Accounting for Intermediates: Production Sharing and Trade in Value Added*

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Abstract

We combine input-output and bilateral trade data to quantify cross-border production linkages. Using a complete trading system, we compute bilateral trade in value added for 87 countries and regions. The ratio of value added to gross exports is a measure of the intensity of production sharing. Across sectors, manufacturing has a relatively low ratio and thus accounts for a smaller share of exported value added than gross exports. Across countries, aggregate ratios are negatively correlated with exporter income, primarily due to cross-country differences in the composition of exports. Across bilateral partners, ratios vary widely and contain information on both bilateral and triangular production chains. Further, bilateral imbalances measured in value added differ from gross imbalances.

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1 Introduction

Trade in intermediate inputs accounts for as much as two thirds of international trade. This trade in intermediates is direct evidence of the fragmentation of the production chain across borders. Well-known examples of international production chains abound, from Barbie Dolls to Dell computers and Apple iPods to Boeing airplanes.[1] These examples have inspired a large volume of theoretical work on global sourcing, as well as the organizational form of cross-border relationships. Yet, they fail to provide a comprehensive empirical characterization of the integrated global production structure. A more complete portrait is necessary to identify the causes and quantify the consequences of production sharing.

In this paper, we combine data from input-output tables with data on bilateral trade to systematically quantify cross-border production linkages. The basic framework draws upon a venerable literature on input-output accounting in multi-region models to transform gross trade flows to a value added basis.[2] Using input-output and trade data for 69 countries plus 18 composite regions, we apply these methods to construct a data set that tracks the value added produced in each country to the final destination at which that value added is consumed.

Differences between value added and gross trade flows reveal substantial information on production sharing relations. To understand this claim, consider two distinct problems with measuring trade in the presence of production sharing. First, traditional trade statistics suffer from a well-known "double-counting" problem. Specifically, trade statistics tally the gross value of goods at each border crossing, rather than the net value added between border crossings. As such, they tend to overstate the implicit value or factor content exchanged among partners. Comparing aggregate or bilateral trade flows measured in terms of value added to gross trade, we quantify the magnitude of the "double-counting" problem and implicitly the scope of production sharing. Second, multi-country production networks imply that intermediate goods can travel to their final destination by an indirect route. For example, intermediates may be produced in Japan and shipped to China for assembly into a final good, which is then consumed in the U.S. In this case, Chinese bilateral exports to the U.S. embody third party (Japanese) content. Since our measure of value added exports allows for this type of triangular processing trade, differences between bilateral value added and gross flows also contain information on this aspect of production sharing.

To convert gross flows to a value added basis, we construct a global input-output system that specifies how each country sources intermediate inputs and consumption goods from abroad. We use destination country import tables to decompose bilateral trade into intermediate versus final use categories and divide intermediates across purchasing sectors. We then combine this import split with domestic input-output tables to construct a synthetic global input-output table. Using this global IO table, we split each country's gross

[1] See Tempest (1996) on the Barbie, Kraemer and Dedrick (2002) on Dell computers, Linden, Kraemer, and Dedrick (2007) and Varian (2007) on the iPod, and Grossman and Rossi-Hansberg (2009) on Boeing.

[2] The basic methods of input-output accounting were of course developed by Wassily Leontief. Important papers on input-output accounting with multiple regions include Isard (1951), Moses (1955), and Miller (1966).

output according to the destination in which it is ultimately consumed. We then compute the value added associated with the implicit output transfer to each destination by applying source-country information on the ratio of value added to output. This calculation requires a minimal set of assumptions and is consistent with the structure of standard trade models. In an extension of the basic framework, we adjust the calculation to allow for export-processing trade in China and Mexico.

Aggregating across sectors and export destinations for each country, the ratio of value added to gross exports can be interpreted as a metric of the domestic content of exports, equivalently a metric of production sharing or vertical specialization.[3] In fact, it is closely related to a previous metric used by Hummels, Ishii, and Yi (2001). The two metrics are identical in the special case where a country exports only final goods, thereby severing the circular production chain. Our metric generalizes the Hummels-Ishii-Yi approach in that we allow each country to both import and export intermediate goods. While this generalization results in only minor adjustments in aggregate domestic content measurements, allowing two-way trade in intermediates is crucially important for generating accurate bilateral value added flows. That is, we obtain accurate bilateral value added flows by combining both source and destination country information. In plain terms, bilateral value added flows depend primarily on how a source country's exports are used in the destination (e.g., for final vs. intermediate use, or for re-export vs. production of local consumption goods), rather than how those exports are produced in the source.

In the data, the ratio of value added to gross exports varies substantially across countries and sectors. Across sectors, we show that value added to export ratios are substantially higher in agriculture, natural resource, and service sectors than in manufacturing, because manufacturing sectors use both manufactured and non-manufactured intermediates intensively. Across countries, we show that richer countries tend to engage in more cross-border production sharing (i.e. have lower value added to export ratios). This results mainly from differences in the composition of exports across countries: richer countries tend to produce and trade manufactures, which have low value added to export ratios. Within the manufacturing sector, aggregate value added to export ratios are uncorrelated with income across countries due to two offsetting features of the data: richer countries tend to have lower value added to export ratios within individual manufacturing sectors, but tend to export in sectors with relatively high value added to export ratios.

Moving from aggregate to bilateral data, we show that production sharing significantly distorts bilateral trade patterns. Consistent with the discussion above, this occurs for two main reasons. First, bilateral production sharing implies that exports and imports are scaled down in value added terms relative to gross terms. Moreover, these scaling factors differ greatly across bilateral partners. For example, U.S. exports to Canada are about 40% smaller measured in value added terms than gross terms, whereas U.S. exports to France are essentially identical in gross and value added terms. Second, multilateral production sharing gives rise to indirect trade that occurs via countries that process intermediate goods. In fact, for some countries the ratio of bilateral value added traded actually exceeds gross trade flows. As a corollary, bilateral trade

[3] Bilateral or sector level ratios of value added to exports do not have this domestic content interpretation.

imbalances also generally differ in value added and gross terms. For example, the U.S.-China imbalance is approximately 15-30% smaller when measured in value added rather than gross terms.

To illustrate the mechanisms at work in generating these results, we highlight two decompositions. In the first decomposition, we show that most of the variation in bilateral value added to export ratios arises due to production sharing, not variation in the composition of goods exported to different destinations. To provide intuition for this result, the second decomposition splits exports according to whether they are absorbed abroad, embedded in goods that are either reflected back to the source of the intermediates, or redirected to third countries embedded in goods ultimately consumed there. Variation in the degree of absorption, reflection, and redirection across partners is an important driver of variation in bilateral value added to export ratios.

1.1 Related Literature

A number of recent papers have used input-output tables to study intermediate goods trade and vertical specialization.[4] Hummels, Ishii, and Yi (2001) and NRC (2006) use source country input-output tables to calculate measures of the import content of exports (termed "vertical specialization") for select countries. Chen, Cheng, Fung, and Lau (2008), Koopman, Wang, and Wei (2008), Dean, Fung, and Wang (2007), and Feenstra and Hong (2007) all use input-output data to study Chinese trade, focusing on the domestic content of exports and the response of employment to changes in exports. Trefler and Zhu (2006), Reimer (2006), and Johnson (2008) argue that accounting correctly for trade in intermediates can improve estimates of the factor content of trade.[5] Belke and Wang (2005) and Daudin, Rifflart, and Schweisguth (2008) also develop concepts and measurements of value added trade and openness along the lines of those used in this paper, though their exposition and data analysis differ considerably from ours.[6] As mentioned above, our work also builds on an old literature on input-output models with multiple regions, including Isard (1951), Moses (1955), and Miller (1966).

A separate line of work focuses on empirical implications of trade in intermediate goods for the response of trade to frictions, relative factor returns, and the transmission of economic shocks.[7] While we do not address these issues directly in this paper, the input-output framework we use could be profitably applied to address these issues. Lastly, there is a substantial amount of work studying the mode by which firms source intermediate goods from international suppliers – alternatively, integration versus outsourcing or

[4] Alternative approaches to quantifying vertical production chains use data on trade in parts and components (e.g., Yeats (1999)) or trade between multinational parents and affiliates (e.g., Hanson, Mataloni, and Slaughter (2005)).

[5] Johnson (2008) shows that the framework developed by Reimer (2006) and Trefler and Zhu (2006) to measure the factor content of gross trade is equivalent to computing the factor content of value added trade.

[6] Daudin, Rifflart, and Schweisguth (2008) focus on studying the role of vertical specialization in generating regionalization in trade patterns, while Belke and Wang (2005) focus on measuring aggregate economic openness.

[7] See Yi (2003) on fragmentation and the growth of trade and Feenstra and Hanson (1999) on offshoring and returns to skill. Also see Bergin, Feenstra, and Hanson (2007), Di Giovanni and Levchenko (2008), and Burstein, Kurz and Tesar (2008) for theory and evidence on cross-border production synchronization.

arms-length versus related-party trade.[8] While sourcing arrangements are interesting in their own right, we do not address them directly. Rather, our work characterizes the value added implications of foreign sourcing, without taking a stand on the organizations/relationships in which trade takes place.

2 Tracking Intermediate Goods and Value Added Trade

In this section, we introduce the accounting framework and demonstrate how intermediate goods trade generates differences between gross and value added trade flows. To present the main ideas clearly, we exposit results in simple two and three country aggregate models where possible. Results from these simple models carry over to the full model with many countries and goods. For simplicity, we also assume Armington specialization and Cobb-Douglas technology below, though neither is necessary to perform the basic accounting exercise.

2.1 Two Countries, One Good Per Country

To begin, consider two countries (denoted 1 and 2), each producing a single differentiated tradable good that is both consumed and used as an intermediate input in production. Output in each country is produced by combining local factor inputs with intermediate goods from both countries according to production functions:

$$q_i = L_i^{1-\alpha_{ii}-\alpha_{ji}} (q_{ii}^m)^{\alpha_{ii}} (q_{ji}^m)^{\alpha_{ji}} \tag{1}$$

where L_i denotes factor input from country i, q_{ji}^m is the quantity of the intermediate input produced in country j used in production in country i, and $\alpha_{ji} \in [0,1)$ is the input share associated with the corresponding intermediate. We assume $1 - \alpha_{ii} - \alpha_{ji} > 0$ in both countries. We define the price of output from country i as p_i and assume the law of one price holds both across countries and across uses of the good. Then, we define the value of production in each country as $y_i \equiv p_i q_i$ and the value of intermediates used in production as $m_{ij} \equiv p_i q_{ij}^m$. It follows that $m_{ij} = \alpha_{ij} y_j$.

A representative consumer in each country consumes goods from both countries. Let the expenditure of consumers in country j on final consumption goods from country i be c_{ij}. Then the market clearing conditions for output from each country are:

$$y_i = c_{ii} + c_{ij} + m_{ii} + m_{ij} \tag{2}$$

Gross exports, denoted x_i, include both exports for consumption and exports destined for intermediate use in the foreign country: $x_i = c_{ij} + m_{ij}$. Then (2) equivalently says that output is divided between domestic consumption, domestic intermediate use, and gross exports.

[8] See Helpman (2006) or Antràs and Rossi-Hansberg (2008) for a review of some of this literature.

Substituting for intermediate input use and stacking the market clearing conditions yields:[9]

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \begin{pmatrix} y_1 \\ y_2 \end{pmatrix} + \begin{pmatrix} c_{11} \\ c_{22} \end{pmatrix} + \begin{pmatrix} c_{12} \\ c_{21} \end{pmatrix}. \quad (3)$$

Using this representation, we can relate output in each country to final demands for each of the goods:

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \left[I - \begin{pmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{pmatrix} \right]^{-1} \begin{pmatrix} c_{11} + c_{12} \\ c_{22} + c_{21} \end{pmatrix}. \quad (4)$$

This system describes how the gross output of each country is embodied in final consumption in each of the two countries. To unpack this result, let y_{ij} denote the value of country i's output used to produce country j's consumption and solve for the breakdown of country 1's production:

$$\begin{aligned} & y_1 = y_{11} + y_{12} \\ & \text{with} \quad y_{11} \equiv M_1 \left(c_{11} + \frac{\alpha_{12}}{1 - \alpha_{22}} c_{21} \right) \quad \text{and} \quad y_{12} \equiv M_1 \left(\frac{\alpha_{12}}{1 - \alpha_{22}} c_{22} + c_{12} \right), \end{aligned} \quad (5)$$

where $M_1 = \left(1 - \alpha_{11} - \frac{\alpha_{12}\alpha_{21}}{1-\alpha_{22}}\right)^{-1} \geq 1$ is a multiplier arising from intermediate production linkages. The first term (y_{11}) is the total amount of country 1's output that is required to produce final goods consumed in country 1. This term includes both output dedicated to producing country 1's consumption of its own goods (c_{11}) as well as output needed to produce country 1's consumption of country 2 goods (c_{21}). The second term (y_{12}) has a similar interpretation in terms of country 2's consumption (c_{22}, c_{12}).

Because (5) geographically decomposes country 1's output, we can translate this into a statement as to where the value added in country 1 is consumed. Value added in country i equals the value of output less intermediate use:

$$va_i = [1 - \alpha_{ii} - \alpha_{ji}] y_i. \quad (6)$$

Combining (5) and (6) yields:

$$va_1 = [1 - \alpha_{11} - \alpha_{21}] y_{11} + [1 - \alpha_{11} - \alpha_{21}] y_{12} \equiv va_{11} + va_{12}, \quad (7)$$

where va_{ij} is value added generated by country i that is consumed in country j.

Naturally, value added exports are related to gross exports. In particular, let us analyze the ratio of value

[9] The basic accounting exercise is valid for any production structure that yields an expression for market clearing of this form. For example, one can easily replace the Cobb-Douglas technology with standard alternatives. One can also allow deviations from the law of one price as long as traded quantities are valued at a common set of prices so that market clearing holds in terms of money values (i.e., production revenue equals expenditure on intermediate and final goods).

added exports to gross exports – "VAX ratio" for short. We write the VAX ratio as:[10]

$$
\begin{aligned}
\frac{va_{12}}{x_{12}} &= \frac{(1-\alpha_{11}-\alpha_{21})y_{12}}{x_{12}} \\
&= \frac{(1-\alpha_{11}-\alpha_{21})}{(1-\alpha_{11})}\left[\frac{x_{12}-\alpha_{12}y_{21}}{x_{12}}\right].
\end{aligned} \tag{8}
$$

To interpret the second line, note that $x_{12} = c_{12} + \alpha_{12}y_2$. Using $y_2 = y_{22} + y_{21}$, then $x_{12} = \alpha_{12}y_{21} + [c_{12} + \alpha_{12}y_{22}]$. The first term $\alpha_{12}y_{21}$ is the portion of country 1's output used as intermediates abroad to produce country 2's output for consumption in country 1. The second term (in brackets) is country 1's output consumed in country 2, either as final goods (c_{12}) or embedded in country 2's own output ($\alpha_{12}y_{22}$). So $x_{12} - \alpha_{12}y_{21}$ is exports less reflected intermediates, or equivalently the portion of exports genuinely consumed abroad. The VAX ratio will always be less than one, so value added exports are scaled down relative to gross exports.

The VAX ratio for a country can be thought of as a metric of the "domestic content of exports." Indeed, it is closely related to previous approaches to measuring domestic content in the literature. To see this, note that the VAX ratio has two components. The first component – $\frac{(1-\alpha_{11}-\alpha_{21})}{(1-\alpha_{11})}$ – is equivalent to a metric of domestic content developed in Hummels, Ishii, and Yi (2001), which we refer to as the HIY metric for short.[11] The HIY metric is equal to the VAX ratio only when country 2 does not use imported intermediates ($\alpha_{12} = 0$), and therefore country 1 exports final goods alone. In contrast, with two-way trade in intermediates the HIY metric overstates the amount of domestic value added that is generated per unit of exports. The second component of the VAX ratio adjusts for two-way trade in intermediates by allowing some exports to be dedicated to producing goods that are ultimately consumed at home. That is, it allows for a portion of exports to reflected back to the source rather than absorbed abroad.

With an eye toward the next section, it is helpful to introduce the distinction between the value added balance (vab) – defined as value added exports minus value added imports – and the conventional trade balance (tb). In the aggregate, these two objects are equal to one another. Using the output decomposition and the definition of exports, one can show that:

$$
\begin{aligned}
tb_{12} &= x_{12} - x_{21} \\
&= [(1-\alpha_{11})y_{12} + \alpha_{12}y_{21}] - [(1-\alpha_{22})y_{21} + \alpha_{21}y_{12}] \\
&= va_{12} - va_{21} = vab_{12}.
\end{aligned} \tag{9}
$$

[10] Mechanically, one can show that $y_{12} = \frac{c_{12}+\alpha_{12}y_{22}}{(1-\alpha_{11})}$ using the output decompositions for both countries. This fact combined with the decomposition of exports in the text yields the second line.

[11] To motivate the HIY metric, recall the market clearing condition for country 1: $(1-\alpha_{11})y_1 = c_{11} + x_{12}$. Then, $\frac{x_{12}}{(1-\alpha_{11})}$ is the amount of domestic production required to produce exports. The domestic value added associated with this output is $(1-\alpha_{11}-\alpha_{21})\frac{x_{12}}{(1-\alpha_{11})}$. The HIY metric is simply this value added divided by gross exports. The VAX ratio is equal to the HIY metric of domestic content only when $y_{12} = \frac{x_{12}}{(1-\alpha_{11})}$, i.e., when the amount of output needed to produce exports is equal to the amount of output that is actually consumed abroad.

While the aggregate trade and value added balances for each country are equal, this is not true in general for bilateral balances as we will see below.

2.2 Three Countries, One Good Per Country

While the two country framework illustrates the basic approach to constructing value added trade flows, additional insights emerge as one introduces a third country to the mix. One can easily extend the accounting procedure outlined in the previous section to three countries. Rather than writing out the solution for the general case, we focus on a special case (in which the algebra simplifies considerably) that illustrates how the accounting framework tracks the final destination at which value added by a given country is consumed even if this value circulates through a multi-country production chain enroute to its final destination.

We construct the special case to approximate a stylized account of how the iPod is produced.[12] The iPod combines a blueprint produced by Apple Inc. in the U.S., with a Japanese display, a Japanese disk drive (manufactured in China), and assorted components of lesser value from Taiwan, China, Korea, etc. These components are assembled in China and the finished iPod is then shipped to the U.S. and inserted into distribution and retail channels.

To formalize this example, let country 1 be the United States, country 2 be China, and country 3 be Japan. Further, assume that China imports intermediates from the U.S. and Japan and exports only final consumption goods only to the U.S. For simplicity, we assume that the U.S. and Japan do not export any final goods and only export intermediates to China. This configuration of production can be represented as:

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} = \begin{pmatrix} \alpha_{11} & \alpha_{12} & 0 \\ 0 & \alpha_{22} & 0 \\ 0 & \alpha_{32} & \alpha_{33} \end{pmatrix} \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} + \begin{pmatrix} c_{11} \\ c_{22} + c_{21} \\ c_{33} \end{pmatrix}. \tag{10}$$

This then can be solved to yield the following three-equation system:

$$\begin{aligned} y_1 &= \underbrace{\left[\frac{1}{(1-\alpha_{11})}c_{11} + \frac{\alpha_{12}}{(1-\alpha_{11})(1-\alpha_{22})}c_{21}\right]}_{y_{11}} + \underbrace{\frac{\alpha_{12}}{(1-\alpha_{22})}c_{22}}_{y_{12}} \\ y_2 &= \underbrace{\frac{1}{(1-\alpha_{22})}c_{21}}_{y_{21}} + \underbrace{\frac{1}{(1-\alpha_{22})}c_{22}}_{y_{22}} \\ y_3 &= \underbrace{\frac{\alpha_{32}}{(1-\alpha_{33})(1-\alpha_{22})}c_{21}}_{y_{31}} + \underbrace{\frac{\alpha_{32}}{(1-\alpha_{33})(1-\alpha_{22})}c_{22}}_{y_{32}} + \underbrace{\frac{1}{(1-\alpha_{33})}c_{33}}_{y_{33}}. \end{aligned} \tag{11}$$

This system provides the implicit output transfers to which one can apply the value added transformation.

[12] See Linden, Kraemer, and Dedrick (2007) or Varian (2007).

Two points are interesting to note. First, as in the two-country case above, U.S. consumption of U.S. output has both a direct component $\frac{1}{(1-\alpha_{11})}c_{11}$ and an indirect component $\frac{\alpha_{12}}{(1-\alpha_{11})(1-\alpha_{22})}c_{21}$ that accounts for the fact that U.S. imports of final goods from China include embedded U.S. content. Thus, a larger share of U.S. output is ultimately consumed at home than bilateral trade statistics would indicate. Correspondingly, Chinese bilateral exports overstate the true Chinese content shipped to the U.S. due to bilateral U.S.-China production sharing.

Second, although Japan does not export directly to the U.S., the U.S. does import Japanese content embedded in Chinese exports to the U.S. This effect, which was absent in the two country case, appears as $\frac{\alpha_{32}}{(1-\alpha_{33})(1-\alpha_{22})}c_{21}$ in the equation for Japan (country 3). To see this result clearly, consider the following decomposition of Japanese exports:

$$x_3 = \alpha_{32}y_2 = \frac{\alpha_{32}}{(1-\alpha_{22})}c_{22} + \frac{\alpha_{32}}{(1-\alpha_{22})}c_{21}, \tag{12}$$

where we have substituted for y_2 using the solution above. The first term $\frac{\alpha_{32}}{(1-\alpha_{22})}c_{22}$ is Japanese exports embedded in Chinese consumption. The second term $\frac{\alpha_{32}}{(1-\alpha_{22})}c_{21}$ is Japanese exports ultimately embedded in U.S. bilateral imports of final goods from China.

It is further instructive to break down China's bilateral exports to the U.S. into Chinese, Japanese, and U.S. content.[13] We can write exports from China to the U.S. as:

$$x_{21} = va_{21} + va_{31} + \alpha_{12}y_{21}. \tag{13}$$

Thus, x_{21} can be explicitly broken down into components that measure value added in China, value added in Japan, and the use of U.S. goods as intermediates, which implicitly contain U.S. value added.

To the extent that fundamental bilateral trade relations are distorted by intermediate goods trade, as we have just shown, so too are bilateral balances. To illustrate this, we define $tb_{12} \equiv x_{12} - x_{21}$ and $vab_{12} \equiv va_{12} - va_{21}$ to be bilateral U.S.-China trade and value added balances. These balances are related as follows:

$$tb_{12} + \alpha_{32}y_{21} = vab_{12}. \tag{14}$$

That is, $tb_{12} < vab_{12}$. So assuming the U.S. runs a trade deficit with China in this example, then it will run a smaller deficit with China in value added terms due to the fact that Chinese bilateral trade contains Japanese value ($\alpha_{32}y_{21}$). As a corollary, the U.S.'s bilateral balance with Japan will be distorted in the opposite direction. Overall, the U.S. aggregate trade balance will be equal to the aggregate value added balance as in the simple two-country case above, but the bilateral balances can be quite different measured in value added versus gross terms.

[13] To do this, note that in this special case, $x_{21} = c_{21}$ and $y_{21} = \frac{c_{21}}{(1-\alpha_{22})}$. Using these facts, we can write: $va_{21} = \frac{(1-\alpha_{22}-\alpha_{12}-\alpha_{32})}{(1-\alpha_{22})}x_{21}$. Using this result and $va_{31} = \frac{\alpha_{32}}{(1-\alpha_{22})}c_{21}$ from (11), the decomposition follows.

2.3 Many Countries, Many Goods

The most general and empirically relevant formulation of the accounting framework allows for multiple goods and countries. Assume there are S sectors and N countries. Each country produces a unique variety within each sector according to production function:

$$q_i(s) = L_i(s)^{1-\alpha_i(s)} \left(\prod_j \prod_t \left[q_{ji}^m(t,s) \right]^{\alpha_{ji}(t,s)} \right), \tag{15}$$

where s denotes sectors, $\alpha_i(s) = \sum_j \sum_t \alpha_{ji}(t,s)$ and $\{\alpha_{ji}(t,s), q_{ji}^m(t,s)\}$ are the cost shares in country i, sector s for inputs from country j, sector t.

Collect the total value of production in each sector in the $S \times 1$ vector y_i and allocate this output to consumption and intermediate use. Denote country i's final consumption of its own goods by $S \times 1$ vector c_{ii} and shipments of final goods from i to country j by the $S \times 1$ vector c_{ij}. Further, denote use of intermediate inputs from i by country j by $A_{ij}y_j$. A_{ij} is an $S \times S$ input-output matrix with elements $A_{ij}(s,t) = m_{ij}(s,t)/y_j(t)$, where $m_{ij}(s,t)$ is the value of intermediates from sector s in country i used by sector t in country j and $y_j(t)$ is the value of output in sector t. Gross exports from i to j ($i \neq j$) are then $x_{ij} = c_{ij} + A_{ij}y_j$.

With this notation in hand, we can stack the SN goods market clearing conditions and invert them to yield a decomposition of output along national and sectoral lines. To do this, define:

$$A = \begin{pmatrix} A_{11} & A_{12} & \dots & A_{1N} \\ A_{21} & A_{22} & \cdots & A_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ A_{N1} & A_{N2} & \dots & A_{NN} \end{pmatrix}, \quad y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{pmatrix}, \quad c = \begin{pmatrix} c_{11} + c_{12} + \cdots + c_{1N} \\ c_{21} + c_{22} + \cdots + c_{2N} \\ \vdots \\ c_{N1} + c_{N2} + \ldots + c_{NN} \end{pmatrix}.$$

Then $y = (I - A)^{-1}c$ yields the output decomposition. We define aggregate value added as: $va_i = \iota[I - A_{ii} - A_{Ii}]y_i$, where $A_{Ii} = \sum_{j \neq i} A_{ji}$ is the total imported intermediate input matrix for country i and ι is a $1 \times S$ vector of ones.

The main results developed in the simple aggregate examples in previous sections go through with this multi-good formulation.[14] Adding to previous results, we emphasize new results regarding the mode by which individual sectors participate in trade and several decompositions that shed light on the forces that generate dispersion in bilateral VAX ratios.

[14] In particular, the aggregate VAX ratio has an identical interpretation as in the previous cases. If we collapse down the multi-country case to a two-country world, then we can write this ratio simply as: $\frac{va_{12}}{\iota x_{12}} = \frac{\iota[I-A_{11}-A_{21}](I-A_{11})^{-1}x_{12}}{\iota x_{12}} - \frac{\iota[I-A_{11}-A_{21}](I-A_{11})^{-1}A_{12}y_{21}}{\iota x_{12}}$. The first term is the HIY measure of domestic content with multiple goods.

With multiple sectors, we can calculate multilateral value added to export ratios at the sector level as well as in the aggregate. These are of interest for several reasons. First, gross exports at the sector level are a misleading guide to whether value added from a given sector is consumed at home or abroad. Producers can directly engage in trade, in which case we observe exports classified as originating in the sector of the producer. Producers can also indirectly engage in trade by selling intermediates to purchasers that produce goods for export. In this case, we observe no direct exports from the intermediate goods supplier, but do observe exports of value added. Examining sector-level value added exports or VAX ratios therefore sheds light on how different sectors engage in trade and fit into cross-border production chains. Second, sector-level VAX ratios also help us understand why aggregate VAX ratios differ across countries. In particular, we document how variation in VAX ratios across sectors interacts with the composition of exports to yield cross-country variation in the aggregate VAX ratio, as well as the VAX ratio within manufacturing.

In addition to studying multilateral VAX ratios, we develop a complementary set of results on bilateral VAX ratios. We construct several decompositions in the data to "inspect the mechanism" and document that production sharing is the fundamental force driving variation in bilateral VAX ratios. The first decomposition splits variation in bilateral VAX ratios into components arising from differences in the composition of exports across destinations and differences in bilateral production sharing relations. The second decomposition looks directly at how output circulates within cross-border production chains. Specifically, we take bilateral exports and approximately split them into shares that are absorbed and consumed in the destination, reflected back and ultimately consumed in the source, and redirected and ultimately consumed in a third destination.

To construct the first decomposition, we split the bilateral VAX ratio into two terms:

$$
\begin{aligned}
\frac{va_{ij}}{\iota x_{ij}} &= \frac{\iota\left[I - A_{ii} - A_{Ii}\right] y_{ij}}{\iota x_{ij}} \\
&= \underbrace{\frac{\iota\left[I - A_{ii} - A_{Ii}\right]\left(I - A_{ii}\right)^{-1} x_{ij}}{\iota x_{ij}}}_{\text{Bilateral HIY (BHIY)}} + \underbrace{\frac{\iota\left[I - A_{ii} - A_{Ii}\right]\left(y_{ij} - \left(I - A_{ii}\right)^{-1} x_{ij}\right)}{\iota x_{ij}}}_{\text{Production Sharing Adjustment (PSA)}}
\end{aligned}
\tag{16}
$$

The first term is equivalent to the Hummels-Ishii-Yi measure of the domestic content of exports calculated using bilateral exports. For a given source country, it varies only due to variation in the composition of the export basket across destinations. The second term is a production sharing adjustment. This adjustment is a function of the difference between the amount of country i output consumed in j – y_{ij} – and the amount of output required to produce bilateral exports to country j – $(I - A_{ii})^{-1} x_{ij}$. When the amount of country i's output consumed in j is less than the amount required to produce exports, the VAX ratio is adjusted downwards relative to the bilateral HIY benchmark (and vice versa). This adjustment arises either because country i's shipments to country j are reflected back to the source or redirected to third destinations, or because country i's content travels to country j via third countries.

We then decompose the variance of the bilateral VAX Ratio for each country across partners as follows:

$$\begin{aligned} \text{var}\left(\frac{va_{ij}}{\iota x_{ij}}\right) &= \text{var}(BHIY + PSA) \\ &= \underbrace{[\text{var}(BHIY) + \text{cov}(BHIY, PSA)]}_{\text{BHIY Term}} + \underbrace{[\text{var}(PSA) + \text{cov}(BHIY, PSA)]}_{\text{PSA Term}} \end{aligned} \tag{17}$$

We report the ratio of the BHIY Term and the PSA Term to the total variance of the the bilateral VAX ratio for selected source countries in the results below.

The second decomposition is constructed using the division of bilateral exports into final and intermediate goods along with the output decomposition for the foreign destination:

$$\begin{aligned} \iota x_{ij} &= \iota\left[c_{ij} + A_{ij} y_j\right] \\ &= \underbrace{\iota\left[c_{ij} + A_{ij} y_{jj}\right]}_{\text{Absorption}} + \underbrace{\iota A_{ij} y_{ji}}_{\text{Reflection}} + \underbrace{\sum_{k \neq j,i} \iota A_{ij} y_{jk}}_{\text{Redirection}} \end{aligned} \tag{18}$$

The first term reflects the portion of bilateral exports absorbed and consumed in destination j, including both final goods from country i and intermediates from i embodied in country j's consumption of its own goods. The second term captures the reflection of country i's intermediates back to itself embodied in country j goods. The third term is the summation of country i's intermediates embodied in j's goods that are consumed in all other destinations – i.e., reflected to third destinations.[15]

3 Data Description

Our primary source of data is the GTAP 6 Data Base assembled by the Global Trade Analysis Project at Purdue University. This data is compiled based on three main sources: (1) World Bank and IMF macroeconomic and Balance of Payments statistics; (2) United Nations Commodity Trade Statistics (Comtrade) Database; and (3) input-output tables based on national statistical sources. To reconcile data from these different sources, GTAP researchers adjust the input-output tables to be consistent with international data sources.[16] The resulting data set includes internally consistent bilateral trade statistics combined with do-

[15]This decomposition is only approximate, because the output split itself used in constructing the decomposition takes into account the entire structure of cross-border linkages. It reflects the first-order reflection/redirection effects associated with production sharing.

[16]The input-output tables are contributed by GTAP users and quality-checked prior to incorporation in the database. See Dimaranan (2006) for details on the harmonization procedure and extensive documentation of the source data. Since raw input-output tables are based on national statistical sources, they inherit all the problems of those sources. For example, import tables are often

mestic and import input-output tables for 57 sectors covering 69 countries plus 18 composite regions in 2001. The sector coverage of the database includes 18 Agriculture and Natural Resources sectors, 24 Manufactures sectors, and 15 Services sectors.[17] Tables 1 and 2 summarize the country and sector coverage in the data.[18]

In the data, we have information on 6 objects $\{y_i, c_{Di}, c_{Ii}, A_{ii}, A_{Ii}, \{x_{ij}\}_{\forall j \neq i}\}$ for each country i, defined as follows:

1. y_i is a 57×1 vector of total production.

2. c_{Di} is a 57×1 vector of domestic final demand (equivalently, "domestic final consumption").

3. c_{Ii} is a 57×1 vector of domestic final import demand (equivalently, "import final consumption").

4. A_{ii} is a 57×57 domestic input-output matrix.

5. A_{Ii} is a 57×57 aggregate import input-output matrix.

6. $\{x_{ij}\}$ is a collection of 57×1 bilateral export vectors for exports from i to j.

Final demand for domestic and imported goods follow the national accounts definition of "final goods," including private consumption, government purchases, and investment.[19]

To set up the accounting framework, we use bilateral trade data to transform the imported intermediates matrix A_{Ii} and the imported final goods vector c_{Ii} into bilateral input-output matrices A_{ji} and bilateral final demand vectors c_{ji}. We assume the breakdown of imports between final and intermediate uses and the allocation of intermediate imports across purchasing sectors is the same for different trading partners within each sector. Specifically, for goods from sector s used by sector t, we define bilateral input-output matrices

constructed using a "proportionality" assumption whereby the imported input table is assumed to be proportional to the overall aggregate input-output table.

[17]Data on bilateral trade in services is limited. GTAP imputes bilateral service exports by assuming that each country's service imports from a given partner are proportional to that partner's share in world service exports. Because services account for less than 20% of exports for most countries, we expect our results to be relatively insensitive to moderate mismeasurement of bilateral services flows.

[18]Composite countries in the database are regional agglomerations of countries for which GTAP does not have original input-output tables. GTAP assigns these composite regions "representative" input-output tables constructed as a linear combination of input-output tables of similar countries. Since composite regions account for only 6% of world value added and 7% of world trade, they do not play an important role in our results.

[19]To construct the global input-output table, we value each country's output (regardless of destination or use) at a single set of prices to ensure production revenue equals expenditure. We use "basic prices," defined as price received by a producer (minus tax payable or plus subsidy receivable by the producer). As a consequence, our measure of value added is distorted relative to the national accounts. Whereas the national accounts measure value added as the value of output at basic prices minus the value of intermediate inputs at the purchaser's price, we calculate value added as the value of output at basic price minus the value of intermediate inputs at basic prices.

and consumption import vectors:

$$A_{ji}(s,t) = A_{Ii}(s,t)\left(\frac{x_{ji}(s)}{\sum_j x_{ji}(s)}\right) \quad \text{and} \quad c_{ji}(s) = c_{Ii}(s)\left(\frac{x_{ji}(s)}{\sum_j x_{ji}(s)}\right).$$

In the main calculation, we assume that production techniques and input requirements are similar for exports and domestically consumed goods. In countries that have large export-processing sectors, such as China and Mexico, this assumption may fail badly. Therefore, we present additional calculations (described below) that allow production techniques to differ between the export processing sector and the rest of the economy for these countries.

4 Empirical Results

4.1 The Raw Data

Before diving into the main results, we pause to describe several important sources of variation in the raw data that underlie the results below. We highlight three important dimensions of the data: (1) cross-sector variation in intermediate input intensity (equivalently, value added to output ratios); (2) cross-country variation in the composition of exports; and (3) cross-country variation in overall openness and bilateral trade patterns.

There are large differences in the intermediate input intensity of individual sectors. Value added to output ratios within particular sectors differ widely across sectors, but are relatively stable across countries. In Figure 1, we plot the quartiles of the cross-country distribution of value added to output ratios within each sector. For reference, the circles in the figure represent the value of this ratio for the U.S. in each sector. Across sectors, value added to output ratios are highest in Agriculture and Natural Resources and Services, and markedly lower in Manufacturing. Across countries, value added to output ratios are somewhat more dispersed in Agriculture and Natural Resources than in other sectors. Further, value added to output ratios in the U.S. mostly lie within the inter-quartile range of the distribution.

These cross-sector differences in the composition of exports interact with cross-country differences in the composition of production and exports. Figure 2 illustrates how the share of Manufactures in total exports varies across countries. Though we plot the ratio for each country separately, we group countries by region and add horizontal lines indicating median Manufactures export shares within each region, along with country labels for selected countries. As is evident, the share of Manufactures in exports varies both across and within regions. It is relatively high in East Asia and Europe, and markedly lower in the Americas and Africa. Looking within regions, Japan, China, and Korea have the highest shares in Asia. Countries along the along the European Union periphery, such as the Czech Republic, Hungary, and Slovenia, have the highest shares in Central and Eastern Europe. We will show below that this cross-country variation in export composition, combined with cross-sector variation in value added to output ratios documented above, plays an important role in explaining variation in aggregate value added to export ratios.

Differences across countries in trade patterns also drive deviations between value added and gross trade. First, countries differ in their overall openness and the share of intermediates sourced from abroad. In our data, the mean share of imported intermediates in total intermediate use is 24.5%, with a standard deviation of 12.5 percentage points. Second, as is well known, countries differ widely in their trade partners. For example, Canada and Mexico are important destinations for the U.S., but not for the other large exporters. For China and Japan, the U.S. and other Asian countries are the dominant export destinations. German exports, on the other hand, are concentrated within Europe and the U.S. This variation in trade partners matters because destination countries differ in how they use imports, whether as intermediates or as final goods. Therefore, the identity of one's trading partners determines whether exports are used for consumption or production sharing.

4.2 Value Added Exports: Aggregate Results

Variation in intermediate intensity across sectors, export composition across countries, and trade patterns combine to generate substantial deviations between value added and gross exports. We begin by documenting variation in value added to export ratios aggregated across destinations for the economy as a whole and then proceed to results disaggregated by composite sector. To organize the cross-country variation, we document regional differences in VAX ratios and characterize how VAX ratios vary with exporter income.

Figure 3 plots the aggregate VAX ratio for all the countries/regions in our data. The first point to note is that value added exports are often substantially smaller than gross exports, representing about 73% of gross exports for the average country.[20] The size of the adjustment varies across regions, with Africa and the Americas having relatively small adjustments and Europe and East-Central Europe larger adjustments. Among European countries, the new E.U. members stand out again. Within East Asia, Japan and China stand out with a high VAX ratio, more than 20-percentage points higher than the regional median and/or Korea. For China, this result is counterintuitive, since popular accounts emphasize that China serves as an assembly hub for much of Asian trade. As we shall see below, China's VAX ratios falls dramatically when we account more carefully for export processing trade.

As discussed in Section 2, one can interpret the ratio of value added exports to total exports as a measure of the domestic content of exports or vertical specialization. Since our domestic content measure is related to the measure developed by Hummels, Ishii, and Yi, it is useful to compare these two alternative measures. Table 3 presents our domestic content measure along with two versions of the HIY measure – one calculated

[20]The fact that value added exports are only a fraction of gross exports means that one should be careful in using the ratio of exports to GDP as a comprehensive measure of the openness of the economy in empirical work.

using our data and the original HIY estimates for 13 countries.[21] Where our sample overlaps with Hummels et al., the HIY metric in our data is close to their original estimates.[22] Comparing the metrics in our data, the VAX ratio is always smaller than the HIY measure, as dictated by the algebra of Section 2, but the discrepancy is generally small. As such, the HIY measure appears to provide a useful approximation for measuring aggregate domestic content, despite ignoring two-way trade in intermediates.[23] Interestingly, however, the VAX ratio deviates from the HIY measure by a sizable amount in one important case – the United States (.79 versus .89). This adjustment brings the U.S. more in line with the typical country.

Moving down a level of disaggregation, we examine VAX ratios by composite sector in Figure 4. VAX ratios are typically greater than or equal to one in the composite Agriculture and Natural Resources and Services sectors, and markedly less than one in Manufactures. Recall that we observe gross exports from a given sector only if output from that sector crosses an international border with no further processing. With this in mind, it is obvious that VAX ratios are greater than one when a sector exports value added embodied in another sector's goods. In the data, it appears that Manufactures, which are directly traded, embody substantial value added from the other sectors. The upshot is that non-manufacturing sectors are far more exposed to international commerce than one would think based on gross trade statistics. As a corollary, the composition of aggregate value added flows differs from that of gross trade. Figure 5 summarizes this fact by plotting the share of each sector in both types of trade for all the countries. The role of Manufactures in value added trade is diminished relative to the two other sectors, especially vis-a-vis Services.

Because we extend the domestic content calculation to many new countries, we are able to document new facts about how domestic content varies across countries with the level of development. The aggregate VAX ratio is negatively correlated with income per capita, and this correlation is highly significant.[24] This relationship is illustrated in Figure 6, where the hollow circles indicate OECD countries. Overall, a one log point increase in value added per capita is associated with a fall in domestic content of 2.5 percentage points with 95% confidence interval $(-3.5, -1.6)$. Unpacking this result, there are several interesting dimensions to this figure. First, there is cross-group (OECD versus non-OECD) variation in value added to export ratios, which combines with cross-group variation in income to generate the overall correlation. Second, looking exclusively within non-OECD countries, VAX ratios are negatively correlated with income.[25] In contrast,

[21] We report values from Hummels, Ishii, and Yi (1999), as they are omitted from their 2001 paper. For most countries, these estimates are based on OECD input-output data. We omit their estimates for Mexico, as they are for the maquiladora sector only.

[22] Discrepancies arise for several reasons. First, our data is from a different source, for different time periods, and processed differently. Second, Hummels et al. perform their calculation using merchandise trade only, while we use all trade including Services. The similarity of the two measures is reassuring evidence that our data source is reasonable and that including Services trade does not drive our results.

[23] Given that their measure relies only on using single country input-output tables in isolation rather than requiring data on the complete world trading system as we do, it is helpful to know that this relatively less data intensive procedure is accurate in practice.

[24] Our measure of income per capita here is really value added (as computed in our data) per capita. Population figures come from the GTAP database. We exclude the Philippines, Singapore, and Vietnam as outliers for clarity sake in the figure. Including these countries does not appreciably change the results, however.

[25] For the non-OECD sample, the point estimates are nearly identical to the overall sample: a one log point increase in value added per capita is associated with a fall in domestic content of 2.7 percentage points with 95% confidence interval (-4.0,-1.3).

there is virtually zero correlation in VAX ratios with income inside the OECD.

The negative relationship between the domestic content of exports and income per capita may seem somewhat counterintuitive, since all else equal, one might expect poorer countries to be natural candidates to integrate themselves into vertical production networks as low value added manufacturing and assembly hubs. However, the data suggest that this mechanism is weak to non-existent in the aggregate. Rather, differences in the sectoral composition of exports between poor and rich countries drive the results. Countries systematically shift toward manufacturing (which has lower value added to output on average) as they grow richer and this depresses the aggregate VAX ratios.

To illustrate this composition effect, we construct a "between-within" decomposition of the aggregate VAX ratio. The decomposition is constructed relative to a reference country as follows:

$$\widehat{VAX}_i = \underbrace{\sum_s \left[VAX_i(s) - \overline{VAX}(s)\right] \left(\frac{\omega_i(s) + \bar{\omega}(s)}{2}\right)}_{\text{Within Term}} + \underbrace{\sum_s [\omega_i(s) - \bar{\omega}(s)] \left(\frac{VAX_i(s) + \overline{VAX}(s)}{2}\right)}_{\text{Between Term}}, \quad (19)$$

where s denotes sector, i denotes country, and $\omega(s)$ and $VAX(s)$ are the export share and VAX ratio in sector s. Bars denote reference country variables, which are constructed based on global composites.[26] In this decomposition, the Within Term varies primarily due to differences in VAX ratios within sectors across countries, while the Between Term is influenced mainly by differences in the sector composition of trade.

Using this decomposition, we can project the Between Term and the Within Term separately on exporter income to judge the relative contribution of each influence on the overall correlation between the aggregate VAX ratio and exporter income.[27] To isolate compositional shifts between Manufactures and non-Manufactures, we perform the calculation using two composite sectors (i.e., pooling Services plus Agriculture and Natural Resources into a single composite sector). The results are reported in the top panel of Table 4. As discussed above, the VAX ratio is negatively correlated with exporter income. This is due exclusively to the strong negative correlation of the Between Term with exporter income. The Within Term is even slightly positively correlated with exporter income, though this is not significant. These results should not be surprising. Examination of Figure 4 shows very little systematic cross-country variation in VAX ratios within sectors. At the same time, Figure 2 illustrates that there is systematic variation in export shares, which then interacts with the large cross-sector differences in value added to output ratios.

For comparison to these aggregate results, we replicate this "between-within" decomposition exercise for Manufactures alone using information on value added and gross exports for 24 sectors. The results are presented in the bottom panel of Table 4. The first column documents the near zero correlation of the

[26]In practice, this means that reference country VAX ratios for each sector are the ratios of value added exports to gross exports for the world as a whole. Export shares are the share of each sector in total world exports.

[27]It is worth pointing out that the the coefficients from regressing the Between and Within Terms on exporter income sum to the coefficient of the regression of $\widehat{VAX}_i$ on exporter income by construction. Hence these separate regressions decompose the overall correlation.

VAX ratio for Manufactures with exporter income per capita. This zero correlation is a manifestation of two offsetting effects. The Within Term is strongly negatively correlated and the Between Term is strongly positively correlated with exporter income. This means that richer countries have relatively lower VAX ratios within manufacturing sectors, but tend to specialize in sectors with high VAX ratios.[28]

4.3 Value Added Exports: Bilateral Results

The aggregate results presented above obscure a number of interesting insights that arise out of bilateral interactions. We illustrate that VAX ratios differ widely for individual exporters across destinations and document that the value added adjustments are related to the intensity of production sharing.

To provide a sense of the spread of bilateral VAX ratios in the data, we plot the quartiles of each country's distribution of bilateral VAX ratios in Figure 7.[29] We then provide greater detail on the distribution of these bilateral ratios for the four largest exporters in Figure 8. There is evidently a lot of variation in bilateral VAX ratios, both in terms of the median value of each country's distribution and the overall spread. Further, a substantial fraction of bilateral ratios are near or exceed one. Though the aggregate VAX ratio is bounded by one for each country, bilateral VAX ratios may be greater than one when an exporter sends intermediates abroad to be processed and delivered to a third country. Among the large exporters, Japan has the most bilateral VAX ratios above one (62%).

To aid understanding, we drill down and look in greater detail at the two largest exporters: the U.S. and Germany. Figures 9 and 10 graphically present bilateral VAX ratios for both exports and imports for the U.S. and Germany vis-a-vis selected trade partners, while Table 5 contains the underlying data.[30]

Looking at the U.S., there is wide variation in VAX ratios, ranging from .4 to 1.4. Despite this broad range, value added exports or imports are quite close to gross exports for some partners. For example, the difference between gross and value added exports to France amounts to less than 0.5% of gross exports.[31] In contrast, gross trade vastly overstates the exchange of value added for NAFTA partners Mexico and Canada. Value added exports to Canada are $62 billion smaller than gross exports, and value added exports to Mexico are $31 billion smaller.[32] Value added trade falls by a similar proportional amount – between 30-50% – for countries like Ireland, Korea, Taiwan, and Singapore. At the other end of the spectrum, countries on Europe's eastern periphery such as Poland, Russia, and Slovakia have VAX ratios toward the U.S. well exceeding one, presumably because they supply intermediates to western European countries than then end

[28] For example, apparel is a sector with a relatively low VAX ratio and is a sector in which poorer countries tend to export.

[29] For clarity, we omit Zambia in the figure. Further, we truncate the upper part of the plot for Madagascar, Mozambique, Venezuela, and Zambia whose 75th percentile lies well above 2 and notate the truncation using solid points in the figure.

[30] We display data for the 15 largest trade partners for each country, plus 5 additional countries selected for illustration purposes from the remaining partners.

[31] In general, the major European – the U.K, Italy, Germany, and France – all have relatively high VAX ratios.

[32] The large changes observed in exports to NAFTA countries are not simply due to the fact that they are large U.S. trade partners. Japan, for example, is also a large destination for U.S. gross exports ($72 billion), but value added exports to Japan are only $3 billion lower than gross exports.

up consumed in the U.S. Lastly, it is worth pointing out that for most countries, the proportional changes in bilateral trade is of a similar order of magnitude for both exports and imports.

Turning to the German data, value added trade is scaled down quite substantially for the vast majority of its large European partners, in contrast to the U.S. This surely in an indication of the integrated structure of production within the European Union and its neighbors. Consistent with anecdotal evidence, this is most pronounced for the Czech Republic and Hungary. Geography appears to play a substantial role, as trade with partners of similar income levels such as the U.S. and Japan is relatively less distorted. As with the U.S., German bilateral exports and imports are often scaled down quasi-proportionally when measured in value added terms.

One consequence of these adjustments to bilateral trade is that bilateral balances differ when measured in gross versus value added terms. Figures 9 and 10 display bilateral balances for the U.S. and Germany. For the U.S., this shifts bilateral balances in Asia.[33] Whereas the gross deficit with China is \$73 billion and the deficit with Japan is \$48 billion, the value added deficits with these two countries are nearly identical at around \$60 billion. This is due to a substantial reduction in U.S. value added imports from China relative to gross imports (\$15 billion) and a large increase in value added imports from Japan relative to gross imports (\$8 billion). Thus, the U.S.-China bilateral trade imbalance contracts by roughly 16% once we adjust for production sharing. This is consistent with what one would expect based on anecdotal evidence on production chains in Asia, in which China serves as a final assembly hub for triangular trade between the U.S. and the rest of Asia. Moreover, as we will discuss below, we believe that this adjustment to the U.S.-China balance understates the true adjustment by half because this baseline calculation does not properly address processing trade. For Germany, there are also a number of large bilateral adjustments with the U.S., the Netherlands, and France.

To shed light on the production sharing mechanism that drives these results, we turn to decompositions of the bilateral VAX ratios and the bilateral trade flows outlined in Section 2.3. In Table 6, we decompose the variance of bilateral VAX ratios for several representative exporters into terms associated with variation in export composition across destinations (i.e., the BHIY Term) and variation in production sharing relations (i.e., the PSA Term). The production sharing adjustment (PSA Term) evidently dominates the decomposition. This means that what drives bilateral VAX ratios is not what an exporter sends to any given destination, but rather how those goods are used abroad. How the goods are used determines the size of the discrepancy between gross output used to produce bilateral exports $(I - A_{ii})^{-1} x_{ij}$ and the amount of output transferred for consumption in the destination y_{ij}. In concrete terms, even though the U.S. sends automobile parts to both Canada and Germany, the U.S. VAX ratio with Canada is lower than with Germany because Canada is part of a cross-border production chain with the U.S.

[33] The bilateral balance also improves substantially with Canada and Mexico, at the expense of European countries such as the United Kingdom and Germany with whom the U.S. bilateral deficits increase. Note that because the multilateral trade balance for a country is equal to the multilateral value added balance, then improvements in one bilateral balance necessarily come at the expense of deteriorations in others.

To look at production chains more directly, we report the decomposition of bilateral exports into absorption, reflection, and redirection terms for informative bilateral pairs in Table 7. Looking at the upper left portion of the table, we see that Japan's exports to China are primarily either absorbed in China or redirected to the U.S.. This result is consistent with the iPod example and the adjustment in bilateral balances that we obtain by converting gross to value added flows. Comparing Japan's trade with China to that with the U.S., we see that Japanese exports to the U.S. are nearly exclusively absorbed by the U.S., indicating minimal bilateral U.S.-Japan production sharing. In contrast, looking at the upper right panel, we see that large portions of U.S. exports to China and Mexico are reflected back to the U.S. for final consumption. Looking at the lower left panel, we see that sharing a common border with two different countries does not necessarily imply tight bilateral production sharing relationships. German exports to France are primarily absorbed there, while nearly half of exports to the Czech Republic are reflected or redirected to third destinations. Finally, in the lower right corner, we see that Korea is engaged in triangular trade with the U.S. and other destinations via China, much like Japan. In contrast, most Korean exports directly to Japan are eventually consumed there. These results are consistent with our priors regarding the role of China as a production sharing hub in Asia.

4.4 Adjusting Data for Processing Trade

For certain countries, much international trade takes place in an export-processing sector. In China and Mexico, for example, roughly two thirds of exported manufactures originate in the export processing sector.[34] These processing sectors often produce distinct goods for foreign markets using different technologies (with lower value added to output ratios) than the rest of the economy. If we fail to allow for this fact and assume that all output and exports are produced with the same economy-wide average input requirements, then we will tend to overstate the value added content of exports.

To gauge the importance of export processing, we implement a modified version of a procedure used by Koopman, Wang, and Wei (2008) to construct separate input-output tables for the export processing sectors in China and Mexico. The basic idea is to use trade data to measure the amount of exports and imports that flow through the export processing sector, and then impute input-output coefficients for the processing sector so as to be consistent with these flows. Though full exposition of the procedure is beyond the scope of this paper, Appendix A outlines the main idea and details our implementation of the procedure.[35]

In Table 8, we describe the results for China and Mexico. In both countries, aggregate VAX ratios are substantially lower once we account for processing trade.[36] China's VAX ratio falls from .8 to .66,

[34]For Mexico, we classify exports originating from maquiladoras as processing exports. For China, we draw on estimates from Koopman, Wang, and Wei (2008) that use Chinese border trade data to measure processing trade.

[35]One point worth noting is that we perform this adjusted calculation at a higher level of aggregation. Namely, we aggregate the data to three composite sectors prior to implementing the adjustment procedure. We believe the results are insensitive to aggregation, as value added flows are nearly identical in the original data whether computed using 57 sectors or 3 composite sectors.

[36]This is a consequence of the fact that value added to output ratios are lower in processing than non-processing sectors. For

bringing it in line with other Asian emerging markets (e.g., Korea and Thailand). Mexico's VAX ratio falls from .79 to .59. Bilateral VAX ratios for the U.S. vis-à-vis China and Mexico are also substantially lower, reflecting the aggregate adjustments. Interestingly, though bilateral flows involving China and Mexico are subject to large changes when we allow for processing trade, bilateral flows not involving either country are minimally altered. Looking at percentage differences between bilateral value added flows not involving China or Mexico before and after the processing trade adjustment, the median difference is .5% and 1^{st} to 99^{th} percentile range is -.07% to 8.8%. Combined with the fact that aggregate VAX ratios depend almost exclusively on source country information, this implies that both our multilateral and bilateral results are robust to mis-measurement of a subset of the underlying input-output tables.

One consequence of these adjustments is that U.S. bilateral value added balances with China and Mexico are further attenuated relative to gross imbalances. Table 8 contains information on U.S.-China and U.S.-Mexico bilateral gross imbalances, as well as bilateral value added imbalances before and after the processing trade adjustment. With the processing trade adjustment, the U.S.-China value added imbalance is approximately 28% smaller than the gross trade imbalance, almost double the change in imbalances without the processing trade adjustment. The U.S.-Mexico imbalance falls by a similar magnitude (32%) allowing for processing trade.

5 Concluding Remarks

Intermediate goods trade and production sharing is a large and growing feature of the international economy. Understanding the nature and consequences of cross-border production linkages is therefore central to understanding a range of issues in both international trade and international macroeconomics. This paper takes a step in that direction by shifting attention away from gross trade to trade in value added. In documenting differences between measures of international engagement and bilateral trade patterns under the two measures, this paper raises as many questions as it answers. We believe much work remains to be done using data of the sort employed in this paper to calibrate and test economic models. We are pursuing several projects along these lines, including studying the role of trade costs in shaping bilateral trade and production sharing, the role of production sharing as a conduit of factor trade, and the importance of intermediate goods linkages in the transmission of shocks across countries.

China, the manufacturing value added to output ratio is .29 in the non-processing sector versus .19 in the processing sector. For Mexico, the manufacturing value added to output ratio is .51 in the non-processing sector versus .17 in the processing (maquiladora) sector.

Appendix A

The basic idea behind the adjustment for processing trade is to split the aggregate economy into separate processing and non-processing units, each with its own input-output structure. Both sectors use domestic and imported intermediates, but they differ in terms of intermediate input intensity and the source (domestic versus imported) of intermediates. Further, all output in the export processing sector is exported.

From the input-output data, we observe the domestic intermediate use matrix m_{ii} and import use matrix as m_{Ii} for the economy as a whole. From trade data, we observe total exports originating from and imported intermediates used by the processing sector, denoted x_i^P and $\bar{m}_{Ii}^P$ respectively. Output in the non-processing sector, denoted y_i^N, is calculated by subtracting x_i^P from total output in the input-output accounts. We seek separate intermediate use matrices for the two sectors $\{m_{ii}^N, m_{ii}^P, m_{Ii}^N, m_{Ii}^P\}$ and value added by sector $\{va_i^N, va_i^P\}$ that satisfy:

$$m_{ii} = m_{ii}^N + m_{ii}^P \tag{20}$$

$$m_{Ii} = m_{ii}^N + m_{Ii}^P \tag{21}$$

$$y_i^N = va_i^N + \iota \left[m_{ii}^N + m_{Ii}^N \right] \tag{22}$$

$$x_i^P = va_i^P + \iota \left[m_{ii}^P + m_{Ii}^P \right] \tag{23}$$

$$\bar{m}_{Ii}^P = m_{Ii}^P \iota', \tag{24}$$

where ι is a conformable row vector of ones and ι' is its transpose.[37]

If there are N sectors, then there are $4(N \times N) + 2N$ unknowns and only $2(N \times N) + 3N$ constraints so we cannot solve directly for the unknown coefficients. We therefore follow Koopman, Wang, and Wei (2008) and use a constrained minimization routine to impute the unknown coefficients, where the objective function minimizes squared deviations between imputed values and target values. Target values are set by splitting intermediate use and value added across processing and non-processing sectors according to their shares in total output.

With the resulting split tables, we use bilateral trade data as in the main text to construct bilateral sourcing matrices and the global input-output table.[38] In performing the calculation, we use processing trade shares from Koopman, Wang, and Wei (2008) for China. For Mexico, we obtain trade data for the maquiladora sector from the Bank of Mexico.[39] To speed computation, we aggregate the data to 3 composite sectors prior to imputing coefficients.[40]

[37] These constraints differ from those used by Koopman, Wang, and Wei (2008) in that we use the domestic and import intermediate use matrices separately, whereas they pool this information into a single overall use matrix.

[38] In the resulting system, China and Mexico effectively have $2N$ sectors, where each of the N sectors is separated into processing and non-processing sub-sectors.

[39] Data is availabe at: http://www.banxico.org.mx/polmoneinflacion/estadisticas/balanzaPagos/balanzaPagos.html.

[40] Because bilateral value added trade results are essentially identical in the main data when computed with 57 sectors or 3 composite sectors, we believe aggregation does not result in diminished accuracy.

Table 1: Country Coverage in the GTAP Data

Country	Abbrev.	Country	Abbrev.	Country	Abbrev.	Country	Abbrev.
Albania	alb	Greece	grc	Philippines	phl	Singapore	sgp
Argentina	arg	Hong Kong	hkg	Poland	pol	Slovakia	svk
Australia	aus	Hungary	hun	Portugual	prt	Slovenia	svn
Austria	aut	India	ind	Rest of Andean Pact	xap	South Africa	zaf
Bangladesh	bgd	Indonesia	idn	Rest of East Asia	xea	Spain	esp
Belgium	bel	Ireland	irl	Rest of EFTA	xef	Sri Lanka	lka
Botswana	bwa	Italy	ita	Rest of Europe	xer	Sweden	swe
Brazil	bra	Japan	jpn	Rest of Former Soviet Union	xsu	Switzerland	che
Bulgaria	bgr	Korea	kor	Rest of FTAA	xfa	Taiwan	twn
Canada	can	Latvia	lva	Rest of Middle East	xme	Tanzania	tza
Central America	xca	Lithuania	ltu	Rest of North Africa	xnf	Thailand	tha
Chile	chl	Luxembourg	lux	Rest of North America	xna	Tunisia	tun
China	chn	Madagascar	mdg	Rest of Oceania	xoc	Turkey	tur
Colombia	col	Malawi	mwi	Rest of S. African CU	xsc	Uganda	uga
Croatia	hrv	Malaysia	mys	Rest of South America	xsm	United Kingdom	gbr
Cyprus	cyp	Malta	mlt	Rest of South Asia	xsa	United States	usa
Czech Republic	cze	Mexico	mex	Rest of Southeast Asia	xse	Uruguay	ury
Denmark	dnk	Morocco	mar	Rest of S. African Dev. Com.	xsd	Venezuela	ven
Estonia	est	Mozambique	moz	Rest of Sub-Saharan Africa	xss	Vietnam	vnm
Finland	fin	Netherlands	nld	Rest of the Caribbean	xcb	Zambia	zmb
France	fra	New Zealand	nzl	Romania	rom	Zimbabwe	zwe
Germany	deu	Peru	per	Russian Federation	rus		

Table 2: Sector Definitions

Sector #	Abbrev.	Description	Composite Sector	Sector #	Abbrev.	Description	Composite Sector
1	pdr	Paddy rice	Ag. & Nat. Resources	29	lea	Leather products	Manufactures
2	wht	Wheat	Ag. & Nat. Resources	30	lum	Wood products	Manufactures
3	gro	Cereal grains nec	Ag. & Nat. Resources	31	ppp	Paper products, publishing	Manufactures
4	v_f	Vegetables, fruit, nuts	Ag. & Nat. Resources	32	p_c	Petroleum, coal products	Manufactures
5	osd	Oil seeds	Ag. & Nat. Resources	33	crp	Chemical, rubber, plastic products	Manufactures
6	c_b	Sugar cane, sugar beet	Ag. & Nat. Resources	34	nmm	Mineral products nec	Manufactures
7	pfb	Plant-based fibers	Ag. & Nat. Resources	35	i_s	Ferrous metals	Manufactures
8	ocr	Crops nec	Ag. & Nat. Resources	36	nfm	Metals nec	Manufactures
9	ctl	Bovine cattle, sheep and goats, horses	Ag. & Nat. Resources	37	fmp	Metal products	Manufactures
10	oap	Animal products nec	Ag. & Nat. Resources	38	mvh	Motor vehicles and parts	Manufactures
11	rmk	Raw milk	Ag. & Nat. Resources	39	otn	Transport equipment nec	Manufactures
12	wol	Wool, silk-worm cocoons	Ag. & Nat. Resources	40	ele	Electronic equipment	Manufactures
13	frs	Forestry	Ag. & Nat. Resources	41	ome	Machinery and equipment nec	Manufactures
14	fsh	Fishing	Ag. & Nat. Resources	42	omf	Manufactures nec	Manufactures
15	coa	Coal	Ag. & Nat. Resources	43	ely	Electricity	Services
16	oil	Oil	Ag. & Nat. Resources	44	gdt	Gas manufacture, distribution	Services
17	gas	Gas	Ag. & Nat. Resources	45	wtr	Water	Services
18	omn	Minerals nec	Ag. & Nat. Resources	46	cns	Construction	Services
19	cmt	Bovine meat products	Manufactures	47	trd	Trade	Services
20	omt	Meat products nec	Manufactures	48	otp	Transport nec	Services
21	vol	Vegetable oils and fats	Manufactures	49	wtp	Water transport	Services
22	mil	Dairy products	Manufactures	50	atp	Air transport	Services
23	pcr	Processed rice	Manufactures	51	cmn	Communication	Services
24	sgr	Sugar	Manufactures	52	ofi	Financial services nec	Services
25	ofd	Food products nec	Manufactures	53	isr	Insurance	Services
26	b_t	Beverages and tobacco products	Manufactures	54	obs	Business services nec	Services
27	tex	Textiles	Manufactures	55	ros	Recreational and other services	Services
28	wap	Wearing apparel	Manufactures	56	osg	Public Admin., Defense, Education, Health	Services
				57	dwe	Dwellings	Services

Table 3: Comparing Estimates of the Domestic Content of Exports

Country	*VAX/X*	HIY	HIY(2001)	Country	*VAX/X*	HIY	HIY(2001)
Albania	0.7801	0.7804		Poland	0.7406	0.7440	
Argentina	0.8826	0.8856		Portugual	0.7327	0.7359	
Australia	0.8595	0.8645	0.89	Romania	0.7078	0.7093	
Austria	0.6366	0.6403		Russian Federation	0.8768	0.8877	
Bangladesh	0.7557	0.7558		Singapore	0.3529	0.3551	
Belgium	0.4746	0.4780		Slovakia	0.5763	0.5784	
Botswana	0.7914	0.7918		Slovenia	0.6185	0.6195	
Brazil	0.8520	0.8564		South Africa	0.8178	0.8232	
Bulgaria	0.6462	0.6466		Spain	0.7212	0.7280	
Canada	0.6799	0.6859	0.73	Sri Lanka	0.6854	0.6856	
Chile	0.8162	0.8171		Sweden	0.6820	0.6860	
China	0.7799	0.7887		Switzerland	0.7472	0.7510	
Colombia	0.8705	0.8722		Taiwan	0.6336	0.6359	0.60
Croatia	0.7168	0.7179		Tanzania	0.8536	0.8537	
Cyprus	0.7229	0.7231		Thailand	0.6270	0.6283	
Czech Republic	0.5661	0.5687		Tunisia	0.6731	0.6738	
Denmark	0.6830	0.6854	0.71	Turkey	0.8017	0.8032	
Estonia	0.5690	0.5700		Uganda	0.8523	0.8525	
Finland	0.6836	0.6858		United Kingdom	0.7767	0.7954	0.74
France	0.7610	0.7778	0.76	United States of America	0.7947	0.8931	0.89
Germany	0.7350	0.7608	0.80	Uruguay	0.7911	0.7917	
Greece	0.7471	0.7497		Venezuela	0.9096	0.9116	
Hong Kong	0.7622	0.7657		Vietnam	0.5554	0.5564	
Hungary	0.5437	0.5446		Zambia	0.7928	0.7932	
India	0.8704	0.8738		Zimbabwe	0.8243	0.8246	
Indonesia	0.7860	0.7881		Central America	0.7185	0.7193	
Ireland	0.5928	0.5940	0.72	Rest of Andean Pact	0.8455	0.8466	
Italy	0.7226	0.7319	0.73	Rest of EFTA	0.7695	0.7734	
Japan	0.8747	0.8972	0.89	Rest of East Asia	0.7634	0.7636	
Korea	0.6525	0.6562	0.66	Rest of Europe	0.6817	0.6842	
Latvia	0.6402	0.6415		Rest of Former Soviet Union	0.7373	0.7433	
Lithuania	0.6248	0.6260		Rest of Free Trade Area of the Americas	0.7814	0.7822	
Luxembourg	0.5395	0.5402		Rest of Middle East	0.8165	0.8230	
Madagascar	0.7603	0.7604		Rest of North Africa	0.9185	0.9209	
Malawi	0.7976	0.7978		Rest of North America	0.5873	0.5875	
Malaysia	0.5962	0.5990		Rest of Oceania	0.7188	0.7195	
Malta	0.5477	0.5478		Rest of South African Customs Union	0.6757	0.6774	
Mexico	0.7508	0.7559		Rest of South America	0.7971	0.7975	
Morocco	0.7702	0.7707		Rest of South Asia	0.8591	0.8596	
Mozambique	0.7552	0.7561		Rest of Southeast Asia	0.9262	0.9282	
Netherlands	0.6522	0.6577	0.63	Rest of Southern African Dev. Com.	0.7968	0.7972	
New Zealand	0.8073	0.8083		Rest of Sub-Saharan Africa	0.8440	0.8475	
Peru	0.8757	0.8763		Rest of the Caribbean	0.6683	0.6686	
Philippines	0.4152	0.4159		Average	0.7287	0.7329	0.75

Notes: VAX/X is the ratio of aggregate value added exports to value added. HIY is the Hummels, Ishii, and Yi (2001) measure of domestic content calculated using our data. HIY (2001) is the original published calculation. See main text for formulas and details.

Table 4: Aggregate and Manufacturing VAX Decompositions

Panel A: Aggregate VAX Decomposition

	Aggregate $\widehat{VAX}_i$	Within Term	Between Term
Log Income Per Capita	-.025***	.010	-.035**
	(.007)	(.011)	(.012)
Constant	.206***	-.138	.344***
	(.057)	(.095)	(.099)
R^2	.14	.01	.09
N	84	84	84

Panel B: Manufacturing VAX Decomposition

	Manufactures $\widehat{VAX}_i$	Within Term	Between Term
Log Income Per Capita	-.001	-.049**	.048***
	(.007)	(.016)	(.014)
Constant	-.012	.492***	-.503***
	(.056)	(.131)	(.114)
R^2	.00	.11	.13
N	83	83	83

Standard errors are in parentheses. Significance levels: * $p < .1$, ** $p < .05$, *** $p < .01$. Income per capita equals exporter value added per capita. Philippines, Singapore, and Vietnam excluded in Panel A and Albania, Hong Kong, Vietnam, and Rest of N.A. excluded in Panel B as outliers.

Table 5: Bilateral Trade for the United States and Germany

Panel A: United States Bilateral Trade

Partner	GX	VAX	Export VAX Ratio	GM	VAM	Import VAX Ratio	TB	VAB
China	29.0	26.1	.90	102.4	87.6	.85	-73.4	-61.5
Japan	71.9	68.8	.96	120.3	128.5	1.07	-48.4	-59.7
Korea	29.4	19.5	.66	36.7	30.4	.83	-7.3	-11.0
Taiwan	22.0	13.7	.62	36.2	27.1	.75	-14.2	-13.5
Malaysia	9.5	3.9	.41	24.2	18.2	.75	-14.7	-14.4
Singapore	20.4	10.3	.51	17.8	7.6	.43	2.6	2.7
India	5.8	6.3	1.10	11.7	12.1	1.03	-5.9	-5.8
Canada	144.7	82.4	.57	197.5	122.4	.62	-52.8	-40.0
Mexico	91.3	60.4	.66	125.1	89.2	.71	-33.8	-28.8
Belgium	18.9	11.5	.61	14.6	10.3	.71	4.3	1.2
France	30.8	30.7	1.00	36.7	37.6	1.02	-5.9	-6.9
Germany	58.5	52.8	.90	70.2	69.8	1.00	-11.7	-17.0
United Kingdom	57.9	53.1	.92	51.1	51.3	1.00	6.8	1.8
Ireland	10.7	5.6	.52	16.4	11.5	.70	-5.8	-5.9
Italy	19.5	18.4	.94	31.9	30.4	.95	-12.4	-12.1
Netherlands	22.2	18.2	.82	13.9	13.4	.97	8.4	4.8
Poland	2.3	3.0	1.33	2.3	2.9	1.28	0.0	0.1
Slovakia	0.5	0.6	1.23	0.4	0.6	1.50	0.1	0.0
Russia	7.0	7.3	1.04	7.5	10.0	1.33	-0.5	-2.7
Mid. East Composite	29.9	28.0	.93	40.1	37.7	.94	-10.2	-9.7

Panel B: Germany Bilateral Trade

Partner	GX	VAX	Export VAX Ratio	GM	VAM	Import VAX Ratio	TB	VAB
China	16.7	12.7	.76	18.6	14.6	.78	-1.9	-1.8
Japan	17.9	17.8	.99	21.3	20.6	.97	-3.3	-2.8
Canada	7.1	5.5	.76	5.3	4.8	.92	1.9	0.6
United States	70.2	69.8	1.00	58.5	52.8	.90	11.7	17.0
Mexico	6.0	4.5	.75	2.7	2.5	.94	3.3	2.0
Austria	29.8	16.7	.56	20.6	10.3	.50	9.2	6.4
Belgium	29.5	13.6	.46	28.1	11.5	.41	1.4	2.1
France	62.2	43.7	.70	43.9	30.9	.70	18.3	12.8
Germany	48.6	38.5	.79	37.4	28.1	.75	11.3	10.4
Ireland	5.3	3.1	.58	9.5	5.4	.57	-4.2	-2.4
Italy	45.0	31.2	.69	37.3	25.2	.67	7.7	6.0
Netherlands	25.5	16.8	.66	33.0	17.3	.52	-7.5	-0.5
Spain	25.8	19.2	.75	17.8	12.5	.70	7.9	6.7
Sweden	12.6	7.5	.59	9.3	6.1	.66	3.3	1.4
Switzerland	24.4	14.6	.60	19.2	11.3	.59	5.3	3.3
Czech Rep.	12.8	5.7	.44	13.5	5.8	.43	-0.7	-0.1
Hungary	8.0	3.5	.44	10.7	4.4	.41	-2.7	-0.9
Poland	13.4	9.2	.69	12.5	7.6	.61	0.9	1.6
Russia	10.0	8.1	.81	7.9	7.5	.94	2.1	0.7
Mid. East Composite	15.4	13.1	.85	6.5	7.0	1.07	8.9	6.1

Figures are in billions of 2001 US Dollars. GX or GM is gross exports or imports, VAX or VAM is value added exports or imports, TB is the trade balance, and VAB is the value added balance.

Table 6: Bilateral VAX Ratio: Bilateral HIY vs. Production Sharing Adjustment

Variance Decomposition

Exporter	BHIY Term	PSA Term
U.S.	6%	94%
Germany	6%	94%
Japan	1%	99%
China	6%	94%
Chile	1%	99%
France	6%	94%
Hungary	12%	88%
India	2%	98%
Korea	14%	86%
Median Country	3%	97%

See the text for details regarding the decomposition. The Median Country is the median statistic for all 87 countries/regions in the data.

Table 7: Decomposing Trade: Absorption, Reflection, and Redirection

Japan exports to:				**U.S. exports to:**			
China		U.S.		Mexico		Canada	
China	67.8%	U.S.	94.0%	Mexico	73.1%	Canada	62.3%
U.S.	10.3%	Canada	0.9%	U.S.	21.6%	U.S.	30.5%
Japan	4.8%	Mexico	0.6%	Canada	0.9%	Japan	0.9%
Hong Kong	2.9%	Japan	0.6%	Germany	0.5%	U.K.	0.7%

Germany exports to:				**Korea exports to:**			
France		Czech Rep.		China		Japan	
France	77.9%	Czech Rep.	52.0%	China	64.8%	Japan	85.6%
U.S.	3.2%	Germany	14.9%	U.S.	11.2%	U.S.	4.9%
Germany	2.7%	U.S.	3.9%	Japan	5.3%	China	1.4%
U.K.	2.3%	U.K.	3.0%	Hong Kong	3.5%	Germany	0.8%

See the text for details regarding the decomposition. The entries in the table describe the approximate share of bilateral exports to each destination that are ultimately consumed in that destination. Shares do not sum to one because we include only the top four destinations for each bilateral pair.

Table 8: Results Adjusted for Processing Trade in China and Mexico

Panel A: Aggregate VAX Ratios

China VAX Ratio	.80
China VAX Ratio with adj.	.66
Mexico VAX Ratio	.79
Mexico VAX Ratio with adj.	.59

Panel B: U.S. Bilateral Trade with China

Export VAX Ratio	.93
Export VAX Ratio with adj.	.72
Import VAX Ratio	.87
Import VAX Ratio with adj.	.72

	USD Billions	Change relative to TB
GTB	-73.4	
VAB	-62.6	-15%
VAB with adj.	-52.8	-28%

Panel C: U.S. Bilateral Trade with Mexico

Export VAX Ratio	.70
Export VAX Ratio with adj.	.49
Import VAX Ratio	.75
Import VAX Ratio with adj.	.54

	USD Billions	Change relative to TB
GTB	-33.8	
VAB	-29.6	-12%
VAB with adj.	-23.1	-32%

See the text for description of adjustment procedure. Bilateral export/import VAX ratios and trade balances are reported from the U.S. perspective. GTB stands for Gross Trade Balance and VAB stands for Value Added Balance.

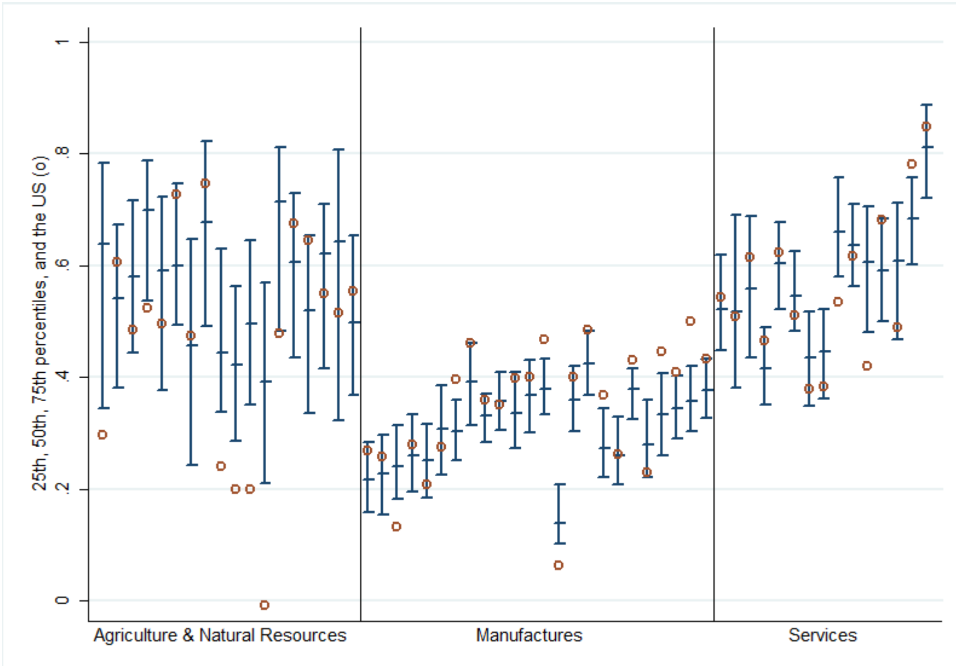

Figure 1: Ratio of Value Added to Output, by Sector

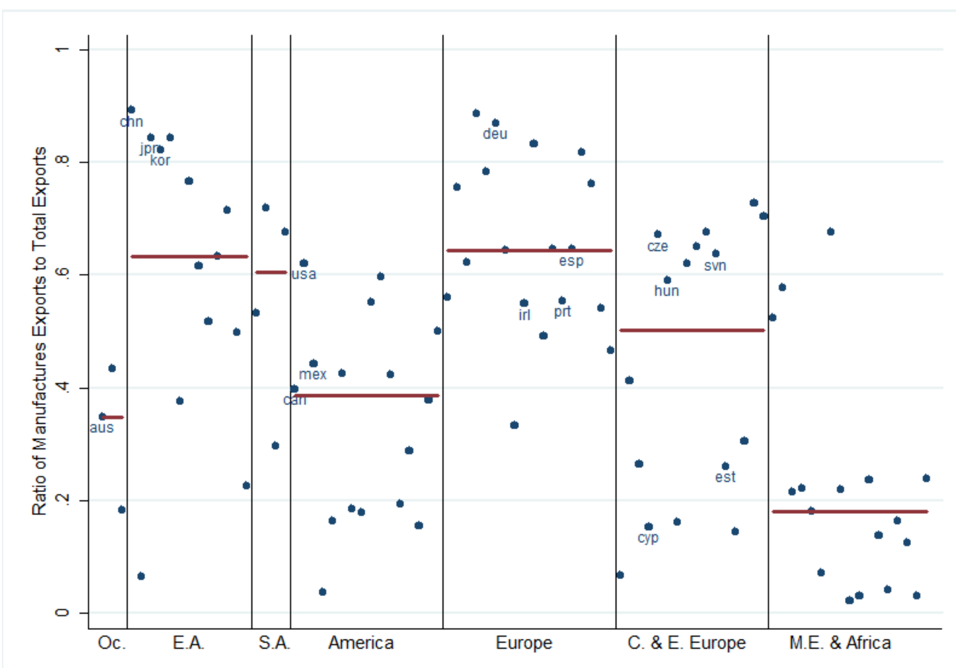

Figure 2: Share of Manufactures in Total Exports, by Country

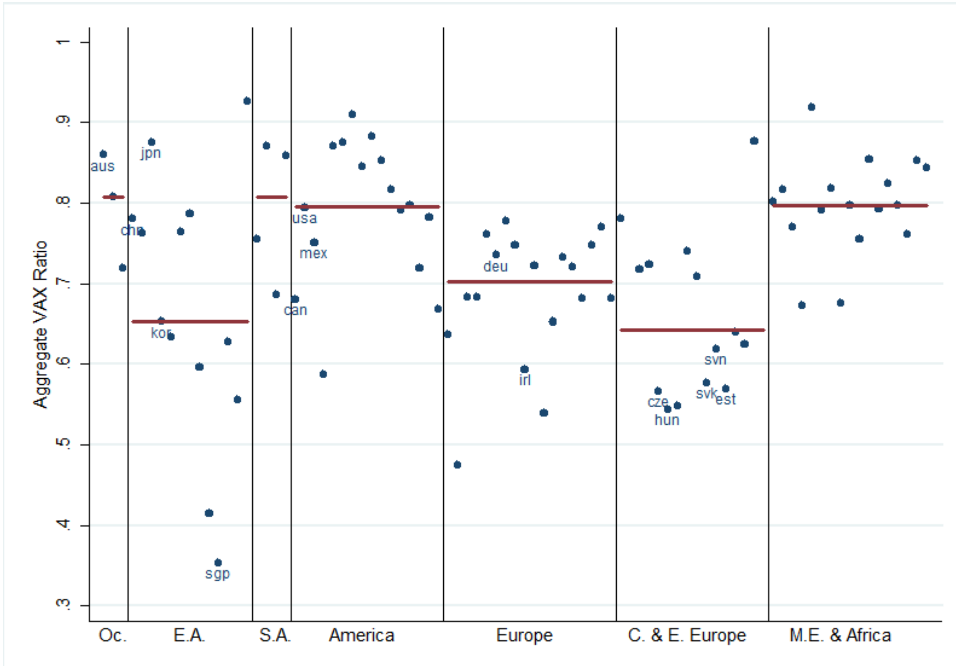

Figure 3: Aggregate Ratio of Value Added Exports to Gross Exports, by Country

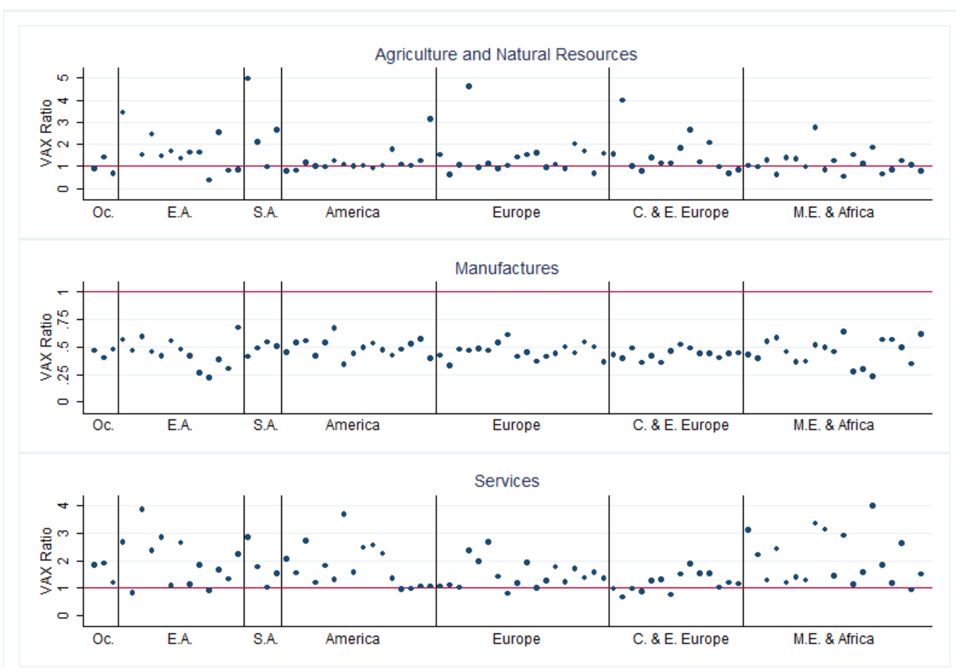

Figure 4: Ratio of Value Added Exports to Gross Exports within Composite Sectors, by Country

Figure 5: Composite Sector Shares of Gross Exports and Value Added Exports, by Country

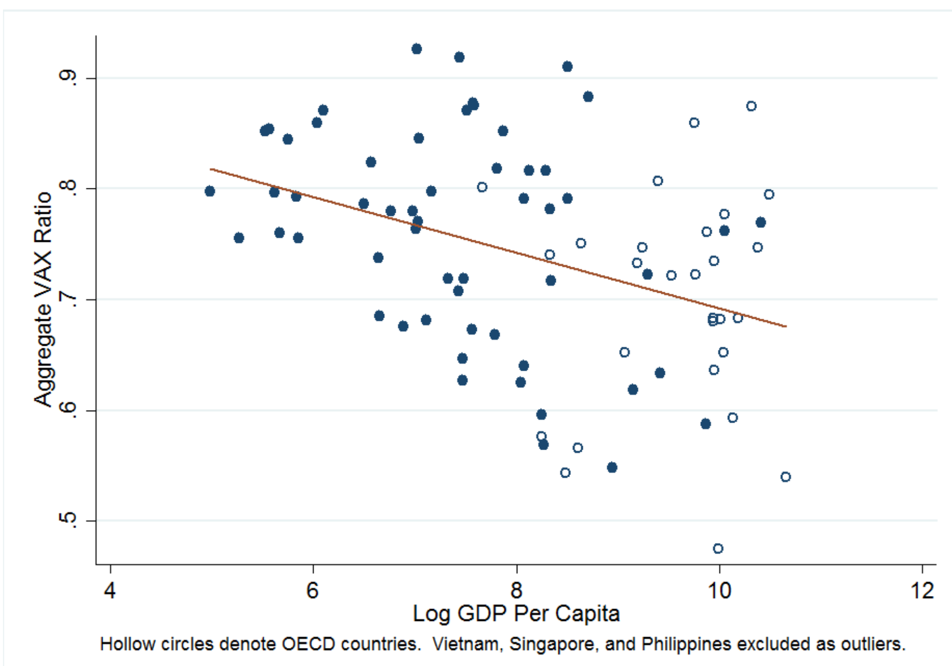

Figure 6: Aggregate Value Added Exports to Gross Exports Ratio versus Value Added Per Capita

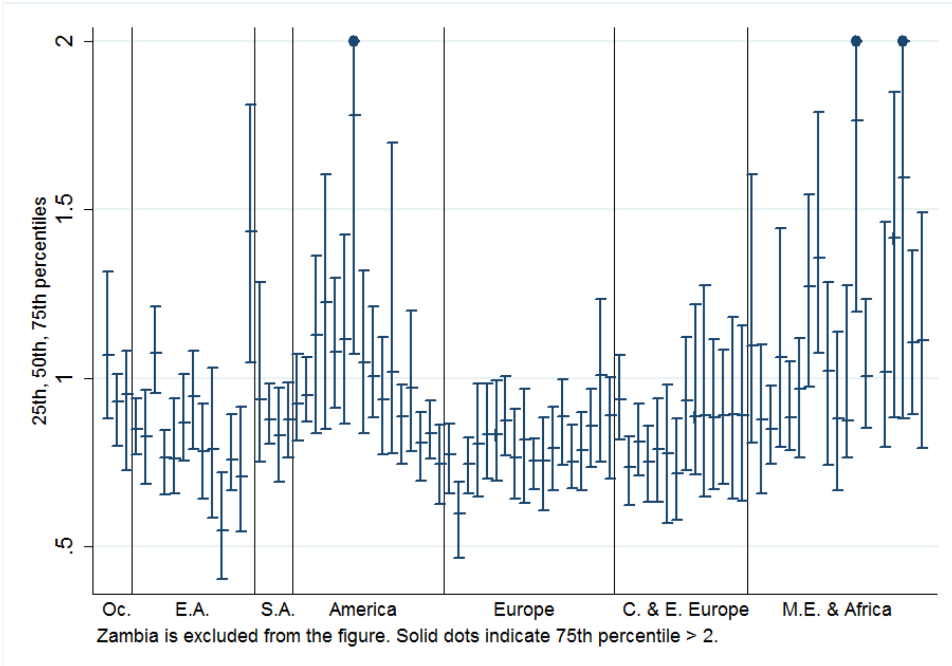

Figure 7: Bilateral Ratio of Value Added Exports to Gross Exports, by Country

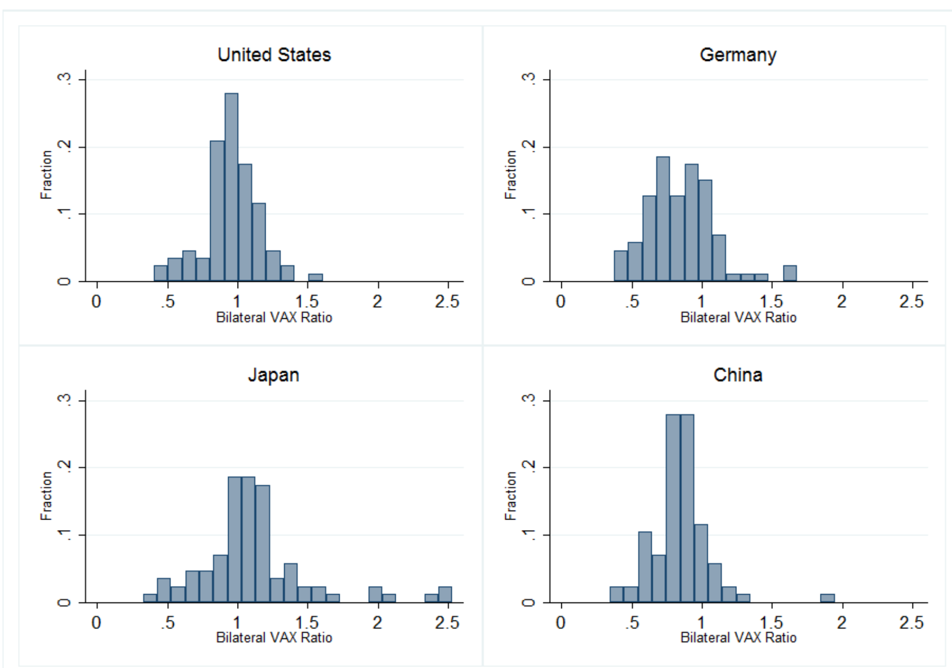

Figure 8: Bilateral Ratio of Value Added Exports to Gross Exports for Four Exporters

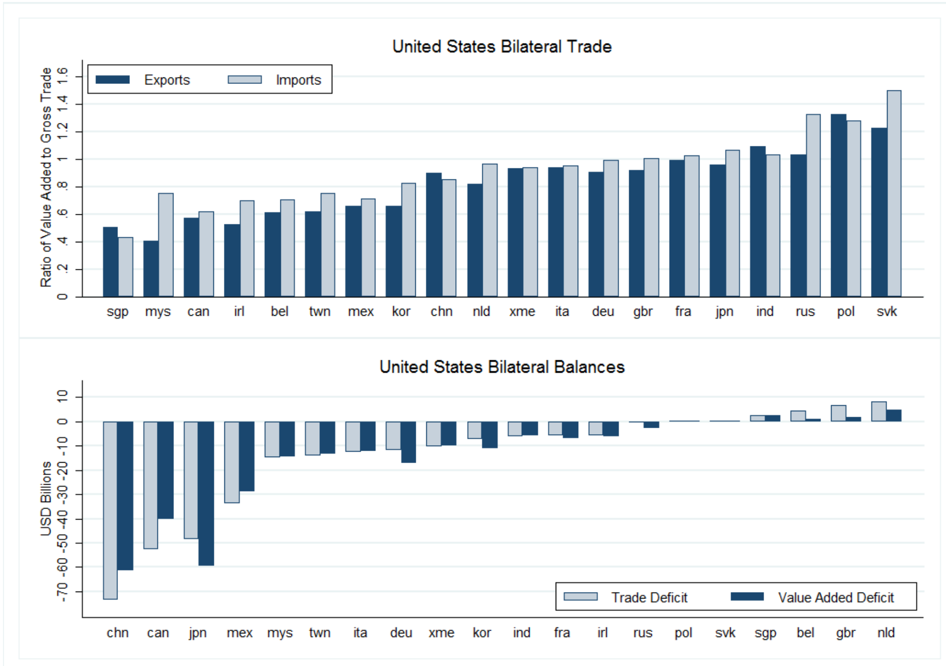

Figure 9: Ratio of Value Added to Gross Trade and Bilateral Balances for the United States, by Partner

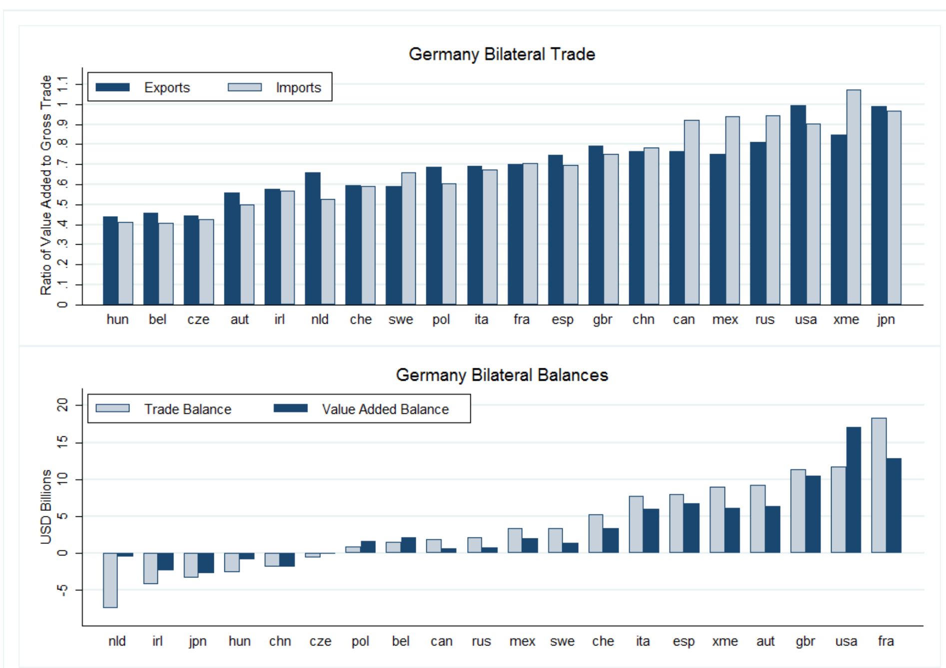

Figure 10: Ratio of Value Added to Gross Trade and Bilateral Balances for Germany, by Partner

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