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Value Chains in Global Production Networks:

An Application of Global Input-Output Tables

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Abstract

The increasing segmentation of a given production process into different stages in different countries posts challenges to the measurement of true value added in international trade. Analysis based on gross trade statistics gives misleading signals for a country's dependence on exports and can exaggerate the technological sophistication of developing countries' exports. In this paper, we extend quantitative measures of vertical specialization proposed by Hummels, Ishii, and Yi (2001) into a consistent framework with many countries based on an international input-output (I-O) model. The extended measures relax the unrealistic assumptions made by Hummels et al. and are consistent in a world in which multiple countries export intermediate inputs that in many cases cross multiple borders.

Like other recent analyses of value chains in the literature, such as Johnson and Noguerra (2008), our measures distribute foreign value-added in a country's exports to its original sources. In addition, our measures provide addition insights by further decompose domestic value-added exported by a country in three ways. These channels include value added embodied in (1) exports of final goods; (2) intermediate goods that sent directly to their final destination, where they are assembled and consumed; and (2) intermediate goods that are sent through multiple markets on their way to their final destination.

Using a global I-O table constructed from the GTAP database (version 7), we compute our measures for 26 country and 40 industries. The examination of value-added sent through each of these channels allows us to rank each country's position in the global value chain. Japan, the United States, and the 15 Western EU members are located farthest upstream in the chain, while Viet Nam, Mexico, China, the 12 Eastern EU member countries and most Asian developing counties are located downstream in the value-chain.

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The increasing segmentation of a given production process into different stages in different countries posts challenges to the measurement of true value added in international trade. Analysis based on gross trade statistics gives misleading signals for a country's dependence on exports and can exaggerate the technological sophistication of some developing countries' exports. While GDP is a net or value-added concept, exports are measured in gross term containing both domestic and foreign value-added.

In this paper, we extend quantitative measures of vertical specialization proposed by Hummels, Ishii, and Yi (2001) into a consistent framework with many countries based on an international input-output (I-O) model. Our new measures not only distribute foreign value-added in a country's exports to its original sources, but also further decompose domestic value-added in a country's exports to a specific destination country into three parts: (1) value-added embodied in direct exports of final goods to that destination; (2) value-added embodied in intermediate goods sent to third countries that are incorporated into final goods and exported to their final destination; and (3) value-added embodied in intermediate goods that are exported to the destination, assembled, and consumed there.

This paper is related to several different strands in the international I-O literature. Several recent papers use international I-O data to estimate the sources of value-added in global exports. These papers include Johnson and Noguera (2008) and Bems, Johnson, and Yi (2009). Other papers have investigated value-added trade in Asian supply chains using the Asian IO tables produced by the Institute of Development Economies. Such Asia-specific papers include Koopman, Wang, and Wei (2009), Pula and Peltonen (2009), and Wang, Powers, and Wei (2009). Our current paper uses a simple, unified framework that allows us to incorporate results of recent papers and to place them in context with Hummels, Ishii, and Yi's (2001) original measures of vertical specialization measuring direct and, importantly, indirect value-added trade.

Using a global I-O table constructed from the most recent GTAP database, we compute our measures for 26 countries and 40 industries, including multiple agricultural, manufacturing, and services sectors. Our results highlight substantial differences between

gross trade flows and their value-added content. For example, consistent with other results in the literature, we show that 29% percent of official trade statistics in 2004 (the latest year for which such decomposition can be done). The differences for specific industries and countries can be much higher.

The inclusion of additional processing trade data from China and Mexico allows us to highlight the importance of processing trade. We compare these production networks to supply chains in Europe, with case studies of supply chains in the electronics and auto industries.

II. Value Chain in Global Production Network: Concepts and Measurement

2.1 Concepts

In their seminal paper, HIY (2001) discussed two ways in which a country can participate in vertical specialization: a country can use imported intermediate inputs to produce exports, or it can export intermediate goods that are used as inputs in goods exported by another country. Based on a single country non-competitive type input-output model (implicit in their paper), HIY derived VS as measure of the value of imports embodied in a country's exports, and VS1 as measure of the value of exported goods that are used as imported inputs to produce other countries' exports. A complete picture of vertical specialization or a county's position in a vertical integrated production network involves both measures. However, VS1 is more difficult to measure than VS, because it requires matching bilateral trade flow data to the input-output tables of all destinations to which the country under consideration exports. Further, although HIY developed a precise definition for their VS measure in mathematical terms, they did not do the same for their VS1 measure, because correctly calculating VS1 requires the existence of a third country in the model.[2]

Two key assumptions are needed for the HIY's measure to work. First, the 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

[2] Yi (1999) noted that on the import side, vertical specialization is just a subset of intermediate goods—it is those intermediates that are used to make goods for export—while on the export side, vertical specialization can include both final goods and intermediate goods. Hence, HIY's VS1 concept is closely related to, but distinct from, trade in intermediate goods.

exports are pervasive due to policy incentives, as in China and Mexico, and exported goods use much greater share of imported intermediate inputs. When data on processing trade are utilized, one can relax the first assumption. Koopman, Wang, and Wei (2008) provide a methodology to re-compute domestic and foreign value added in such cases.[3]

The second key assumption is that all imported intermediate inputs must contain 100% foreign value added.[4] That is, there can be no indirect domestic content in a country's imports. The second assumption generally does not hold because, by the nature of production fragmentation, any given country's exports could contain imported inputs from many other countries, including from itself. For example, computer parts imported by China could very well contain Chinese domestic value if other countries imported Chinese parts, processed them, and subsequently exported them back to China. In fact, a key phenomenon behind fragmentation is that countries increasingly link sequentially to produce final goods. Such a multiple-border-crossing, back-and-forth aspect of trade is what HIY intended to use VS and VS1 to measure. Obviously, a measure which combines VS and VS1 and also captures any domestically sourced content embodied in a country's imported intermediate inputs (such as our VAS matrix described in the next section) will be more consistent with the back-and-forth nature of trade that much of the anecdotal and case study evidence suggests has risen dramatically in recent decades.

Data from a world input-output table permit the relaxation of the second assumption. In our view, an international supply chain can be seen as distribution of value-added share among countries (regions) 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. The sum of the value added by every stage in the chain equals the value of final goods produced by the network. To precisely define such chains across many countries one needs to quantify the contribution of each country (region) to the total value-added generated in the process of supplying final products. In this regard, a world input-output table provides the best available information, allowing

[3] This paper has not incorporated information on processing trade, which is the subject of ongoing work. Limitations are addressed in the empirical results in section 3.

[4] This is equivalent to the assumption that the first exporting country's exports have to be 100% domestically sourced when computing VS1 in the HIY framework.

us to completely slice up the value chain across all related countries at the industry average level.[5]

In detail, a world input-output table would contain a number of sub-matrices that have information on (a) transaction flows of intermediate products and final goods within and between each country in the world at the industry level, (b) the direct value-added of each industry in all countries, and (c) the gross output of each industry in all countries. In other words, the world IO table not only provides the origin and destination of all transaction flows by industry, but also specifies every intermediate and/or final use for all such flows. For example, the Asian IO table describes not only the number of electronics produced in China that were shipped to the United States, but also the number that were used as intermediate inputs in each U.S. sector and the number that were used for U.S. private household consumption and capital formation. Similarly, the tables provide the information on the amount of steel used as intermediate inputs in Japan's motor vehicle industry, and also have information on which part of the world this steel comes from. Since this type of IO table matches bilateral trade-flow data to input-output relations and includes more detailed source/destination, supply/use information than a single country IO table, it is more suitable for measuring production fragmentation and vertical specialization.

In the next four sub-sections, we will use an international input-output model to illustrate how value added along a multi-country production chain can be decomposed into the sum of each participating country's net contributions. We will combine the VS and VS1 concepts proposed by HIY(2001) and extend them, in both plain English and mathematical terms, to a framework that includes many countries, thus providing a better and more precise measure of the nature and growth of value chains (vertical specialization) in global production networks. To present the major concepts and show the difference between the HIY measures and the new measures developed in this paper

[5] 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).

clearly, we start from two- and three-country cases and then extend to a world with many countries.[6]

2.2 Two-country case

Assume a two-country (home and foreign) world, in which each country produces N differentiated tradable products that can be consumed directly or used as intermediate inputs. Let X^r denote the N by 1 gross output vector of country r, Y^r the N by 1 final demand vector including domestic final demand in r and exports of final goods from r, and A_{sr} the N by N input-output coefficient matrix, giving intermediate use in country r of goods produced in s. Then the two-country production and trade system can be written in block matrix notation as follows:

$$\begin{bmatrix} X^1 \\ X^2 \end{bmatrix} = \begin{bmatrix} I - A_{11} & -A_{12} \\ -A_{21} & I - A_{22} \end{bmatrix}^{-1} \begin{bmatrix} Y^1 \\ Y^2 \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} Y^1 \\ Y^2 \end{bmatrix}, \quad (1)$$

where B_{sr} denotes the N by N block Leontief inverse, which is the total requirement matrix that gives the amount of total output in producing country s required for a one-unit increase in final demand in country r. As final and intermediate goods are distinguished by country of use, we can write

$$\begin{bmatrix} X^1 \\ X^2 \end{bmatrix} = \begin{bmatrix} A_{11}X^1 + Y^{11} + E^{12} \\ A_{22}X^2 + Y^{22} + E^{21} \end{bmatrix}, \quad (2)$$

where $\begin{bmatrix} E^{12} \\ E^{21} \end{bmatrix} = \begin{bmatrix} A_{12}X^2 + Y^{12} \\ A_{21}X^1 + Y^{21} \end{bmatrix} = \begin{bmatrix} A_{12}(x^{21} + x^{22}) + Y^{12} \\ A_{21}(x^{12} + x^{11}) + Y^{21} \end{bmatrix}$

and E^{sr} denotes the N by 1 vector of exports (both intermediate and final goods) from s to r.

Equation (2) decomposes each country's production and exports. It shows that there are three components in each country's gross exports. For country 1, these consist

[6] 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.

of the following: (i) final goods consumed in the foreign country (Y^{12}); (ii) intermediate goods used to produce final goods consumed in the foreign country ($A_{12}x^{22}$); and (iii) intermediate goods used by the foreign country to produce final goods shipped back and consumed in the home country ($A_{12}x^{21}$).

It can be shown that in the two-country case, the blocks of the total requirement matrix are equal to the following (see Appendix for the derivation):

$$B_{11} = ((I - A_{11}) - A_{12}(I - A_{22})^{-1}A_{21})^{-1} \quad (3)$$

$$B_{22} = ((I - A_{22}) - A_{21}(I - A_{11})^{-1}A_{12})^{-1} \quad (4)$$

$$B_{12} = (I_1 - A_{11})^{-1}A_{12}B_{22} = B_{11}A_{12}(I - A_{22})^{-1} \quad (5)$$

$$B_{21} = (I_2 - A_{22})^{-1}A_{21}B_{11} = B_{22}A_{21}(I - A_{11})^{-1} \quad (6)$$

Let V_s be the 1 by N direct value-added coefficient vector. Each element of V_s is equal to one minus the intermediate input share from all countries, which is the share of direct domestic value added in total output. Based on the input-output coefficient adding-up condition,

$$V_1 = (u - uA_{11} - uA_{21}) \text{ and } V_2 = (u - uA_{12} - uA_{22}) \quad (7)$$

These equations are sufficient to define our basic measure of vertical specialization in a production network as

$$\text{VAS\_WWP E} = \begin{bmatrix} V_1B_{11} & V_1B_{12} \\ V_2B_{21} & V_2B_{22} \end{bmatrix} \begin{bmatrix} E^{12} & 0 \\ 0 & E^{21} \end{bmatrix} = \begin{bmatrix} V_1B_{11}E^{12} & V_1B_{12}E^{21} \\ V_2B_{21}E^{12} & V_2B_{22}E^{21} \end{bmatrix}, \quad (8)$$

where VAS is a 2 by 2N matrix. Although rather elementary with only two countries, the product of VAS and the export matrix expresses all major concepts of our vertical specialization measures.

Diagonal elements of VAS 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, which correspond to the HIY VS and VS1 measures. It is easy to show that the sum along each of the 2N columns of VAS is unity:

$$V_1B_{11} + V_2B_{21} = V_1B_{12} + V_2B_{22} = u. \quad (9)$$

$$V_1 B_{11} + V_2 B_{21} = (I - A_{11} - A_{21})B_{11} + (I - A_{12} - A_{22})(I - A_{22})^{-1} A_{21} B_{11}$$
$$= (I - A_{11} - A_{21})(I - A_{11} - A_{12}(I - A_{22})^{-1} A_{21})^{-1}$$
$$+ (A_{21} - A_{12}(I - A_{22})^{-1} A_{21})^{-1})((I - A_{11}) - A_{12}(I - A_{22})^{-1} A_{21})^{-1}$$
$$= (A_{21} + I - A_{11} - A_{21} - A_{12}(I - A_{22})^{-1} A_{21})^{-1})((I - A_{11}) - A_{12}(I - A_{22})^{-1} A_{21})^{-1} = u$$

Therefore, the home country's total gross exports can be decomposed into domestic value-added (DV) and foreign value-added (VS) as follows:

$$\mathrm{DV}^1\_\mathrm{WWP} = V_1 B_{11} E^{12} = V_1((I - A_{11}) - A_{12}(I - A_{22})^{-1} A_{21})^{-1} E^{12} \quad (10)$$

and

$$\mathrm{VS}^1\_\mathrm{WWP} = V_2 B_{21} E^{12} = (I - A_{12} - A_{22})(I - A_{22})^{-1} A_{21} B_{11} E^{12}$$
$$= (I - A_{22})(I - A_{22})^{-1} A_{21} B_{11} E^{12} - A_{12}(I - A_{22})^{-1} A_{21} B_{11} E^{12}$$
$$= (A_{21} - A_{12}(I - A_{22})^{-1} A_{21})((I - A_{11}) - A_{12}(I - A_{22})^{-1} A_{21})^{-1} E^{12} \quad (11)$$

Using the same notation, VS as defined by HIY (2001, page 80, equation 3) can be expressed as

$$\mathrm{VS\_HIY} = \begin{bmatrix} uA_{21}(I - A_{11})^{-1} \\ uA_{12}(I - A_{22})^{-1} \end{bmatrix} \begin{bmatrix} E^{12} & 0 \\ 0 & E^{21} \end{bmatrix} = \begin{bmatrix} uA_{21}(I - A_{11})^{-1} E^{12} \\ uA_{12}(I - A_{22})^{-1} E^{21} \end{bmatrix} \quad (12)$$

As shown by KWW (2008), domestic value-added (DV) in a country's exports is the mirror of VS in HIY's single country framework, and can be defined as:

$$\mathrm{DV\_HIY} = \begin{bmatrix} V_1(I - A_{11})^{-1} \\ V_2(I - A_{22})^{-1} \end{bmatrix} \begin{bmatrix} E^{12} & 0 \\ 0 & E^{21} \end{bmatrix} = \begin{bmatrix} V_1(I - A_{11})^{-1} E^{12} \\ V_2(I - A_{22})^{-1} E^{21} \end{bmatrix} \quad (13)$$

Comparing equation (11) to (12) and equation (10) to (13), we can see that the HIY measures accurately capture value added in trade only when A_{12}=0 or A_{21}=0, which means that only one country can export intermediate products that are used in the other country's production process. As we will see throughout this section, whenever two or more countries export intermediate products, the HIY measures diverge from the true measures of value added in exports.

For example, when both countries export intermediate goods, the total domestic value-added in home's exports has to take into account the value-added embodied in

intermediate goods that are exported to the foreign country, used to produce final goods abroad, and then shipped back and consumed at home. The term

$$A_{12}(I - A_{22})^{-1} A_{21} \tag{14}$$

in equation (10) is the quantitative measure of such an adjustment for each unit of gross exports from the home country. This term is equal to the HIY measure of VS for the foreign country, $A_{12}\ (I\text{-}A_{22})^{-1}$, which represents the imported content of the foreign country's exports, multiplied by $A_{21,}$ the direct IO coefficient matrix of foreign inputs used in home production. This product equals the amount of home country intermediate input returned from abroad that was used to produce one unit of final goods in the foreign country.

The HIY measure of foreign vertical specialization (VS) is subject to further adjustment when both countries export intermediate goods. In equation (11), as above, an adjustment must be made to domestic intermediate input use to include the domestic content embedded in goods imported from abroad. A second adjustment must be made to imported intermediate use (i.e., matrix A_{21}) because home's imports of its own intermediate goods embodied in the foreign country's exported final goods should not counted as imported foreign content. The adjustment term is exactly the same as term (14).

The second HIY measure of value added in international supply chains is VS1, which measures the value of exports that are used as intermediate inputs to produce other countries' exports. Although HIY never define their VS1 measure mathematically, VS1 can be specified precisely based on our measures of vertical specialization in VAS. In a two-country world, the home country's VS1 measure can be defined as

$$\begin{aligned} &\mathrm{VS1}^{1}\_\mathrm{WWP} = V_1 B_{12} E^{21} = V_1 B_{11} A_{12} (I - A_{22})^{-1} E^{21} \\ &= V_1 ((I - A_{11}) - A_{12} (I - A_{22})^{-1} A_{21})^{-1} A_{12} (I - A_{22})^{-1} E^{21} \end{aligned} \tag{15}$$

The equation has two parts. First, $A_{12}(I - A_{22})^{-1} E^{21}$ is the home country's intermediate exports embodied in the foreign country's exports, or the foreign country's imported content. Second, $V_1((I - A_{11}) - A_{12}(I - A_{22})^{-1} A_{21})^{-1}$ is the domestic value-added share of the home country's exports (see equation 10), including both intermediate and final goods. Therefore, the product of these two terms equals domestic value-added embodied

in the home country's intermediate goods exported to the foreign country and used by the foreign country as inputs to produce its exports. It measures the indirect domestic value-added embodied in the foreign country's exports, which must equal the domestic content of the home country's imports in a two-country world.

2.3 Three-country case:

While the two-country case illustrates the basic concept of our value-chain measures and their relationship to HIY's original measures, additional insights emerge when a third country is added to the framework. Using similar notation as in the previous sub-section, we can specify the production and trade system of the three-country world as follows:

$$\begin{bmatrix} X^1 \\ X^2 \\ X^3 \end{bmatrix} = \begin{bmatrix} I - A_{11} & -A_{12} & -A_{13} \\ -A_{21} & I - A_{22} & -A_{23} \\ -A_{31} & -A_{32} & I - A_{33} \end{bmatrix}^{-1} \begin{bmatrix} Y^1 \\ Y^2 \\ Y^3 \end{bmatrix} = (I - A)^{-1} Y \tag{16}$$

$$\begin{bmatrix} X^1 \\ X^2 \\ X^3 \end{bmatrix} = \begin{bmatrix} A_{11} X^1 + Y^{11} + E^1 \\ A_{22} X^2 + Y^{22} + E^2 \\ A_{33} X^3 + Y^{33} + E^3 \end{bmatrix} \tag{17}$$

where $\begin{bmatrix} E^1 \\ E^2 \\ E^3 \end{bmatrix} = \begin{bmatrix} E^{12} + E^{13} \\ E^{21} + E^{23} \\ E^{32} + E^{33} \end{bmatrix} = \begin{bmatrix} A_{12} X^2 + Y^{12} + A_{13} X^3 + Y^{13} \\ A_{21} X^1 + Y^{21} + A_{23} X^3 + Y^{23} \\ A_{31} X^1 + Y^{31} + A_{32} X^2 + Y^{32} \end{bmatrix}$

The main difference between equations (16) and (17) and equations (1) and (2) is the added dimension. Each country's exports now need to be divided among two different destinations instead just one destination.

The block inverse matrix becomes

$$\begin{bmatrix} I - A_{11} & -A_{12} & -A_{13} \\ -A_{21} & I - A_{22} & -A_{23} \\ -A_{31} & -A_{32} & I - A_{33} \end{bmatrix}^{-1} = (I - A)^{-1} = \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{21} & B_{22} & B_{23} \\ B_{31} & B_{32} & B_{33} \end{bmatrix} \tag{18}$$

Similar to the two-country case, our basic measure of vertical specialization (or value-chain in a production network) in this three-country N-industry world is defined as

$$\text{VAS} = \begin{bmatrix} V_1B_{11} & V_1B_{12} & V_1B_{13} \\ V_2B_{21} & V_2B_{22} & V_2B_{23} \\ V_3B_{31} & V_3B_{32} & V_3B_{33} \end{bmatrix}$$ where V_s is a 1 by N direct value-added coefficient vector of the producing country, B_{sr} is a N by N block inverse matrix, and the resulting V_sB_{sr} is a 1 by N row vector. Therefore VAS is a 3 by 3N matrix. Each of its elements has a similar economic meaning as in the two-country case. Diagonal elements define the domestic value-added share in a unit of each country's exports. Off-diagonal elements along the column provide information on the share of each country's net value-added contribution to the production chain. The sum of these off-diagonal elements along a column is the share of foreign value-added embodied in a unit of the country's exports, which is the share 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. This sum is the indirect value-added share in a unit of the country's total exports, or the share of VS1. Detailed specifications of the B_{sr} terms and their derivation are given in the appendix; here we only discuss each element in the first row and column to highlight the additional adjustments that have to be made due to the presence of a third country.

The first diagonal element of the VAS matrix is given by

$$\begin{aligned} V_1B_{11} = V_1\{&(I - A_{11}) - A_{12}[(I - A_{22}) - A_{23}(I - A_{33})^{-1}A_{32}]^{-1}[A_{21} + A_{23}(I - A_{33})^{-1}A_{31}] \\ &- A_{13}[(I - A_{33}) - A_{32}(I - A_{22})^{-1}A_{23}]^{-1}[A_{31} + A_{32}(I - A_{22})^{-1}A_{21}]\}^{-1} \end{aligned} \quad (19)$$

where $V_1 = (u - A_{11} - A_{21} - A_{31})$. Comparing equation (19) with equation (10), there are more adjustments in the three-country case than that in the two-country case, all involving intermediate exports via a third country. More specifically, to measure the domestic value-added share of country 1's total exports, the value-added embodied in its intermediate exports to countries 2 and 3 has to be accounted for. Country 1's (home's) intermediate goods could be used by an importing country (country 2 or country 3) to produce final goods that are exported back to the home country, or further exported instead to a third country (country 3 or country 2), and then used by the third country to produce exports to the home country. Adjustments have to be made to each of these intermediate flows. For example, compared to equation (10), in the three-country case

$A_{23}(I-A_{33})^{-1}A_{32}$ represents is an adjustment made to (I-A_{22}), and $A_{23}(I-A_{33})^{-1}A_{31}$ is a similar adjustment made to A_{21}. The interpretation of these adjustments is similar to term (14). The term $A_{23}(I-A_{33})^{-1}A_{32}$ measures the adjustment for country 2's intermediate goods exported to country 3 that are subsequently shipped back to country 2, while $A_{23}(I-A_{33})^{-1}A_{31}$ measures the adjustment for country 2's intermediate goods exports to country 3 that are subsequently shipped to country 1.

The remaining elements in the first column and row of the VAS matrix are given by

$$V_1B_{12} = V_1B_{11}[A_{12} + A_{13}(I-A_{33})^{-1}A_{32}][(I-A_{22}) - A_{23}(I-A_{33})^{-1}A_{32}]^{-1} \quad (20)$$

$$V_1B_{13} = V_1B_{11}[A_{13} + A_{12}(I-A_{22})^{-1}A_{23}][(I-A_{33}) - A_{32}(I-A_{22})^{-1}A_{23}]^{-1} \quad (21)$$

$$V_2B_{21} = V_2[(I-A_{22}) - A_{23}(I-A_{33})^{-1}A_{32}]^{-1}[A_{21} + A_{23}(I-A_{33})^{-1}A_{31}]B_{11} \quad (22)$$

$$V_3B_{31} = V_3[(I-A_{33}) - A_{32}(I-A_{22})^{-1}A_{23}]^{-1}[A_{31} + A_{32}(I-A_{22})^{-1}A_{21}]B_{11} \quad (23)$$

Comparing equations (20) and (21) to equation (15), and equations (22) and (23) to equation (11), the third country adjustment terms such as $A_{13}(I-A_{33})^{-1}A_{32}$ and $A_{23}(I-A_{33})^{-1}A_{32}$ appearing in each of these equations have a similar structure and interpretation as term (14).

Similar to the two-country case, it also easy to show that

$$V_1B_{11} + V_2B_{21} + V_3B_{31} = V_1B_{12} + V_2B_{22} + V_3B_{32} = V_1B_{13} + V_2B_{23} + V_3B_{33} = u \quad (24)$$

Therefore, in the three-country case we can define related measures of vertical specialization in a way similar to that in two-country case. Total domestic value-added embodied in country 1's exports is given by

$$\mathrm{DV}^1\_\mathrm{WWY} = V_1B_{11}E^1 \quad (25)$$

This includes direct value-added exports to country 2 and 3 as well as indirect value-added exports via country 2 to country 3 and indirect value-added exports via country 3 to country 2. Domestic value-added embodied in the home country's imports from country 2 and country 3 are included as part of this indirect value-added export in our new measure. Foreign value added embodied in the home country's exports is given by

$$\mathrm{VS}^1\_\mathrm{WWY} = V_2B_{21}E^1 + V_3B_{31}E^1 \quad (26)$$

Indirect domestic value-added exports via third countries is given by

$$\text{VS1}^1\_\text{WWY} = V_1 B_{12} E^2 + V_1 B_{13} E^3 \tag{27}$$

This measures the value-added embodied in a country's intermediate exports used to produce a third country's exports that are returned to the home country or sent to other destinations.

Multiplying the VAS matrix by a country's exports at different aggregations, such as a country's total exports or its exports to a particular destination, as weights, we can obtain total and indirect domestic value added as well as each country's value added contribution to the production network at different levels. For example, at the most aggregate level

$$VAS\ E = \begin{bmatrix} V_1 B_{11} E^1 & V_1 B_{12} E^2 & V_1 B_{13} E^3 \\ V_2 B_{21} E^1 & V_2 B_{22} E^2 & V_2 B_{23} E^3 \\ V_3 B_{31} E^1 & V_3 B_{32} E^2 & V_3 B_{33} E^3 \end{bmatrix} \tag{28}$$

is a 3 by 3 matrix, which provides a complete picture of how value-added is generated geographically for each country's total exports, where

$$E = \begin{bmatrix} E^1 & 0 & 0 \\ 0 & E^2 & 0 \\ 0 & 0 & E^3 \end{bmatrix} = \begin{bmatrix} E^{12} + E^{13} & 0 & 0 \\ 0 & E^{21} + E^{23} & 0 \\ 0 & 0 & E^{31} + E^{32} \end{bmatrix}$$ is a 3N by 3 matrix.

We could obtain a similar measure for value added in goods exported from countries 2 and 3 to country 1 by focusing on only bilateral exports. This approach also works when exports are disaggregated by sector, an approach we will use in the empirical section below.

2.4 Many countries

After working through the two- and three-country cases and gaining an understanding of all the relevant concepts and measures of vertical specialization, let us now move from theory to the real world with many countries. Without loss generality**,** assume there are G countries, with N industries in each country. The production in each sector in any country can potentially use intermediate inputs from any sector (including its own) from any country. Assuming a predetermined location of production that defines the structure of the global economy, the deliveries of goods and services between

countries are determined by imbalances between supply and demand inside the different countries. A world IO table is 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 = Gross output of industry *i* in country *r*; v_i^r = Direct value added by production of industry *i* in country *r*; z_{ij}^{sr} = Delivery of good *i* produced by country *s* and used as an intermediate by sector *j* in country *r*; and y_{ik}^{sr} = Delivery of good *i* produced in country *s* for final use in final demand type 'k' in country *r*. The total number of final demand types, such as private consumption or gross capital formation, is H. Then the following two accounting identities describe the relationship among elements of each row (*i*, *r*) and column (*j*, *s*) of the international IO table:

$$\sum_{s=1}^{G}\sum_{j=1}^{N} z_{ij}^{sr} + \sum_{s=1}^{G}\sum_{k=1}^{H} y_{ik}^{sr} = x_i^r \tag{29}$$

$$\sum_{r=1}^{G}\sum_{i=1}^{N} z_{ij}^{rs} + v_j^s = x_j^s \tag{30}$$

The two equations have straightforward economic meanings. A typical row in Equation (29) 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 (30) 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 (29) and (30) 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 (29) and (30) could be re-written as:

$$\begin{bmatrix} X^1 \\ : \\ X^G \end{bmatrix} = \begin{bmatrix} I - A_{11} & ... & -A_{1G} \\ : & I - A_{ss} & : \\ -A_{G1} & ... & I - A_{GG} \end{bmatrix}^{-1} \begin{bmatrix} Y^1 \\ : \\ Y^G \end{bmatrix} = (I - A)^{-1} Y \tag{31}$$

where A is a NG by NG square matrix with G^2 number of N by N block submatrices. It shows inter-industry input/output coefficients not only within each country, but also across all of the countries. There is no qualitative difference between equation (31) and equation (16). The only difference is their dimensions. Therefore, all the concepts and measures constructed in the previous sub-section could be straightly extended to current section. Although the analytical solution for the block matrix inverse is too complicated when the number of countries exceed three, we can define each element in the block inverse matrix B as $B_{sr} = [b_{ji}^{sr}]$ 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 1 by GN vector of direct value-added. Then we can define our basic measure of value added in a global production network as a G by GN matrix

$$\text{VAS} = \begin{bmatrix} V_1 B_{11} & .... & V_1 B_{1G} \\ : & V_s B_{ss} & : \\ V_G B_{G1} & .... & V_G B_{GG} \end{bmatrix} = [vas_i^{sr}] = \left[\sum_{j=1}^{N} av_j^s b_{ji}^{sr} \right] \tag{32}$$

Each of its elements is the column sum of the product between a value-added coefficient and a total requirement coefficient, where industry *i* in destination country *r* represents the using industry, and industry *j* in source country *s* represent the supply industry. The direct value-added coefficient is from the producing industry *j* used in source country *s*. Intuitively, this is the same as pre-multiplying the Leontief inverse by the direct value-added ratio and summing over the columns (industries) for each bilateral transaction in every country and industry, so we obtain the value-added generated directly and indirectly in one unit of final product for each industry in each country. The value-share contributed from all countries for a particular industry equals unity.

Similar to the three-country case, we can define the domestic value-added share in the corresponding source country's total exports as:

$$\text{Share of } DV^s = \frac{V_s B_{ss} E^s}{uE^s} = \frac{vas_i^{ss} e_i^s}{\sum_{i=1}^{N} e_i^s} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} av_j^s b_{ji}^{ss} e_i^s}{\sum_{i=1}^{N} e_i^s} \tag{33}$$

which are the diagonal elements of the VAS matrix weighted by the structure of the source country's exports. Please note $e_i^s = \sum_{s \neq r}^{G} e_i^{sr}$.

The diagonal elements of the VAS matrix capture domestically produced intermediate inputs in gross output of country *r* at the second, third, fourth, and subsequent stages before they become embodied in final goods delivered to other countries. Diagonal elements also capture the domestic value added embodied in intermediate exports to a third country used to produce subsequent exports of final goods. As before, the domestic value-added share based on HIY (i.e., one minus HIY's VS share) will underestimate domestic value added by neglecting both domestic value-added embodied in home's imports and indirect exports via indirect intermediate exports to third countries.

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

$$\text{Share of } VS^s = \frac{\sum_{s \neq r}^{G} V_s B_{sr} E^s}{uE^s} = \frac{\sum_{s \neq r}^{G} vas^{sr} e_i^{sr}}{\sum_{s \neq r}^{G} \sum_{i=1}^{N} e_i^{sr}} = \frac{\sum_{s \neq r}^{G} \sum_{i=1}^{N} \sum_{j=1}^{N} av_j^s b_{ji}^{sr} e_i^{sr}}{\sum_{s \neq r}^{G} \sum_{i=1}^{N} e_i^{sr}} \tag{34}$$

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 off-diagonal elements in a column (for all r≠s, holding the destination country r constant) in the VAS matrix capture imported intermediate input from source country *s* in output of destination country *r* at the second and subsequent stages before it becomes embodied in final goods imported by destination country *r*. Therefore, the sum over source country s is similar to the VS measure proposed by HIY without the assumption that imported intermediates are 100% foreign sourced. This revised VS measure also decomposes the foreign value-added embodied in direct exports of country *s* to destination country *r* into each of its original source countries.

The indirect value-added share of total exports from source country *s* due to intermediate exports that are exported as final goods by third countries (VS1) becomes

$$\text{Share of } VS1^s = \frac{\sum_{r\neq s}^{G} V_s B_{sr} E^r}{uE^s} = \frac{\sum_{r\neq s}^{G} vas^{sr} e_i^{sr}}{\sum_{r\neq s}^{G}\sum_{i=1}^{N} e_i^{sr}} = \frac{\sum_{r\neq s}^{G}\sum_{i=1}^{N}\sum_{j=1}^{N} av_j^s b_{ji}^{sr} e_i^{sr}}{\sum_{s\neq r}^{G}\sum_{j=1}^{N} e_i^{sr}} \quad , \tag{35}$$

which 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). Just as our modified VS measure provides a way to further decompose VS into all source countries, our modified VS1 measure provides a way to further decompose each country's value-added trade into direct and indirect value-added exports to the final destination.

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

$$\text{Share of } DV_i^s = \frac{vas_i^{ss}}{e_i^s} = \frac{\sum_{j=1}^{N} av_j^s b_{ji}^{ss} e_i^s}{e_i^s} \tag{36}$$

$$\text{Share of } VS_i^s = \frac{\sum_{s\neq r}^{G} vas_i^{sr}}{\sum_{s\neq r}^{G} e_i^{sr}} = \frac{\sum_{s\neq r}^{G}\sum_{j=1}^{N} av_j^s b_{ji}^{sr} e_i^{sr}}{\sum_{s\neq r}^{G} e_i^{sr}} \tag{37}$$

At a disaggregate level, however, VS1 may not be expressible as a share of a country's exports at that detailed level, 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.

Obviously, our basic value chain measure, VAS, is an extension of HIY's vertical specialization measures (VS and VS1) to G countries. It includes both domestic value-added shares (along the diagonal) and foreign value-added share from and to all other countries, thus combining VS and VS1 in a consistent framework. The detailed distribution of foreign value added in a country's direct and indirect exports to a destination country revealed by this systematic measure will enable us to quantify each

country's position in the production chain. In addition, it relaxes the unrealistic assumptions that imported intermediate inputs have 100% foreign content and that only a single country exports intermediate products, which are necessary for the HIY measures to empirically measure value-added trade.

IV. Summary

Coming soon.

Table 1 Decomposition of exports

Country/region	Gross exports (billion US$)	Share of interme-diates in gross exports	Channels of domestic value-added in exports (share of each value added in total gross exports)				Domestic value-added share		Share of intermediate exports that return to source country in final goods
			Total	Exports of final goods to dest	Intermediates exported directly to final destination	Intermediates exported through multiple countries	Final goods	Intermediate goods	
	(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)	(7)
Australia, New Zealand	124	69.3	88.1	27.1	49.0	12.1	88.2	88.1	0.4
Brazil	114	68.5	87.1	27.6	50.5	9.0	87.5	86.9	0.1
Canada	324	63.9	70.5	23.4	42.7	4.4	64.9	73.8	0.8
China	674	43.4	62.3	28.2	21.5	12.6	49.9	78.5	0.5
EU accession countries	274	57.8	68.3	28.8	35.0	4.5	68.2	68.3	0.6
EU 15	1,574	57.3	81.1	38.0	37.4	5.7	88.9	75.3	5.5
Hong Kong	122	62.4	71.9	27.3	34.1	10.5	72.6	71.4	0.6
Indonesia	88	70.8	77.5	20.7	44.6	12.2	70.7	80.3	0.3
India	101	63.7	79.7	30.0	40.5	9.1	82.7	77.9	0.1
Japan	620	56.9	84.9	38.3	33.1	13.5	88.9	81.9	2.4
Korea	282	57.7	65.3	29.4	24.2	11.8	69.3	62.3	0.5
Mexico	192	51.6	52.5	20.9	26.0	5.6	43.2	61.3	0.1
Malaysia	152	70.3	58.5	16.8	30.5	11.2	56.5	59.4	0.4
Philippines	51	71.6	57.8	17.6	27.1	13.0	62.1	56.0	0.1
Latin America and Carib.	211	71.8	84.9	23.9	52.5	8.5	84.8	85.0	0.4
EFTA	260	66.7	74.3	23.1	45.8	5.4	69.2	76.8	0.4
Rest of the world	718	81.1	82.9	14.9	60.3	7.7	78.8	83.8	1.0
Russian Federation	161	88.5	89.1	9.8	68.9	10.5	85.3	89.6	0.4
Singapore	151	71.7	36.2	11.0	19.7	5.5	38.9	35.2	0.2
South Asia	37	37.1	77.1	47.3	24.4	5.4	75.2	80.3	0.1
Thailand	120	55.1	60.0	27.8	23.6	8.6	62.0	58.4	0.1
Taiwan	220	68.8	58.1	19.0	24.9	14.3	60.7	56.9	0.2
United States	1,058	63.1	74.8	32.6	35.9	6.4	88.3	67.0	10.4
Vietnam	33	42.9	62.7	33.0	23.7	6.0	57.8	69.3	0.0
Rest of East Asia	27	51.4	78.3	35.5	35.4	7.4	73.1	83.2	0.1
South Africa	62	71.3	81.6	23.3	48.9	9.4	81.3	81.7	0.1
World	7,746	62.1	74.4	28.5	37.6	8.3	75.1	73.9	3.0

Table 2 Decomposition of imports

	Gross imports (billion US$)	Share of interme-diates in gross imports	Channels of foreign value-added in imports (share of each value added in total gross imports)				Foreign value-added share		Share of home country's value-added in its imports of final goods
			Total	Final goods	Intermediates imported directly from source	Intermediates imported through multiple countries	Final goods	Intermediate goods	
Country/Region	(1)	(2)	(4)	(5)	(6)	(7)	(8)	(9)	(3)
Australia,New Zealand	131	50.0	88.8	39.3	39.0	10.5	78.6	98.9	0.5
Brazil	79	65.0	81.3	27.7	46.5	7.2	79.1	82.5	0.4
Canada	306	60.3	68.8	32.6	29.7	6.6	82.2	60.1	1.3
China	571	78.6	55.6	16.8	26.0	12.8	78.4	49.4	1.3
EU accession countries	307	63.8	71.7	30.7	35.8	5.2	84.7	64.3	0.9
EU 15	1,627	61.1	81.7	28.6	45.9	7.2	73.6	86.9	7.8
Hong Kong	104	60.7	67.0	25.7	28.2	13.1	65.5	68.1	1.2
Indonesia	74	68.6	73.2	22.9	42.1	8.3	72.8	73.4	0.7
India	122	80.5	83.3	14.5	63.8	5.0	74.1	85.5	0.3
Japan	513	61.9	81.8	26.7	45.4	9.8	70.0	89.0	4.4
Korea	248	75.8	60.5	18.4	36.7	5.4	76.1	55.5	1.4
Mexico	185	74.2	50.5	22.0	20.5	8.1	85.0	38.5	0.2
Malaysia	102	71.9	38.3	19.4	10.6	8.3	69.1	26.2	1.4
Philippines	47	75.2	54.0	17.7	29.4	7.0	71.3	48.4	0.4
Latin America and Carib.	182	55.8	82.5	36.2	38.6	7.7	81.9	83.0	0.7
EFTA	208	61.6	67.9	33.1	29.7	5.0	86.1	56.5	0.8
Rest of the world	649	51.3	81.1	40.8	33.3	7.0	83.7	78.6	1.9
Russian Federation	121	42.1	85.6	49.1	28.1	8.3	84.9	86.6	0.7
Singapore	156	79.0	38.7	16.1	17.8	4.8	76.5	28.6	0.5
South Asia	51	63.0	83.3	29.9	46.4	7.0	80.9	84.7	0.1
Thailand	98	75.7	51.0	19.1	26.8	5.0	78.9	42.0	0.4
Taiwan	171	72.4	46.2	22.7	18.8	4.8	82.0	32.6	0.8
United States	1,589	54.8	83.2	30.1	42.4	10.7	66.7	96.9	9.7
Vietnam	35	71.5	64.5	22.5	36.0	5.9	79.2	58.6	0.1
Rest of East Asia	17	65.7	65.7	25.3	31.5	9.0	73.7	61.5	0.1
South Africa	54	61.1	79.0	31.9	40.2	6.9	82.1	77.1	0.2
World	7,746	62.1	74.4	28.5	37.6	8.3	75.1	73.9	4.9

Table 3 Measures of international dependence

	Direct exports as % of gross output	Total exports as % of gross output	Value-added exports as % of GDP	Direct imports as % of total absorbtion	Total imports as % of total absorption	Value-added imports as % of value-added absorption
Country/Region	(1)	(2)	(3)	(4)	(5)	(6)
Australia, New Zealand	9.1	17.9	15.6	9.6	21.5	16.4
Brazil	10.4	22.3	17.3	7.4	14.2	11.9
Canada	18.2	30.4	24.7	17.4	28.6	23.3
China	14.5	29.1	25.0	12.6	17.0	20.1
EU accession countries	16.2	33.7	29.8	17.8	31.1	33.3
EU 15	6.9	13.5	11.8	7.1	13.9	12.2
Hong Kong	28.9	53.9	53.2	25.8	44.4	47.5
Indonesia	17.5	30.0	27.3	15.1	27.1	23.0
India	8.4	15.4	12.8	10.0	18.7	15.7
Japan	7.1	15.8	11.6	5.9	11.5	9.5
Korea	18.2	34.9	27.5	16.3	23.0	23.6
Mexico	17.3	22.0	16.4	16.7	20.2	15.3
Malaysia	52.3	78.7	76.9	42.4	41.5	59.4
Philippines	29.9	41.7	35.3	28.2	37.6	32.0
Latin America and Carib.	13.9	24.3	22.2	12.3	24.6	19.3
EFTA	23.1	35.0	31.8	19.4	31.8	25.4
Rest of the world	20.2	29.9	30.2	18.7	37.6	27.7
Russian Federation	15.5	31.1	28.7	12.2	25.2	22.6
Singapore	50.6	63.8	53.1	51.6	48.5	55.7
South Asia	10.6	19.7	15.8	14.0	27.7	21.8
Thailand	31.8	50.7	44.6	27.5	33.5	35.8
Taiwan	31.4	54.5	41.8	26.3	28.7	30.8
United States	5.1	8.4	6.9	7.5	15.6	11.0
Vietnam	32.8	48.4	47.4	33.8	55.6	49.3
Rest of East Asia	25.9	47.2	46.4	18.1	30.3	31.5
South Africa	13.0	27.6	25.0	11.6	22.3	22.1
World	10.0	18.0	11.0	10.0	19.1	11.0

Note: Direct and total are used in the input-out sense, and do not refer to exports sent directly or indirectly to another country.

Table 4 Decomposition of value added exports from major sectors

	Sector generating domestic value-added in exports (share of each in total gross exports)				Sector generating foreign value-added in imports (share of each in total gross imports)				VS1: Value-added in intermediates exported via third countries (share of each in gross exports)			
Country/Region	Raw materials (2)	Manu-facturing (3)	Services (4)	Total (5)	Raw materials (6)	Manu-facturing (7)	Services (8)	Total (9)	Raw materials (10)	Manu-facturing (11)	Services (12)	Total (13)
Australia, New Zealand	30.3	21.1	36.7	88.1	10.0	42.7	36.0	88.8	6.2	5.3	5.8	17.3
Brazil	22.9	37.7	26.6	87.1	12.6	35.7	33.0	81.3	2.8	5.2	3.7	11.6
Canada	14.8	32.1	23.7	70.5	7.2	33.6	28.0	68.8	2.0	3.4	2.3	7.7
China	9.2	37.2	15.9	62.3	9.0	25.5	21.1	55.6	1.0	4.4	1.8	7.2
EU accession	5.7	35.7	26.8	68.3	8.3	32.7	30.7	71.7	0.5	3.6	2.6	6.6
EU 15	4.0	35.0	42.2	81.1	15.3	33.8	32.7	81.7	0.6	5.9	6.3	12.8
Hong Kong	2.7	11.7	57.4	71.9	8.6	30.7	27.8	67.0	0.8	2.6	6.7	10.1
Indonesia	33.5	28.7	15.2	77.5	14.0	29.4	29.9	73.2	9.0	6.2	3.0	18.3
India	17.3	35.1	27.3	79.7	23.8	29.9	29.5	83.3	2.6	5.2	3.5	11.2
Japan	1.1	49.8	34.0	84.9	21.0	29.1	31.7	81.8	0.2	10.5	6.6	17.3
Korea	1.4	45.4	18.5	65.3	13.5	23.2	23.9	60.5	0.2	9.1	3.2	12.5
Mexico	12.8	35.1	4.7	52.5	6.7	23.8	20.0	50.5	1.8	3.9	0.4	6.1
Malaysia	13.0	32.2	13.3	58.5	5.1	17.7	15.5	38.3	2.8	8.8	2.7	14.3
Philippines	6.5	38.4	12.8	57.8	12.8	23.3	18.0	54.0	0.9	12.4	3.4	16.8
Latin Am. and Carib.	34.8	24.2	25.9	84.9	9.8	39.4	33.2	82.5	5.3	4.6	3.4	13.3
EFTA	18.3	26.4	29.7	74.3	6.2	29.0	32.7	67.9	3.5	3.4	3.3	10.3
Rest of the world	44.4	16.2	22.2	82.9	9.4	36.5	35.1	81.1	11.3	2.7	3.3	17.3
Russian Federation	37.4	23.0	28.8	89.1	11.9	34.9	38.8	85.6	9.5	5.7	6.2	21.4
Singapore	0.8	17.6	17.8	36.2	4.5	17.2	16.9	38.7	0.1	4.9	2.5	7.5
South Asia	14.0	29.7	33.4	77.1	20.3	32.5	30.5	83.3	1.0	2.0	2.9	5.9
Thailand	10.9	31.0	18.1	60.0	9.9	21.7	19.4	51.0	1.3	6.3	2.8	10.5
Taiwan	0.9	37.0	20.2	58.1	7.7	21.5	17.1	46.2	0.1	9.6	4.2	13.9
United States	5.5	32.5	36.9	74.8	13.8	39.4	30.1	83.2	0.9	7.4	6.4	14.7
Vietnam	25.9	27.5	9.3	62.7	11.3	30.3	22.9	64.5	6.0	2.6	1.5	10.0
Rest of East Asia	22.6	22.4	33.3	78.3	13.5	27.4	24.8	65.7	4.3	1.9	3.9	10.2
South Africa	12.9	31.2	37.4	81.6	13.6	36.4	29.0	79.0	2.3	7.5	5.7	15.5
World	12.4	32.6	29.4	74.4	12.4	32.6	29.4	74.4	2.4	5.9	4.5	12.8

Table 5 Source of value-added in national final goods exports

Country/Region	aus	bra	can	chn	EU access	EU 15	hkg	idn	ind	jpn	kor	mex	mys	phl	lac	efta	row	rus	sgp	South Asia	tha	twn	usa	vnm	rea	zaf	HHI[a]
Australia, NZL	88.2	0.1	0.2	0.8	0.1	3.1	0.2	0.3	0.1	1.0	0.3	0.1	0.4	0.0	0.2	0.2	1.3	0.1	0.2	0.0	0.2	0.3	2.1	0.2	0.1	0.1	88.3
Brazil	0.1	87.5	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	87.6
Canada	0.3	0.4	64.9	1.2	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	22.3	0.0	0.0	0.1	68.8
China	0.5	0.4	0.4	65.7	0.2	4.1	1.6	0.6	0.3	7.4	3.6	0.2	1.5	0.5	0.6	0.3	2.2	0.6	0.5	0.1	0.8	3.7	3.6	0.1	0.1	0.2	66.6
EU accession	0.2	0.2	0.2	1.1	68.2	20.0	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	71.2
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	88.9
Hong Kong	1.1	0.1	0.4	1.8	0.2	5.4	72.6	0.5	0.7	4.6	1.6	0.1	0.7	0.3	0.4	0.4	2.3	0.3	0.4	0.2	0.5	1.8	3.2	0.1	0.1	0.2	73.1
Indonesia	1.6	0.3	0.5	2.3	0.2	5.1	0.3	70.7	0.7	4.4	1.6	0.1	0.9	0.2	0.5	0.4	3.3	0.3	1.4	0.1	0.7	1.0	3.0	0.2	0.1	0.2	71.2
India	1.1	0.1	0.2	1.2	0.2	3.9	0.2	0.3	82.7	0.7	0.4	0.1	0.3	0.0	0.3	0.8	4.3	0.4	0.2	0.2	0.2	0.3	1.4	0.0	0.1	0.5	82.9
Japan	0.5	0.1	0.2	1.1	0.1	1.8	0.2	0.4	0.1	88.9	0.7	0.0	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	88.9
Korea	1.1	0.3	0.4	2.5	0.2	4.1	0.5	0.6	0.3	7.0	69.3	0.1	0.6	0.3	0.7	0.4	3.5	0.6	0.4	0.1	0.3	1.1	5.2	0.1	0.1	0.3	70.2
Mexico	0.1	0.5	1.2	1.7	0.3	4.0	0.1	0.2	0.2	2.3	1.0	54.3	0.3	0.3	1.3	0.3	0.9	0.2	0.2	0.1	0.3	0.5	29.3	0.0	0.1	0.2	62.0
Malaysia	1.2	0.3	0.5	2.8	0.3	7.9	0.4	1.6	0.5	7.6	2.2	0.2	56.5	1.1	0.8	0.5	2.5	0.4	1.9	0.1	1.6	2.0	6.5	0.2	0.1	0.3	58.3
Philippines	0.7	0.3	0.4	3.5	0.2	4.8	0.4	1.0	0.4	8.9	2.6	0.1	1.3	62.1	0.5	0.5	2.8	0.4	0.8	0.1	0.9	2.8	4.2	0.1	0.0	0.1	63.4
Latin Am.	0.1	1.3	0.5	0.7	0.2	3.4	0.1	0.1	0.1	0.6	0.4	0.4	0.1	0.0	84.7	0.2	1.0	0.3	0.1	0.1	0.1	0.2	5.0	0.0	0.0	0.1	85.0
EFTA	0.2	0.2	0.4	0.6	0.8	19.7	0.2	0.1	0.2	0.9	0.2	0.1	0.1	0.0	0.6	69.2	1.8	0.7	0.1	0.0	0.2	0.2	3.0	0.0	0.0	0.1	72.1
Rest of world	0.4	0.3	0.2	1.2	0.8	9.2	0.1	0.2	0.7	0.9	0.6	0.1	0.2	0.0	0.4	0.6	78.8	1.5	0.1	0.2	0.2	0.3	2.2	0.0	0.0	0.5	79.4
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	85.6
Singapore	1.1	0.3	0.7	4.6	0.7	13.1	0.8	2.3	0.8	8.8	2.5	0.3	4.6	1.3	0.7	0.8	3.2	0.5	38.9	0.1	1.3	3.0	8.6	0.2	0.1	0.2	43.9
South Asia	0.7	0.2	0.2	4.0	0.2	3.6	0.3	0.7	1.9	1.4	1.5	0.0	0.6	0.0	0.3	0.3	3.8	0.3	0.3	75.2	0.7	1.4	1.9	0.1	0.1	0.1	75.6
Thailand	1.4	0.5	0.4	2.8	0.3	5.3	0.5	0.9	0.6	8.6	1.4	0.1	1.9	0.4	0.6	0.5	4.1	0.5	0.8	0.1	62.0	1.3	4.0	0.2	0.5	0.3	63.2
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	4.1	1.0	0.4	0.1	0.5	60.7	5.5	0.1	0.1	0.7	62.2
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	0.7	0.2	1.2	0.2	0.1	0.0	0.1	0.3	88.3	0.0	0.0	0.1	88.4
Vietnam	1.1	0.3	0.4	6.2	0.2	4.6	0.4	1.2	0.9	4.1	3.9	0.1	1.3	0.2	0.8	0.6	4.5	0.8	0.9	0.3	1.8	4.4	2.8	57.8	0.4	0.2	59.1
Rest of E. Asia	0.5	0.4	0.3	5.3	0.2	4.0	1.0	0.5	0.5	1.9	1.3	0.1	0.8	0.1	0.3	0.2	1.7	0.5	0.7	0.2	1.9	2.1	2.1	0.3	73.1	0.1	73.6
South Africa	0.5	0.4	0.2	0.8	0.3	6.9	0.1	0.2	0.3	1.5	0.2	0.1	0.2	0.0	0.5	0.3	3.9	0.2	0.1	0.1	0.2	0.3	1.5	0.0	0.0	81.3	81.7
World	1.6	1.4	3.1	9.4	3.1	24.7	1.5	1.0	1.3	11.0	3.9	1.7	1.4	0.5	2.3	2.5	5.5	1.1	0.8	0.7	1.5	2.4	16.1	0.4	0.4	0.7	34.4

[a] Herfindahl-Hirschman Index

Table 6 Countries in database and corresponding GTAP regions

Countries or region	Corresponding GTAP regions
Australia and 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, United Kingdom
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 Eastern 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