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The Value of Value Added: Measuring Global Engagement with Gross and Value-added Trade

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Abstract:
As production has become more globally integrated, imported components account for a rising share of the value of exports. Many countries may contribute inputs to a good, and the final assembler may capture only a small share of the product's value. Official trade statistics, which attribute all value to the final exporter, can be uninformative or misleading about a country's global engagement and its participation in global supply chains. New measures are required that incorporate both production and trade and track the flow of inputs, and their value, through industries and across national borders. This paper examines the construction and use of value-added measures that incorporate the necessary production and trade data, and evaluates their performance against similar measures based on gross trade. Relative to gross trade, value-added measures are less detailed, are less up-to-date, and require additional assumptions in their construction. Despite these limitations, however, value-added measures provide a more revealing look into global integration that is consistent across different measures and analytical approaches.

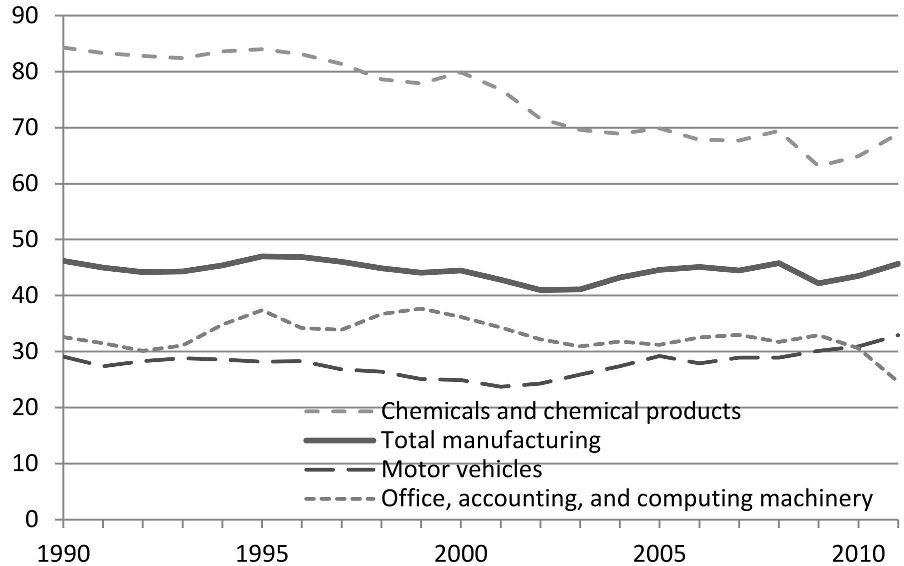
1. Introduction

Global production has become increasingly integrated over the last few decades, and the rise of global supply chains has led to the restructuring of many industries. The changes have been most apparent in the electronics industry, and the U.S. television industry is instructive in this regard. While U.S. companies were significant producers of televisions for decades, most production shifted to Mexico in the late 1990s.[1] In the last decade, production has become truly global. Display panels use glass produced in Japan and Korea, and are assembled in those countries and Taiwan. Chipsets are designed in the United States and elsewhere, and produced in China, Korea, Singapore, and Taiwan. Assembly of sets for the U.S. market, which accounts for less than 6 percent of the total value of the television, occurs in Mexico and China. As with the now iconic example of the Apple iPod, U.S. value accrues in inputs such as design and specialized chips, but largely from retail distribution of finished products.[2]

Despite mounting evidence in numerous case studies, employment trends, and production data, traditional trade statistics provide surprisingly little support. The television and iPod examples lead one to expect a falling share of imported intermediate inputs in U.S. electronics imports, a decline largely absent in the data (figure 1) until quite recently.[3] Intermediates in total U.S. manufacturing imports show even less change in the period. Only certain industries, such as chemicals, show a protracted decline in the share of imported intermediates. This puzzling lack of change in the data is not confined to the United States. Globally, there has been little evidence of a rise in the share of intermediate inputs in total trade since the 1980s.[4]

[1] See USITC (2011) for a fuller discussion of the industry.
[2] Kraemer et al. (2011) analyzes the sources of value in recent Apple products.
[3] The consolidation in supply chains following the 2008–2009 global trade collapse is apparent in the data.
[4] See Sturgeon and Memedovic (2011) and Meng et al. (2012).

Figure 1: Intermediate inputs in U.S. imports



Source: OECD, Bilateral trade database by industry and end-use category (BTDIxE).

Regional sourcing patterns are more instructive in trade data, though they often have the opposite problem of overstating changes in integration. As is well known, China has accounted for an increasing share of U.S. imports since the 1990s, and is now the United States' largest source of merchandise imports. Beltramello et al. (2012) show that, more broadly, developing countries doubled their share of global intermediate goods trade between 1967 to 2007. But trade data can overstate the gains made by developing countries. As the television and iPad examples illustrate, developing exporters may capture only a small share of the value in final goods they export. And, since inputs can cross borders multiple times, cumulative trade values will "double count" these inputs.

As the limitations of traditional trade statistics have become apparent, a number of researchers have refined the analysis of such data. For example, Sturgeon and Memedovic (2011) show that improved sector-specific measures of trade in intermediate inputs do exhibit the expected trend of a rising intermediate share of global trade in electronics (though not in autos or apparel). And Dean et al. (2009) use particularly detailed data from China Customs on foreign-invested enterprises and special export processing regimes. They show the large share of foreign imports (often from Japan) embodied in Chinese exports of final goods (often sent to the United States) giving a much better picture of the extent of vertical specialization in Chinese exports. But overall, the need for precise adjustments and unique datasets merely reinforces the fact that most publicly available trade statistics are ill-suited for analysis of global value chains.

If traditional trade statistics provide less than expected insight, or do so only under some duress, what approaches provide a clearer picture of global integration? The literature has highlighted several approaches, including firm-level surveys of outsourcing and offshoring, network analysis of global ownership links, and global value-added analysis based on linked input-output tables. This paper looks at the last of these approaches, which provides the ability to delineate the contributors and ultimate destination of the value embodied in traded products. Value-added analysis reveals increasing global interdependence that reflects the evidence in case studies and production data. For example, Johnson and Noguera (2012b) show that the domestic value that the United States adds to its own exports fell from 88% in 1990 to 77% in 2008 before bouncing back above 80% in 2010. Overall, U.S. production became more reliant on foreign inputs in the 20-year period. Other major global traders (Japan, Germany, China) show the same or greater declines in domestic value in exports in the period, and a similar reversal after 2008.

Global value-added data also provides other useful evidence of global integration. First, the breakdown of value added received, produced, and exported illustrates each country's position and role in global supply chains. Second, value-added data can quantify "double" counting in gross trade statistics that occurs when inputs cross multiple borders, and can remove this double counting when estimating sources and destination of value. Finally, value-added analysis can provide much greater insights into the effects of shocks and polices in an interrelated world. Policy analysis lies outside the scope of this paper, but a growing literature shows that national competitiveness and welfare can depend on policies and developments in other countries, such as at the effects of tariffs applied at national borders, non-tariff measures applied behind the border, and shocks to supply and demand abroad.[5]

Value-added analysis also has its limitations. In particular, data requirements are extensive and global databases are generally several years out of date. In addition, data limitations require the use of some simplifying assumptions that tend to understate the degree of international

[5] See, for example, Yi (2010), Bems et al. (2011) , and De Backer and Miroudot (2012).

engagement and its effects on the domestic economy. Thus in the next section of this paper we will look at the construction of a global value-added database and estimates to get a better sense of the reliability and limitations of these estimates. Section 3 provides a comparison of global engagement measured with official trade data and value-added data. Section 4 concludes.

It should be noted at the outset, however, that value-added data cannot replace trade data. Official trade data are still perfectly accurate to track gross values that cross borders; e.g., for purposes of imposing tariffs or calculating a country's balance of payments. After all, if a government has imposed a 5% tariff on wheat, for revenue purposes it is irrelevant that some of the value accrues to fertilizer company using petrochemicals imported from a third country. Similarly, if an iPad assembled in China arrives at the U.S. border with an import price of $275, Apple owes a Chinese producer the full $275, even if Chinese assembly operations added only $10 of this value.[6]

2. Construction and use of inter-country input output tables

The validity of a value-added trade measure depends on how that measure is constructed and the data on which it is measured. We cannot judge the validity of these measures without knowing at least the basics of how they are constructed. The measures discussed in this paper are all derived from inter-country input-output (ICIO) tables. An ICIO table shows the international sources of inputs in goods produced throughout the world. Distinguishing the national and global sources of these inputs can be highly revealing about a country's position and role in global supply chains.

[6] This $10 includes only direct labor inputs, and so understates total value added in China. The indirect contribution of value from second- or third-tier suppliers has not been estimated at the product level (Kraemer, Linden, and Dedrick, 2011)

Figure 2: A two-country ICIO table

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

An ICIO table is a combination of national IO tables and trade data that breaks down the use of goods according to the country of their origin.[7] For example, an ICIO could report the value of Japanese electronics components that are used directly by companies in China to produce final electronics goods. It would similarly break down final goods, denoting the value of final electronics goods consumed in the United States from China and every other source. Figure 2 shows an example with 2 countries and *N* industrial sectors. Rows in the table indicate how and where products are used. The uppermost row in the table, for example, indicates global use of product 1 produced in country 1, and indicates whether that product is used as an intermediate input by industry or is used as a final good by consumers in country 1 or 2. The sum of all uses must equal the total output of this product. Columns in the tables indicate supply of goods for production. The leftmost column in the table, for example, indicates the total inputs from country 1 and 2, plus the value added in country 1, that must be supplied to produce the total output of product 1 in country 1. Value added consists of the value generated by primary factors, and is equal to compensation of workers plus payments to capital.

Dividing the elements of each column of the intermediate use portion of the table by the respective value of total output produces A, the matrix of direct intermediate use, and F, the vector of direct factor payment shares:

[7] Although we refer to only goods in this discussion, in practice ICIOs contain information on the supply and use of services as well as goods.

$$A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \text{ and } F = \begin{bmatrix} F_1 & F_2 \end{bmatrix}$$

where A_{ij} is the NxN matrix of direct intermediate use coefficients that gives the share of total cost of goods in country i due to intermediates from country j, and F_i is the 1xN vector of direct factor inputs per unit of gross output in country i.[8]

In addition, we can define two more vectors based on the ICIO table diagrammed above:

$$X = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \text{ and } C = \begin{bmatrix} C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} C_{11} + C_{12} \\ C_{21} + C_{22} \end{bmatrix}$$

where X_i is the Nx1 vector of gross outputs by country i; C_{ij} is the Nx1 vector denoting the value of i's final goods consumed in country j; and C_i is the Nx1 vector denoting total world consumption of final goods produced in i. Note that these matrices contain values rather than shares.

There is a long history, dating back to Leontief in 1949, of using input-output tables to calculate the amount of inputs used to produce final goods. As noted, elements of A show the amount of inputs used directly in production. But the direct coefficients will not account for all value in a product, since intermediate inputs themselves are made of less finished components and raw materials. These indirect inputs can make up a substantial portion of the value of a good.
The calculations in an international setting are analogous, but inputs may be sourced from multiple countries and may cross multiple borders before being put into a finished product and consumed.

To calculate the inputs used both directly and indirectly in the production of final goods, we start by noting that all goods must be used either as an intermediate good or a final good, either at home or abroad. For a single country (here, country 1), this can be written as

[8] In some cases, F is a matrix with multiple rows to distinguish payments to different factors.

$$X_1 = A_{11}X_1 + A_{12}X_2 + C_{11} + C_{12}. \tag{1}$$

For the ICIO, this can be expressed analogously as

$$X = AX + C. \tag{2}$$

Rearranging,

$$X = (I - A)^{-1}C. \tag{3}$$

The $(I - A)^{-1}$ matrix is known as the Leontief inverse. With 2 countries, it is a 2Nx2N matrix, though this framework is generalizable to any number of countries. Elements of this matrix express the total output, used both directly and indirectly, that is required to produce $1 of final goods. For example, an element might show that, on average, it takes $0.25 of Japanese electronics inputs to produce $1 of final electronics goods in the United States. The Leontief inverse will capture the amount of Japanese inputs that are assembled into final goods throughout the world and consumed in the United States, even if none of the Japanese electronics are shipped directly to the United States.

To fully describe the source and destination of value added in global production networks, we need only add factor payments shares to this framework. Premultiplying by the F vector defined above generates the V matrix of value-added in global production:

$$V = \hat{F}(I - A)^{-1}\hat{C}. \tag{4}$$

To preserve the full dimensionality of the Leontief inverse, we have to diagonalize F and C (denoted by a hat). If full sectoral and national detail is not required, the vectors F or C can be used instead. The V matrix reports the value added by a particular industry in a particular country that is embodied in products in each sector and country throughout the world.

Distinguishing the sources of value can provide a much better look at global integration than is visible from traditional "gross" trade statistics alone. But the validity of any value-added estimate will depend on the data and assumptions used in the construction of the ICIO table.

2.1 Data requirements

ICIO tables are assembled from (1) national input-output tables, (2) bilateral sectoral trade data, and (3) additional information about the use of imported inputs by industry. In practice, not all of this information is readily available. Not every country has an input-output table, and those that do often report these tables with a long lag. Bilateral trade data is available for nearly all countries and sectors. The biggest challenge in constructing a global ICIO, however, is that few countries report how imported inputs are allotted to domestic industries. Thus most ICIO tables assume that the proportion of imported inputs by source in each industry is equal to the proportion in aggregate imports. In other words, if 20 percent of U.S. imported intermediate steel comes from China, the ICIO table assumes that 20% of imported steel inputs in each industry come from China. This assumption is known as the proportionality assumption. The proportionality assumption is generally unavoidable, but it is not innocuous. Winkler and Milberg (2009) and Puzzello (2012) show that assuming proportionality can understate the true use of foreign inputs in key sectors and downplay effects of offshoring on domestic employment.

Some improvements over standard proportionality are possible. Koopman, Powers, Wang, and Wei (2010), hereafter KPWW, and the world input-output database (WIOD), for example, use detailed trade information to distinguish imports of inputs and final goods. Although proportionality must still be maintained for imported intermediate inputs, this provides additional constraints that improve the accuracy of the estimates. Improvements are also possible for specific regions and countries. The Institute of Developing Economies (IDE-JETRO) has produced a regional Asian IO table that surveyed firms in key sectors in 10 countries about imported intermediate use. The Asian IO table is the most accurate ICIO to date, though it is not global in scope.[9] Corrections are also possible for specific countries to account for processing trade (imported inputs that do not enter the domestic economy but are used to produce goods for

[9] See WTO and IDE-JETRO (2011) for estimates employing the Asian IO tables.

exports). This raises estimates of foreign content in exports for these countries, consistent with the literature cited above.[10]

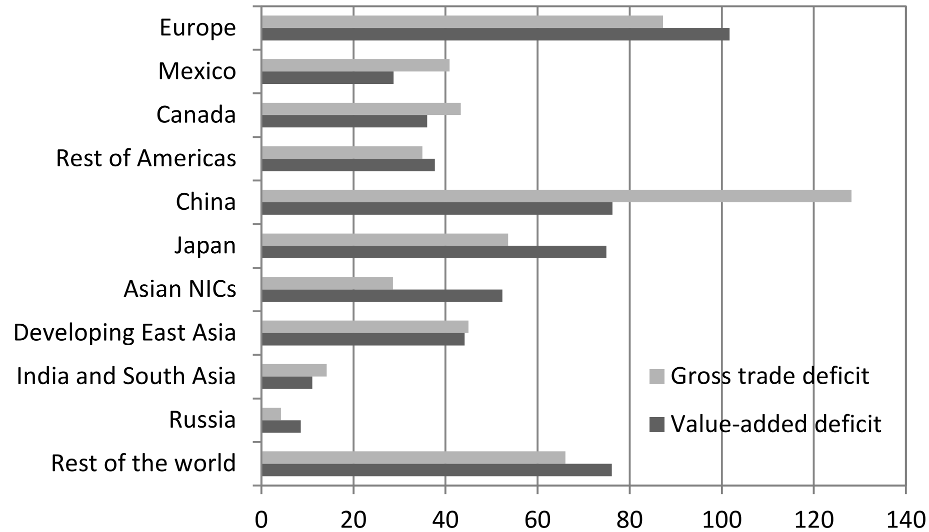
3. Comparison of gross and value-added trade measures

3.1 Estimates based on the location where goods are consumed

Examining U.S. trade on a value-added basis yields a different picture about how much countries contribute to the U.S. deficit. The value-added trade balance is the difference between exports of value added (domestic value added consumed abroad) and imports of value added (foreign value added consumed at home). The countries with the biggest gap between the gross and value-added deficits are those tightly integrated to the major regional supply chains in East Asia and North America. China has by far the largest difference, with the value-added deficit about 40% lower than the gross trade deficit. Since China sources components from countries throughout Asia, the gross value of Chinese exports to the United States is much larger than Chinese value added consumed in the United States.[11] Major sources of inputs to China are Japan and the so-called newly industrialized countries of Hong Kong, Korea, Singapore, and Taiwan, which all have larger gross deficits than value-added deficits. The U.S. deficits with North American countries show similar patterns to China. Like China, Mexican exports contain relatively high shares of foreign value added (often U.S. value). Canada is also highly integrated in North American supply chains, and its exports also contain substantial U.S. value. It is worth noting that the value-added calculation does not change in any way the overall U.S. balance of payments. Added across all countries, the U.S. value-added deficit is exactly the same as the official gross trade deficit. (See Stehrer, 2012, for proof).[12]

[10] See KPWW and Johnson and Noguera (2012a) for details.
[11] Chinese imports narrow the difference a bit—because many Chinese imports do not enter its domestic economy, China's consumption of U.S. value added is lower than the gross value of Chinese imports from the United States.
[12] For additional analysis of global value chains based on the location of consumption, see Timmer et al. (2012).

Figure 3: U.S. trade deficits on a gross and value-added basis, 2004



Sources: USITC (2011) and KPWW database.

3.2 Estimates based on the decomposition of gross trade

All value-added trade measures examined so far have been based on value in final consumption abroad. The major interest of many international organizations, academics, and policy makers, however, lies in trade flows rather than consumption. For example, international organizations are interested in decomposing gross export flows into value added components to better examine trade's contribution to growth and development. Trade policy makers are naturally more focused on goods when they arrive at the border than when they are consumed. And academics remain interested in foreign content in exports as evidenced by the large literature employing the measures of vertical specialization developed by Hummels et al. (2001).

To examine the potential mismatch between consumption- and trade-based measures, China again provides a good example. Because of its extensive use of processing exports, close to one-half of Chinese imports in recent years have entered as processing trade, which requires that these imports not be consumed domestically to qualify for preferential tariff treatment. In this case, estimates based on Chinese final consumption will considerably understate foreign content arriving at the Chinese border.[13] And, while China may be an outlier, all countries have some mismatch between imports and consumption.

One approach to looking at foreign content at the border is to focus on only final goods trade. This approach is directly applicable to equation (4) and conceptually straightforward—simply replace the consumption matrix with final goods trade. Yet it shines little light on much of world trade, because it precludes analysis of intermediate inputs.

Hence there is a need to decompose value in export flows including both intermediate inputs and final goods. KPWW provides this breakdown, bridging official trade statistics and value-added measures. Although the algebra of this decomposition is beyond the scope of the present paper, KPWW show that exports can be decomposed into three broad value-added components:[14]

1. Domestic value added consumed abroad
2. Domestic value added in inputs that are exported, processed abroad, and then return home for consumption
3. Foreign value added

For each country, these three components sum to exactly 100% of gross trade.

Table 1 presents this decomposition for major regions and selected exporting countries in those regions for 2004, based on KPWW. Several regional patterns stand out starkly in the data. Asian NICs and emerging Asian countries are the regions with the lowest domestic value-added in the world. Only a few countries outside of Asia (such as Mexico) have similarly low domestic value-added shares, and emerging economies elsewhere in the world tend to have higher than average shares. Domestic value-added in exports that returns home is not a major component for most countries—only large advanced countries have substantial domestic value added in this component. The U.S. has substantially more returned value than any other country. In large part this reflects the tight integration of the North American production network.

[13] See Dean et al. (2011) and Koopman et al. (2012a) for details.
[14] These components blur the distinction between domestic value added and domestic content. See KPWW and Koopman et al. (2012b) for details.

Table 1: Decomposition of gross export flows into value-added terms, 2004

Region and selected countries	Domestic value added absorbed abroad	Domestic value added that returns home	Foreign value added
Advanced economies	**78.9**	**6.9**	**14.2**
Western EU	81.2	7.4	11.4
Japan	84.8	2.9	12.2
United States	74.6	12.4	12.9
Asian NICs[a]	**64.1**	**0.8**	**35.1**
Emerging Asia	**65.3**	**0.7**	**34.1**
China	63.6	0.8	35.7
Malaysia	58.6	0.9	40.5
India	79.6	0.4	20.1
Other emerging	**78.2**	**1.4**	**20.4**
Brazil	87.0	0.3	12.7
Mexico	51.7	0.4	48.0
New EU countries	68.2	1.0	30.8
Russia	89.1	0.7	10.2
World average	**74.4**	**4.0**	**21.6**

Source: KPWW.
[a] Excluding Singapore.

One complication arises when the Leontief inverse is applied to trade with intermediate inputs. Recall that Leontief inverse coefficients give the amount of output required for a one-unit increase in final demand in a particular country. Foreign value added in intermediate exports cannot be exactly determined, however, because the final destination, and hence the correct Leontief inverse coefficient, cannot be known at the border for all intermediate inputs. Thus decomposing intermediate exports with a Leontief inverse will invariably introduce some terms that cannot be traced to a particular country's final demand. Koopman et al. (2012b) shows that these terms are generally small, amounting to about 6 percent of total global export values, and that they do not overturn any conclusions presented in earlier work. However, the share of such terms are higher for some countries, particularly those in East Asia, and as of yet there are no estimates of such terms in bilateral and sectoral exports.

A common measure of international engagement is the ratio of exports to GDP. As global fragmentation has increased, however, this measure has become an increasingly unreliable measure. In particular, it will overstate the importance of trade for countries that have relatively low domestic value-added in exports. A more accurate measure is the ratio of domestic value added in exports to GDP. Table 2 shows that many countries appear highly dependent on trade, even when using the more informative domestic value added measure. (The correlation between the two measures is 0.92.) Yet the measure is reduced for countries such as China, much of Asia, Mexico, and to a lesser extent emerging EU economies. Note China's measure of engagement based on value added was actually below that of Canada and Indonesia in 2004 (though this would not be the case in more recent years).

The decomposition approach can also be used to decompose trade for a specific country. Figure 4 presents U.S. imports from major trading partners and geographic regions in gross and value-added terms. This decomposition provides results consistent with the analysis of U.S. deficits presented in figure 3, although the analytical approaches differ. The comparison shows that Europe's contribution rises slightly in value-added terms, but remains near one-quarter of total imports by either measure.[15] The contribution by countries in the Americas also remains roughly the same by either measure, at about 31 percent, but value added provides a much different impression of the sources of this contribution. In particular, the share of U.S. value, which is zero by definition in gross imports, rises to 8 percent in value-added terms, while both Canada and Mexico have sharp declines. As noted above, Canadian and Mexican exports, particularly those destined for the U.S. market, contain substantial U.S. content. The Asian contribution is slightly lower in value added terms (31.8%) than in gross terms (34.4%), but the major change is again reallocation of value within the region. China's value-added contribution is 30% lower than the gross value of its exports to the United States, while Japan's contribution is 20% higher. Surprisingly, the United States contributed more value added (8.3%) to its own imports than China (7.7%) in 2004.

[15] Because this is a complete decomposition of gross imports value, the total imports in each case are $1.6 billion dollars.

Table 2: Comparison of export-to-GDP ratios, 2004

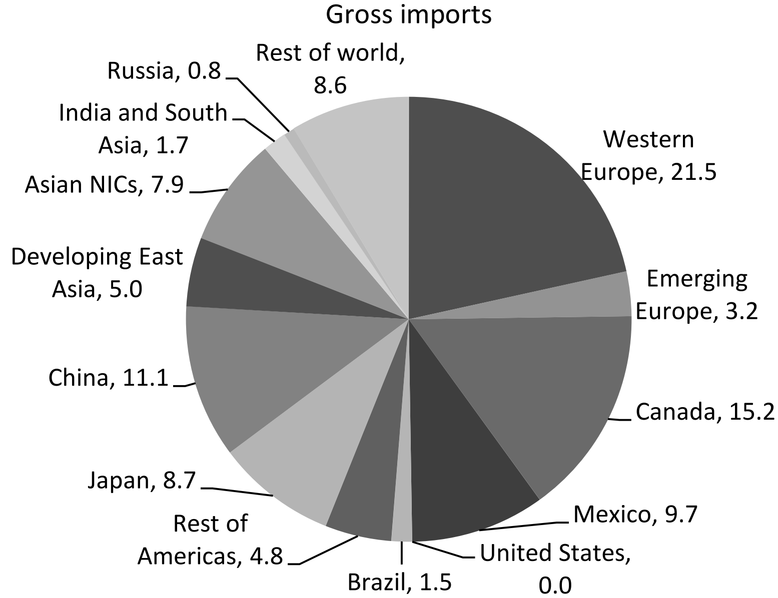
Country or region	Exports / GDP	Domestic value added in exports[a] / GDP
Advanced economies	**12.8**	**11.0**
Australia	16.2	14.4
Canada	33.1	23.7
EFTA	41.4	31.0
Western EU	12.8	11.3
Japan	13.5	11.8
United States	9.1	7.9
Asian NICs[b]	**53.5**	**34.7**
Hong Kong	73.4	53.3
Korea	41.6	27.5
Taiwan	68.2	40.3
Emerging Asia	**36.3**	**23.9**
China	34.7	22.4
Indonesia	33.8	26.0
Malaysia	128.3	76.3
Philippines	57.8	33.6
Thailand	74.0	44.6
Vietnam	71.3	44.9
Rest of East Asia	105.7	82.9
India	14.4	11.5
Rest of South Asia	19.1	15.0
Other Emerging	**30.7**	**24.4**
Brazil	17.0	14.9
New EU countries	38.7	26.8
Mexico	27.9	14.5
Rest of Americas	28.2	24.1
Russia	27.1	24.3
South Africa	28.4	23.2
Rest of the world	35.6	30.4
World average	**19.6**	**15.4**

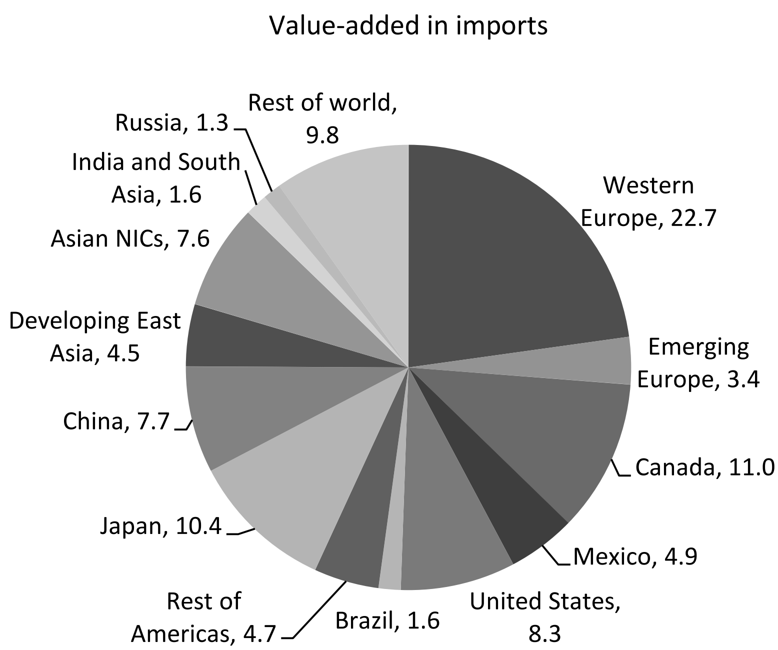
Source: KPWW database.

[a] Including both domestic value consumed abroad and reflected back to the home economy.

[b] Excluding Singapore.

Figure 4: Contribution to U.S. imports, 2004





Source: USITC (2011) and KPWW database.

4. Conclusion

Official trade data provide an accurate measure of the value of goods and services that arrive at a nations border. Official data can provide great detail on the type of good being imported and the location from which the good was exported. But with the rise of truly global production, many countries may have contributed value, and the final exporter may have captured a relatively low share. Hence new types of trade data are needed to accurately track the sources and destination of value in global supply chains.

This paper has examined the construction and use of value-added trade data. While this approach is more revealing, it also has its limitations, and value added measures may never be as precisely measured as official gross trade statistics. First, the construction of a globally consistent trade and production database underpinning value-added calculations means that these measures will be produced with longer lags and greater approximations than official statistics. Second, the reliance on input-output tables produces estimates for a few dozen aggregated industries rather than the 5,000-plus products available in gross trade statistics. Finally, value-added methodology continues to improve, and best practices are still being developed to decompose intermediate exports on a bilateral or sectoral basis.

Yet these limitations are largely outweighed by the insights provided by the new data. This paper has shown that value added analysis can delineate the contribution and role of each country in global value chains. This analysis provides a different and important perspective that is consistent across different trade flows (imports, exports, and trade deficits). Results are also consistent when using alternative analytical approaches, based on either value added in consumption abroad or in gross exports. The large number of academics and international organizations (including the OECD, WTO, WIOD, and others) examining value-added flows indicates a broad consensus on the importance of this analysis. Most studies to date have focused on delineating countries' roles in global production networks. The next challenges will be to understand the effects these networks have on national competitiveness and growth, and the ways they alter the effects of policies at home and abroad.

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