the standard measure of such costs. Trade costs include the bilateral international transportation margins and import tariffs faced by the exporting country. Columns (3) reports the share of foreign value added in final goods exports, including domestic value that returns to the source country.[37] These imported intermediate inputs are used to produce final goods exports, and so incur multiple tariffs and transportation costs. The sum of the costs incurred by the exporting country are given in column (4), as a share of its final goods export value. Specifically, this column reports the trade-weighted average cost for each intermediate input from the other 25 countries/regions in our database before it was used in the exporting country to produce final goods exports. Column (5) reports the ratio between the total trade cost and standard

[36] As Yi (2010) points out, vertical specialization and the location of production are endogenously determined with the structure of global transportation and tariff costs.

[37] Values in column (3) of table 6 are specific to final goods, and so differ slightly from the values in table 3, which include both final and intermediate goods. There is a similar discrepancy for column (6) discussed below.

trade cost. This represents a lower bound of the true multi-stage tariff costs, because these inputs may have already crossed multiple borders before reaching the supplier of such inputs to the exporter.

There is less consistency within regions in this ratio than in the other measures we have presented. This occurs largely because of the high variation in tariff rates and international transportation margin applied to imported intermediate inputs. Emerging Asia has some of the highest ratios because they are involved in a longer supply chain, use more imported inputs and impose some of the highest tariffs on their imports. The effects of these barriers in terms of our magnification ratio are tempered somewhat by the quite high standard trade cost these countries face on their exports because of longer distance transportation to final destination of their exports than other emerging economies. China is notable for having the lowest trade costs on imports in the region, and hence the lowest magnification factor in the region. Relative to Asia, other emerging countries in our dataset typically involve shorter supply chains, use less imported inputs and apply lower tariffs to their own imports, and hence have lower ratios. Mexico is an unusual case. The ratio for its normal exports is quite low but its processing regime has the highest magnification ratio in our dataset. Even though tariffs applied to processing imports are quite low (1.3%), because the imported content is quite high (64.5%) in Mexican processing exports and such exports are largely tariff-free within NAFTA (and therefore face lower standard trade costs), the magnification of the tariff rates on these exports is quite high.

Developed economies apply the lowest tariffs to their intermediate imports, and their magnification ratios are generally quite low. The magnification ratio for Canada and EFTA appears somewhat high, because like Mexico, much of their goods are exported duty free. The three largest economies also have the lowest ratios, in part because they have the lowest share of foreign value in their exports.

5. Conclusions

We have developed a unified measure for value-added trade with a transparent conceptual framework based on the block-matrix structure of an inter-regional IO model. This new framework incorporates all previous measures of vertical specialization and value-added trade in the literature while adjusting for the back-and-forth trade of intermediates across multiple borders prevalent in modern international production networks. The framework also enables a complete concordance between value-added trade and official gross trade statistics. Using this measure, we can completely decompose gross exports (imports) into domestic and foreign content and further decompose domestic value added in exports (foreign value added in imports) into components that reveal each country's upstream and downstream positions in a global value chain.

Empirical results employ a global IRIO table for 2004 based on version 7 of the GTAP database. We refined the database by applying an end-use classification to detailed trade statistics to distinguish final and intermediate goods in gross trade flows. The resulting dataset appears less distorted than others 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 East 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, because they send a greater share of 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. Among the major developed economies, Japan exports the most value-added in intermediates processed in multiple countries before reaching their final consumer, with the United States not far behind by this measure. The United States uses more imported intermediate inputs to produce exports than the EU and Japan, though much of its trade in global supply chains is funneled through its North American trading partners.

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 been 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 an analysis of the causes and consequences of differences in supply chain participation. For example, 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 trade. These results may also be fruitfully applied to examine the causes of growth. Evidence is accumulating that a country’s participation in global supply chains can affect the variability of trade and national income (Bems, Johnson, and Yi, 2010), and such participation could plausibly affect the rate of growth as well.

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Table 1. Share of Intermediate Inputs in Trade, Proportion and End-Use Methods

Country	Gross exports			Gross imports		
	Value, billion U.S. dollars	Share of intermediates (%)		Value, billion U.S. dollars	Share of intermediates (%)	
		Proportion	End-use		Proportion	End-use
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Advanced economies						
Australia, New Zealand	122.5	71.7	69.4	131.5	56	50.2
Canada	323.0	61	63.7	305.8	63	60.4
EFTA	259.5	71.2	66.7	208.0	65.6	61.8
EU	1,575.5	60.4	57.2	1,624.2	62.8	61.1
Japan	618.9	60.4	56.7	513.9	64.2	61.9
United States	1,062.3	61.4	63.2	1,590.1	57.2	54.7
Asian NICs						
Hong Kong	121.7	63.4	62.6	104.8	61.3	60.5
Korea	283.1	63.7	57.5	245.1	81.2	76.6
Taiwan	219.8	67.9	68.4	170.3	75.4	72.6
Emerging Asia						
China	670.6	54.6	43.1	568.8	82.6	77.4
Malaysia	152.0	67.5	70.4	101.6	73.5	72.1
Philippines	50.1	62	71.6	46.6	75.1	74.8
Thailand	119.4	61.8	54.9	98.0	75.3	75.6
Vietnam	32.3	55.8	42.7	34.5	72.9	72.1
Indonesia	86.7	70.5	70.8	73.2	65.5	71
Rest of East Asia	25.7	57.8	51.5	17.1	68.4	64.5
India	99.9	59.2	63.5	121.1	75.8	81.9
South Asia	36.0	47.1	36.5	51.3	56.2	60.6
Other emerging economies						
Brazil	113.0	63.5	68.7	77.1	67.4	67.1
EU accession countries	273.7	58.2	57.9	306.1	66.9	64
Rest of Americas	209.3	69.9	71.9	183.1	55.8	55.7
Mexico	190.5	55.7	52.4	183.4	63.1	74.6
Russian Federation	160.2	82.8	88.8	121.3	46.4	42.3
South Africa	61.4	71	71.5	54.1	65.1	61
Rest of the world	715.9	79.2	81.1	647.0	49.6	51.2
World	7,733.4	63.7	62.1	7,733.4	63.7	62.1

Source: Authors' estimates based on domestic supply in GTAP database and UN BEC end-use classification.

Table 2. Share of Intermediate Inputs in Electronic Machinery Imports, 2004

	U.S. electronic machinery imports				Japanese electronic machinery imports			
	Value[a]	Share of intermediate inputs (%)			Value[a]	Share of intermediate inputs (%)		
Country		Proportion	End-use	Difference		Proportion	End-use	Difference
(1)	(5)	(2)	(3)	(4)	(9)	(6)	(7)	(8)
Advanced economies								
Australia and New Zealand	176	54.2	61.7	-7.5	26	46.2	52.3	-6.1
Canada	7,242	54.2	67.9	-13.7	246	46.2	76.8	-30.5
EFTA	409	54.2	60.8	-6.6	55	46.2	36.3	9.9
EU	11,455	54.2	66.3	-12.1	2,330	46.2	48.7	-2.5
Japan	23,364	54.2	57.5	-3.3				
United States					7,165	46.2	67.6	-21.3
Asian NICs								
Hong Kong	348	54.2	41.4	12.8	112	46.2	48.1	-1.9
Korea	18,718	54.2	42.4	11.8	6,244	46.2	75.0	-28.8
Taiwan	13,175	54.2	62.4	-8.2	8,423	46.2	77.9	-31.7
Emerging Asia								
China	57,357	54.2	33.5	20.8	20,088	46.2	13.0	33.3
Indonesia	1,765	54.2	34.9	19.3	1,074	46.2	33.3	12.9
Malaysia	21,035	54.2	49.2	5.0	5,638	46.2	59.6	-13.3
Philippines	3,245	54.2	82.2	-28.0	4,999	46.2	73.0	-26.8
Thailand	4,787	54.2	30.4	23.8	3,901	46.2	60.0	-13.8
Viet Nam	78	54.2	24.8	29.4	289	46.2	80.7	-34.5
Rest of East Asia	26	54.2	67.0	-12.8	9	46.2	64.4	-18.1
India	145	54.2	86.2	-32.0	7	46.2	50.8	-4.6
Rest of South Asia	11	54.2	90.9	-36.7	8	46.2	97.2	-51.0
Other emerging economies								
Brazil	556	54.2	34.0	20.2	9	46.2	90.3	-44.1
EU accession countries	1,950	54.2	57.5	-3.3	221	46.2	38.6	7.7
Mexico	25,737	54.2	41.7	12.5	247	46.2	16.8	29.5
Rest of Americas	734	54.2	93.9	-39.6	99	46.2	94.3	-48.0
Russian Federation	17	54.2	86.1	-31.8	2	46.2	84.0	-37.8
South Africa	17	54.2	75.3	-21.1	1	46.2	79.6	-33.4
Rest of the world	1,503	54.2	66.5	-12.3	194	46.2	49.7	-3.4
World	201,526	54.2	47.1	7.1	65,563	46.2	51.5	-5.3

Source: Authors' estimates based on domestic supply in GTAP database and UN BEC end-use classification.

[a] Imports of both intermediate and final goods, in millions of U.S. dollars

Table 3. Decomposition of Gross Exports

	Total		Domestic value added					Foreign value added	
				Absorbed by direct importer		Processed and exported to third countries			
Country	Domestic value added	Foreign value added	Domestic value added returned from abroad	Final goods	Inter-mediate inputs	Final goods	Inter-mediate inputs	Final goods	Inter-mediate inputs
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Advanced economies									
Australia, New Zealand	88.0	11.5	0.6	27.0	33.6	10.5	16.9	3.7	7.8
Canada	70.5	28.1	1.3	23.5	36.2	4.0	6.9	12.8	15.3
EFTA	74.0	25.2	0.8	23.0	36.3	5.1	9.7	10.3	15.0
EU	81.1	11.4	7.4	38.1	29.6	5.0	8.5	4.8	6.7
Japan	84.9	12.2	2.9	38.4	18.5	12.2	15.7	4.8	7.4
United States	74.6	12.9	12.4	32.5	27.6	5.5	9.0	4.3	8.7
Asian NICs									
Hong Kong	71.9	27.5	0.6	27.2	25.8	9.1	9.8	10.2	17.3
Korea	65.2	33.9	0.9	29.5	13.5	10.4	11.8	13.1	20.8
Taiwan	58.2	41.1	0.8	19.2	12.6	13.1	13.3	12.4	28.6
Emerging Asia									
China	62.8	35.7	0.8	36.5	14.6	4.9	6.8	20.5	15.2
Indonesia	76.5	22.9	0.6	20.0	28.1	10.9	17.5	9.2	13.7
Malaysia	58.6	40.5	0.9	16.7	17.7	10.4	13.7	12.9	27.6
Philippines	57.8	41.9	0.4	17.6	11.1	12.4	16.6	10.8	31.0
Thailand	60.0	39.7	0.3	27.9	14.0	7.9	10.2	17.2	22.5
Vietnam	62.6	37.0	0.4	32.9	15.3	4.8	9.6	24.4	12.6
Rest of East Asia	78.2	21.7	0.1	35.3	26.9	6.1	10.0	13.3	8.4
India	79.6	20.1	0.4	30.2	30.8	7.7	10.9	6.4	13.7
Rest of South Asia	78.6	21.3	0.1	48.8	19.2	4.9	5.6	14.6	6.7
Other emerging economies									
Brazil	87.0	12.7	0.3	27.4	40.7	7.5	11.5	3.9	8.7
EU accession countries	68.3	30.8	1.0	28.7	29.2	4.3	6.0	13.4	17.4
Mexico	51.3	48.0	0.4	21.6	20.3	3.6	6.0	26.0	22.0
Rest of Americas	84.9	14.4	0.7	23.8	40.6	7.5	12.9	4.3	10.1
Russian Federation	89.1	10.2	0.7	9.5	49.1	9.4	21.1	1.6	8.5
South Africa	81.6	18.2	0.2	23.1	34.5	8.5	15.4	5.3	12.8
Rest of the world	83.0	14.6	2.5	15.0	45.6	6.8	15.6	3.9	10.7
World average	74.4	21.5	4.0	29.2	27.7	6.8	10.7	8.7	12.8

Source: Authors' estimates
Note: All columns are expressed as a share of total gross exports.

Table 4. Decomposition of Gross Imports

	Total			Value added from source country				Value added from other foreign countries	
					Intermediate inputs, used in:				
	Value added from source country	Value added from other foreign countries	Domestic value added returned from abroad	Final goods	Final goods at home	Final goods sent to third countries	Intermediates sent to third countries	Final goods	Inter-mediate inputs
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Advanced economies									
Australia, New Zealand	78.4	21.1	0.5	39.9	27.8	7.3	3.4	11.3	9.7
Canada	83.0	15.6	1.4	32.9	20.3	16.2	13.5	9.4	6.2
EFTA	85.1	14.0	0.9	32.9	20.7	18.7	12.8	9.0	5.0
EU	77.3	15.5	7.2	29.3	36.9	6.5	4.6	8.9	6.5
Japan	76.6	19.9	3.4	28.4	33.5	8.9	5.8	11.9	8.1
United States	73.6	18.1	8.3	31.8	33.2	5.8	2.9	9.1	9.1
Asian NICs									
Hong Kong	73.0	26.3	0.7	28.4	12.7	20.0	11.8	15.6	10.7
Korea	79.5	19.4	1.1	18.5	21.9	24.0	15.1	14.9	4.5
Taiwan	78.6	20.4	1.0	22.7	2.9	37.0	16.0	15.9	4.6
Emerging Asia									
China	75.0	23.1	0.9	17.6	15.4	17.9	24.1	18.6	4.5
Indonesia	72.2	27.1	0.7	22.4	22.7	16.2	10.9	20.6	6.4
Malaysia	68.6	30.0	1.4	20.2	—[a]	—[a]	—[a]	22.7	7.3
Philippines	71.7	27.9	0.4	18.7	8.0	33.4	11.6	21.4	6.5
Thailand	77.4	22.2	0.4	19.5	9.6	27.4	20.9	17.3	4.9
Vietnam	69.9	29.7	0.4	22.2	13.1	11.8	22.8	24.0	5.7
Rest of East Asia	73.4	26.5	0.2	26.8	14.1	12.6	19.9	17.8	8.7
India	81.6	18.1	0.3	13.8	51.2	11.3	5.3	13.9	4.2
Rest of South Asia	78.9	21.0	0.1	31.8	32.2	4.7	10.3	13.4	7.6
Other emerging economies									
Brazil	82.2	17.4	0.4	27.1	36.5	12.8	5.8	11.7	5.7
EU accession countries	84.6	14.6	0.9	30.6	26.5	15.5	12.0	9.5	5.1
Mexico	82.8	16.5	0.4	21.7	11.2	22.8	27.0	13.0	3.5
Rest of Americas	82.0	17.2	0.8	36.5	29.0	11.5	4.9	9.6	7.5
Russian Federation	84.0	15.1	0.9	49.1	21.5	11.3	2.2	6.9	8.2
South Africa	83.0	16.8	0.2	32.2	30.1	14.6	6.1	10.0	6.7
Rest of the world	83.0	14.3	2.7	41.0	25.8	11.8	4.3	7.5	6.8
Average	77.8	18.1	4.0	29.2	27.1	12.8	8.7	11.3	6.8

Source: Authors' estimates.
[a] Outdated Malaysian IO table biases estimates of intermediate shares.
Note: All columns are expressed as a share of total gross imports.

Table 5. Sources of Domestic Value Added that Returns Home Embodied in Final Goods

	United States		Japan		EU	
Exporter	U.S. share in imports from partner	Partner's share of total	Japanese share in imports from partner	Partner's share of total	EU share in imports from partner	Partner's share of total
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Advanced economies						
Australia, New Zealand	2.2	0.2	0.7	0.5	2.9	0.5
Canada	24.7	32.4	0.7	0.2	3.3	0.6
EFTA	3.0	0.4	0.9	0.5	19.6	18.1
EU	2.1	4.4	0.9	3.9		0.0
Japan	2.0	2.1		0.0	1.8	2.0
USA		0.0	1.1	4.4	2.8	6.3
Asian NICs						
Korea	5.4	2.2	5.1	4.7	4.3	2.3
Hong Kong	3.1	0.6	4.3	3.0	5.6	1.0
Taiwan	5.5	1.2	7.8	5.3	4.5	1.4
Emerging Asia						
China	4.2	7.0	8.7	58.0	4.1	6.7
Malaysia	7.5	1.5	8.0	3.5	8.0	1.4
Indonesia	3.5	0.3	5.6	1.7	5.0	0.6
Philippines	3.7	0.2	9.6	3.2	5.1	0.3
Thailand	4.4	0.8	8.3	6.2	5.3	1.4
Viet Nam	2.8	0.2	4.0	1.0	5.1	0.7
Rest of East Asia	2.3	0.1	1.3	0.1	4.2	0.4
India	1.5	0.2	0.5	0.0	3.8	1.0
South Asia	1.9	0.2	1.0	0.1	3.5	0.7
Other emerging economies						
Brazil	2.8	0.3	0.3	0.0	2.9	0.4
EU accession countries	1.7	0.2	0.9	0.2	20.8	34.3
Mexico	39.8	42.2	1.4	0.2	3.6	0.2
Rest of America	6.3	1.9	0.5	0.2	3.2	1.2
Russia	0.9	0.0	0.2	0.0	4.8	0.5
South Africa	1.6	0.0	3.3	0.5	5.8	0.7
Rest of the world	2.0	0.6	0.6	0.3	9.5	14.3
World	10.0	100.0	4.3	100.0	7.8	100.0
Comparison of export processing regimes						
China normal	1.6	0.8	1.4	3.3	2.4	1.8
China processing	5.3	6.2	12.8	54.7	5.6	4.9
Mexico normal	5.1	0.7	0.3	0.0	1.7	0.0
Mexico processing	44.9	41.5	2.9	0.2	5.2	0.2

Source: Authors' estimates.

Table 6. Magnification of Trade Costs on Final Goods Exports from Vertical Specialization

Country or region	Standard trade costs for final goods exports	Multiple border effects		
		Foreign content of final goods exports[a]	Trade cost for imported inputs in final goods exports	Magnification factor
(1)	(2)	(3)	(4)	(5)
Advanced economies				
Australia, New Zealand	22.2	12.9	1.3	1.1
Canada	3.2	38.3	1.4	1.4
EFTA	5.5	36.1	2.3	1.4
EU	9.5	12	0.7	1.1
Japan	8.8	11.6	0.4	1
United States	7	13.6	0.6	1.1
Asian NICs				
Hong Kong	13.9	40.8	1.7	1.1
Korea	8.7	31.3	2.2	1.3
Taiwan	7.8	41.3	3.1	1.4
Emerging Asia				
China normal	17.7	13.4	2.1	1.1
China processing	8.3	54.2	1.8	1.2
Indonesia	13.4	32.7	3.3	1.3
Malaysia	6.7	45.2	4.7	1.7
Philippines	10.8	38.8	2.8	1.3
Thailand	15.9	39.9	6.6	1.4
Vietnam	18.7	43	13.2	1.7
Rest of East Asia	14.7	31.2	6.9	1.5
India	13.9	18.1	4.1	1.3
Rest of South Asia	14.9	24.3	5.5	1.4
Other emerging economies				
Brazil	17.3	13	2	1.1
EU accession countries	6.3	34	1.9	1.3
Rest of America	20.9	16.6	3.1	1.2
Mexico normal	9	11.6	1.3	1.1
Mexico processing	1.8	64.5	1.3	1.7
Russian federation	11.3	18.2	2.9	1.3
South Africa	14.2	19.9	2.5	1.2
Rest of the world	11.1	24.8	3.9	1.4

Source: Authors' estimates.
[a] Includes returned domestic value added.

Figure 1a. Decomposition of Gross Exports

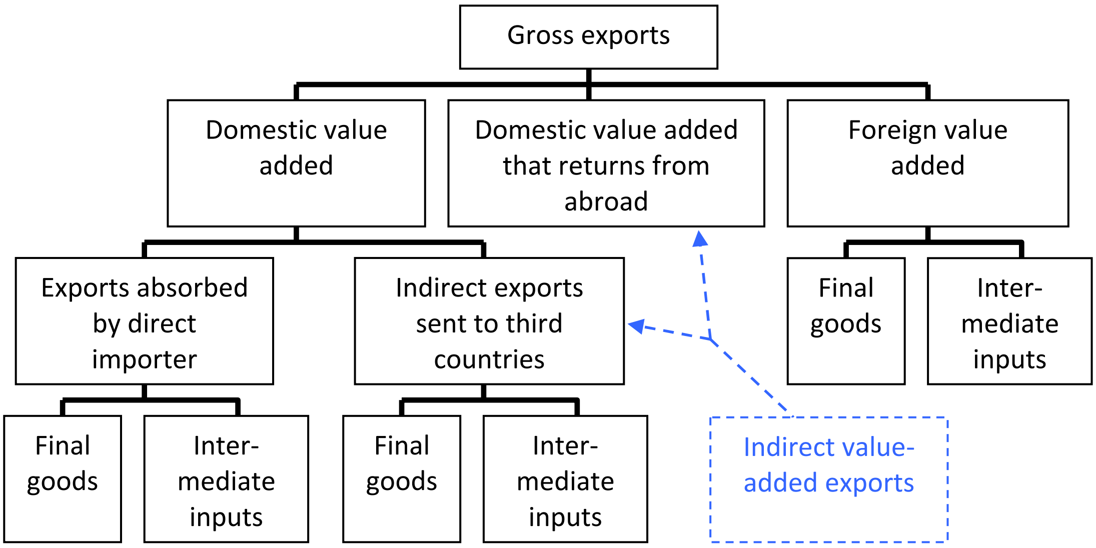


Figure 1b. Decomposition of Gross Imports

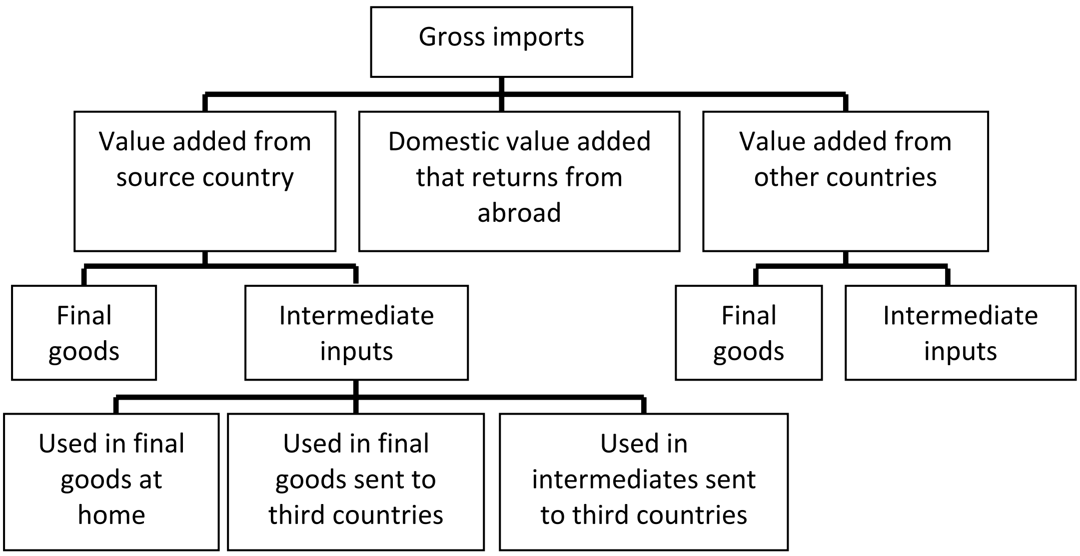
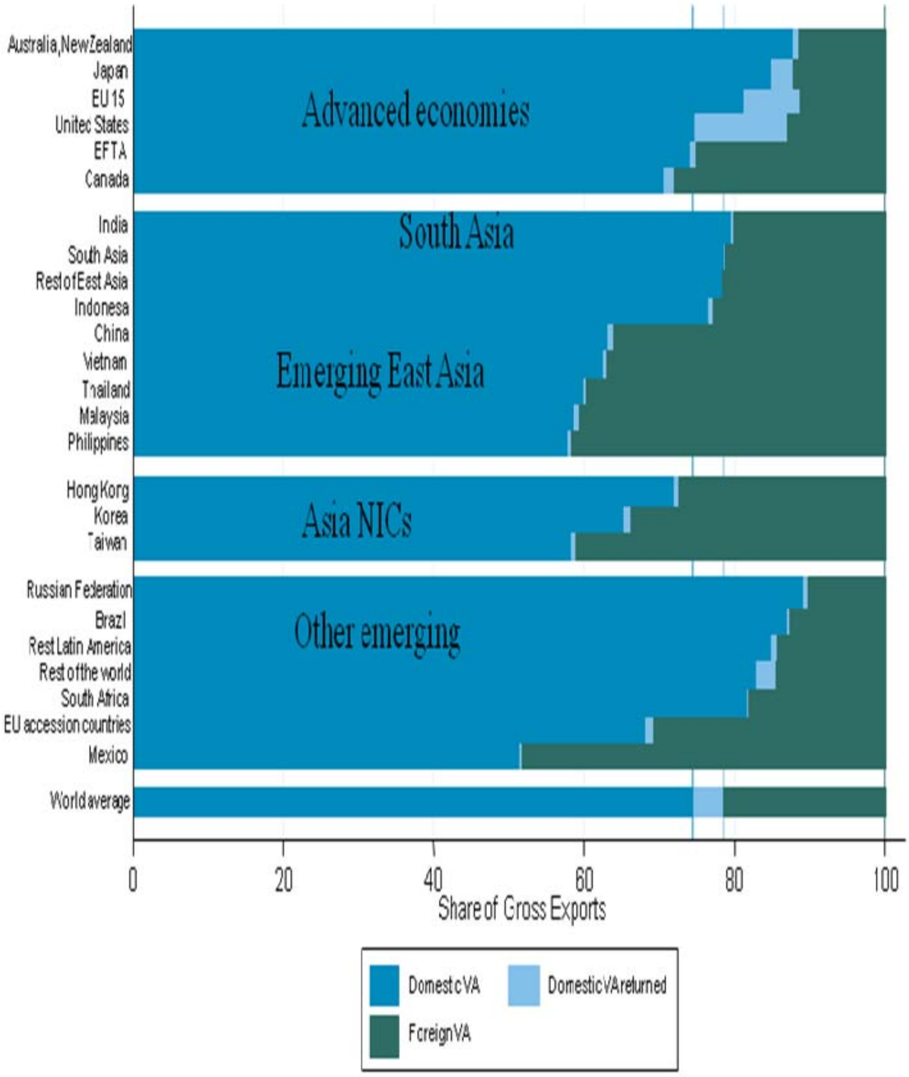


Figure 2. Decomposition of Gross Exports, by Country and Region, 2004



Source: Authors' estimates.

Appendix

Table A1. Countries in Database and Corresponding GTAP Regions

Country or region	Corresponding GTAP region(s)
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, Kyrgyzstan, 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