

## **Five Facts about Value-Added Exports and Implications for Macroeconomics and Trade Research**

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**I**nternational trade data record the gross value of goods as they cross borders. This poses a challenge for researchers who want to connect canonical international trade and macroeconomic models, which are typically cast in value-added terms, with the data. The most common approach has been to treat gross trade data *as if* it is comparable to data on value added. In the past, this assumption was tolerable. Vertical specialization in trade—that is, the use of imports to produce exports—was limited in most countries (Hummels, Ishii, and Yi 2001). In other words, gross exports contained very nearly 100 percent domestic value added.

In recent decades, the emergence of global supply chains has changed matters. As inputs pass through these chains, they cross borders many times. This means that gross trade data include substantial double-counting, so gross exports overstate the amount of domestic value-added in exports. When supply chains span multiple countries, it also means that bilateral gross exports do not tell us where the value added embodied in those exports is ultimately consumed. As a result, gross trade is an increasingly misleading guide to how value added is exchanged between countries.

This realization has prompted concerns that gross trade data distort perceptions about the nature of international integration and the role of particular countries in international markets, which in turn leads to tensions in the world trade system. Lamy (2011), for example, emphasizes that a clearer view of how countries are linked together via global supply chains breaks down mercantilist (“us” versus “them”) views of trade. Prompted by these real world concerns, along with the

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desire to measure trade in a manner consistent with the value-added thinking that underlies popular models, there has been a recent push toward developing new value-added measures of trade.

To measure trade in value added, we need to follow goods through the global supply chain from input producers to final consumers, allocating the value added in final goods to producers at each stage. Of course, this is easier said than done. While national input-output accounts describe domestic supply chains, they stop at the border. To overcome this problem, recent work has combined national input-output tables with bilateral trade data to construct input-output tables with global scope. These global input-output tables describe input shipments across both sectors and countries, and hence enable us to trace the value added embodied in final goods back to its source. With this new data, we can measure the hidden trade in value added underlying gross trade.

In this paper, I highlight one measure of trade in value added—"value-added exports." Value-added exports measure the amount of domestic value added embodied in final expenditure in each destination (Johnson and Noguera 2012a). Just as gross exports break down gross output sold across destinations, value-added exports break down GDP sold across destinations. This value-added export concept is the appropriate measure of exports in international models that are written in value-added terms.

After describing how value-added exports are computed, I summarize five key facts about differences between gross and value-added exports. First, these differences are large and growing over time, currently around 25 percent. Second, manufacturing trade looks more important (relative to services) in gross than value-added terms. Third, these differences are heterogeneous across countries, with value-added exports ranging from 50 percent (Taiwan) to 90 percent (Russia) of gross exports. Fourth, the differences between gross and value-added exports are heterogeneous across bilateral partners, with even more variation across partners than across individual countries. Fifth, these differences are changing unevenly over time across countries and partners, with fast-growing emerging markets and pairs of countries that adopt bilateral trade agreements seeing larger declines in value-added relative to gross exports.

Taking these five facts into account points researchers toward better quantitative answers to important macroeconomic and trade questions. To illustrate this point, I discuss how value-added exports can be applied in analysis of some widely discussed questions. In macroeconomics, value-added exports help quantify the strength of demand spillovers, the consequences of relative price movements for competitiveness, and the size of relative price changes needed to close trade imbalances. In trade, value-added exports can be applied in analysis of the impact of frictions on trade, the role of endowments and comparative advantage in trade, and trade policy.

## **Background: Computing Value-Added Exports**

A basic fact of national income accounting is that expenditure on final goods equals the amount of value added generated during the production process.

Therefore, final expenditure directly tells us how much value added is consumed in each country. But the national accounts do not tell us where that value added comes from.

For specific goods (like iPods or notebook PCs), we can try to decompose the value added embodied in them across countries by breaking them apart and examining their constituent parts (Linden, Kraemer, and Dedrick 2009; Debrick, Kraemer, and Linden 2010). This deconstructive approach is conceptually straightforward, but complicated in practice. One reason is that the production process has many layers. It is not enough to break the iPod into component parts (for example, the screen, disk drive, plastic shell); one needs to also break down those components into subcomponents (metal, plastic, and so on). Pushing further, even the subcomponents need to be further broken down until one knows where the value added in the metal, plastic, and other basic inputs originates.

The goal of this process is to be able to make statements like “one third of the \$299 value of an iPod sold in the United States is Japanese value added.”<sup>1</sup> Though this value added is produced in Japan, it is consumed in the United States. As a matter of definition, we then say that Japan exports roughly \$100 of value added to the United States as part of the iPod production process.

Implementing this approach on a good-by-good basis and then aggregating up to produce aggregate value-added export data is nigh impossible. Nonetheless, the basic logic of this good-by-good calculation can be adapted to track value added in the aggregate. To see this, it is useful to think of the process in two steps.

The first step is to measure how much output from each source country is needed to produce the final goods that are consumed in a given destination. For example, how much Japanese gross output (disk drives, metal, and everything else) is needed to produce final goods (iPods) consumed in the United States? In this step, we need to know not only how many Japanese disk drives are used, but also how much Japanese metal and plastic are used in production of those disk drives.

The second step is to measure how much local value added is generated in production of that gross output. That is, how much Japanese value added is generated in assembling the disk drives, plus how much Japanese value added is embodied in the metal used?

To implement this two-step approach economy-wide, we need to describe the sector-level production process in a manner analogous to how we described the production process for individual goods. That is, we need to measure the value of final goods purchased from each source country and measure input use and value-added contributions along the production chain. To do this, we turn to a

<sup>1</sup> This estimate is based on Linden, Kraemer, and Dedrick (2009). It is the value of iPod components from Japanese-headquartered companies (for example, the hard drive from Toshiba) divided by the sales price of the iPod. However, this estimate does not actually measure true value added by Japanese suppliers. First, it does not identify where Toshiba produces the hard drive, which determines the country in which value added is recorded. Second, it only captures the last layer of the production process. For example, it does not identify whether Toshiba uses imported inputs to produce the hard drive. To my knowledge, no product case study has yet been able to address these problems.

global input-output framework. On the input side, global input-output tables record the sectors and countries from which inputs are sourced to produce output in a given country and sector. On the output side, they record the destinations to which final goods from each sector are shipped. Combining these, we can take final goods shipments and trace backwards using input requirements to allocate the value added in those final goods to their source.

For example, suppose we see final goods being shipped from US manufacturers to Canadian final consumers. Then, if we know the sector and country origin of inputs used in US manufacturing (for example, inputs from Japan used in US manufacturing), this is analogous to knowing the iPod's components. Building on this, if we also know where those input suppliers get their own inputs (for example, inputs from China used by Japan), this is analogous to knowing the breakdown of components into subcomponents. Further, the input-output accounts record how much value added is generated in producing output in each country and sector, which enables us to convert gross production at each stage to value added. In this way, applying input-output accounting principles, we approximate the iPod accounting exercise for the economy as a whole.<sup>2</sup>

The main challenge in implementing this approach lies in assembling the data needed to form the global input-output framework. In an ideal world, national statistical authorities would coordinate to produce these input-output accounts. As a second best, various researchers and organizations have assembled synthetic input-output tables from existing national accounts and trade data. The basic procedure uses bilateral trade data to split sector-level multilateral final and intermediate goods imports, which are reported in official input-output tables, across source countries. The result is a global input-output table, which describes bilateral final and intermediate input use. Table 1 lists several public use datasets that contain national input-output tables, global or regional input-output tables, or value-added trade data.

Not surprisingly, different research teams have used varying data sources and assumptions in constructing these global input-output tables. I will not dwell here on the many different choices that have been made by various researchers. Rather, I want to highlight that there is tremendous agreement across alternative data sets about how value-added exports compare to gross exports. The core facts that I discuss below are robust across alternative datasets.

<sup>2</sup>To sketch the underlying math, suppose we observe a global input-output matrix, denoted  $A$ , which is a square matrix of input use requirements with dimensions equal to the number of countries times the number of sectors. The columns of this matrix describe input requirements for producing gross output in each country and sector, with elements equal to the value of inputs purchased from a particular source country and sector as a share of gross sector-level output in the destination. The "Leontief inverse" of the global input-output matrix, given by  $(I - A)^{-1}$ , tells us how much output from each source country and sector is needed to produce any vector of final goods, where final goods are identified by sector and country source. To convert these gross output requirements into value added, multiply by value added to output ratios in the source country and sector, which can be obtained by taking one minus the column sums of  $A$ . See Johnson and Noguera (2012a) for details.

Table 1

**Public Datasets for Research on Value-Added Exports**

<i>Name of dataset</i>	<i>Key features</i>	<i>Selected research using this data</i>
Global Trade Analysis Project Database	Input-output tables for over 100 countries for various benchmark years, mostly after 2000. <a href="https://www.gtap.agecon.purdue.edu">https://www.gtap.agecon.purdue.edu</a>	Trefler and Zhu (2010), Daudin, Riffart, and Schweisguth (2011), Johnson and Noguera (2012a), and Koopman, Wang, and Wei (2014)
World Input-Output Database	Global tables covering OECD countries and major emerging markets from 1995–2011. <a href="http://www.wiod.org">http://www.wiod.org</a>	Baldwin and Lopez-Gonzales (2013), Costinot and Rodríguez-Clare (2013), Timmer, Los, Stehrer, and de Vries (2013)
IDE-JETRO Asian Input-Output Tables	Regional tables covering 8 East Asian countries at five-year intervals between 1985 and 2000. <a href="http://www.ide.go.jp">http://www.ide.go.jp</a>	Various chapters in Hiratsuka and Uchida (2010), IDE-JETRO and WTO (2011), Puzzello (2012)
WTO-OECD TiVA Database (Trade in Value Added)	Value-added exports and other measures of global supply chain activity for 57 countries in 1995, 2000, 2005, 2008 and 2009. <a href="http://stats.oecd.org">http://stats.oecd.org</a>	De Backer and Miroudot (2013)
OECD Input-Output Tables	Input-output tables for OECD countries and major emerging markets, available various years from 1970–2005. <a href="http://www.oecd.org/trade/input-outputtables.htm">http://www.oecd.org/trade/input-outputtables.htm</a>	Hummels, Ishii, and Yi (2001), Johnson and Noguera (2012b, 2014)

**Five Facts about Value-Added Exports**

This section reviews five high-level facts about how value-added exports compare to gross exports for the world as a whole, across sectors, across countries, and across bilateral trade partners.

*Fact 1: World value-added exports are equal to about 70–75 percent of gross exports today, down from about 85 percent in the 1970s and 1980s.*

Recent estimates suggest that value-added exports are equal to 70–75 percent of the value of gross exports. Using the World Input-Output Database, the ratio of value-added to gross exports was about 0.71 in 2008. Johnson and Noguera (2014) put it at about 0.76 in the same year. Johnson and Noguera (2012a) report that the median ratio of value-added to gross exports across 94 countries was 0.73 in 2004. Despite differences in underlying data and methods, these estimates lie within a comfortably narrow range.

The ratio of value-added to gross trade has declined over time, down from around 85 percent in the early 1970s (Johnson and Noguera 2014). This decline implies that there is more double counting in gross trade data now than in the past. This increased double counting is symptomatic of the growing importance of global supply chains in mediating trade, as goods cross borders more than once when supply chains span multiple countries.<sup>3</sup>

One important feature of the data is that the decline in value-added relative to gross exports occurs almost entirely after 1990 (Johnson and Noguera 2014). This decline coincides with rapid changes in the world economy: trade liberalization in emerging markets, the expansion of the European Union, the adoption of major regional trade agreements, and the information technology revolution. Writ large, these events lowered international trade costs, induced substitution of foreign for domestic input suppliers, and drove down the value-added content of trade.

*Fact 2: Manufacturing trade is relatively smaller, and services trade relatively larger, when measured in value-added terms.*

For the world as a whole, manufacturing accounts for nearly 70 percent, and services account for 20 percent, of total gross exports. In contrast, manufacturing and services both account for about 40 percent of total value-added exports. This reallocation of trade shares is illustrated in Figure 1.

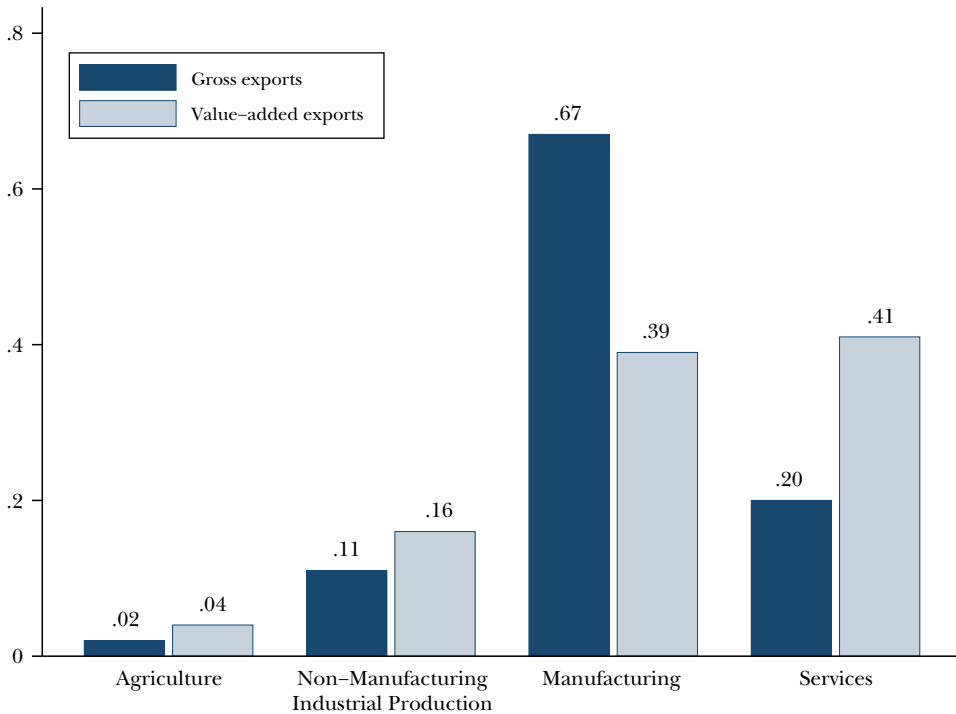
Put differently, the ratio of value-added to gross exports is lower for manufacturing than services trade. There are two reasons for this. First, gross manufacturing exports include value added from the services sector, because manufacturing firms buy services as inputs. The value-added export data strip this services value added out of manufacturing exports and reassign it to the services sector. Second, manufacturing features a higher degree of vertical specialization than services (that is, a higher import content of exports), which pushes down the ratio of value-added to gross exports in manufacturing relative to other sectors.

*Fact 3: Across countries, value-added exports range from 50 to 90 percent of the value of gross exports.*

There is wide variation across countries in the ratio of value-added to gross exports. Table 2 reports the ratio of value-added to gross exports in 2008 for the top 20 exporting countries, computed using the World Input-Output Database. Among these countries, the range is roughly 0.5 to 0.9. Using a broader 89 country sample from the Global Trade Analysis Project database, in Johnson and Noguera (2012a), we document a 10th–90th percentile spread of about 0.6 to 0.85 in 2004.

<sup>3</sup>Fally (2012) shows that the inverse of the world value-added to gross export ratio can be interpreted as a weighted average count of the number of border crossings associated with producing \$1 of final goods, where the weights reflect the value added by each country.

Figure 1

**Sector Shares in Total World Value-Added and Gross Exports**

Sources: World Input-Output Database (WIOD) and author's calculations.

Notes: Data are for 2008. Agriculture includes Forestry, Hunting, and Fishing. Non-Manufacturing Industrial Production includes Mining and Quarrying, Electricity/Gas/Water Supply, and Construction. Manufacturing is the remainder of Industrial Production.

Among other determinants, the ratio of value-added to gross exports is strongly negatively correlated with the share of manufacturing in total exports (Johnson and Noguera 2012a). This observation relates back to Fact 2. The ratio of value-added to gross exports is lowest in manufacturing, so the composition of trade matters.

*Fact 4: Gaps between bilateral value-added and gross exports are large and heterogeneous across trade partners.*

Table 3 reports the ratio of value-added to gross exports for the top four exporting countries for alternative destination countries and composite regions. Though regional aggregation obscures many interesting bilateral details, it serves to highlight some key aspects of the data.

First, there is as much variation across bilateral partners as there is across source countries. For Germany, the ratio of value-added to gross exports ranges

Table 2

**The Ratio of Value-Added to Gross Exports for the Top 20 Exporting Countries**

	<i>WIOD</i> 2008	<i>WIOD</i> Change 1995–2008	<i>Johnson–Noguera</i> Change 1970–2008
Germany	0.69	−0.10	−0.16
United States	0.78	−0.05	−0.14
China	0.75	−0.09	−0.20
Japan	0.80	−0.12	−0.09
United Kingdom	0.78	−0.01	−0.04
France	0.71	−0.08	−0.13
Italy	0.73	−0.07	−0.12
Netherlands	0.62	−0.06	−0.11
Canada	0.76	0.02	−0.11
South Korea	0.58	−0.18	−0.18
Russia	0.92	0.00	
Belgium	0.53	−0.07	−0.15
Spain	0.69	−0.09	−0.17
Taiwan	0.51	−0.16	
Mexico	0.70	−0.03	−0.21
India	0.78	−0.12	−0.20
Sweden	0.66	−0.08	−0.13
Australia	0.84	−0.04	−0.06
Brazil	0.86	−0.05	−0.10
Austria	0.65	−0.10	−0.17
Minimum	0.51	−0.18	−0.21
Median	0.72	−0.08	−0.14
Maximum	0.92	0.02	−0.04

*Sources:* World Input-Output Database (WIOD) and author's calculations, Johnson and Noguera (2014).

*Notes:* The column "WIOD 2008" is the ratio of value-added exports to gross exports for each country in 2008 from the World Input-Output Database. The column "WIOD change 1995–2008" is the change in this ratio from 1995 to 2008. The column "Johnson–Noguera change 1970–2008" is the change in the ratio of value-added exports to gross exports for each country from 1970 to 2008, from Johnson and Noguera (2014). Blank entries in that column reflect missing data. Exporting countries are ordered top to bottom by total gross exports in 2008.

from 0.6 to 1 across destinations. Second, value-added exports to some destinations exceed gross exports. For example, Japanese value-added exports to the United States are 7 percent larger than their gross exports. This reflects the fact that Japan exports intermediate goods to third countries (such as China) that then re-exports those intermediates to the United States embodied in final goods. Third, the ratio of value-added to gross exports tends to be lower within regions or regional trade agreement blocs than across them. For example, US value-added exports are 64 percent as large as gross exports to Mexico and Canada, while US value-added exports are about 90 percent as large as gross exports to the European Union or Japan. Similar patterns hold for Japan and Germany among their Asian and European Union partners, respectively.



Table 3

**Ratio of Bilateral Value-Added to Gross Exports for Top 4 Exporting Countries**

Source country	Partner country or region						
	United States	Canada and Mexico	European Union	China	Japan	Other Asia	Other
China	0.84	0.71	0.79		0.73	0.52	0.73
Germany	0.99	0.80	0.60	0.77	1.00	0.70	0.74
Japan	1.07	0.86	1.06	0.69		0.53	0.76
United States		0.64	0.87	0.83	0.91	0.69	0.79

Sources: World Input-Output Database (WIOD) and author's calculations.

Notes: Data are for 2008. "Other Asia" includes Indonesia, South Korea, and Taiwan. "Other" includes all other destinations not listed in table.

*Fact 5: Changes in value-added relative to gross exports have been heterogeneous across countries and bilateral trade partners.*

Table 2 also reports changes in the ratio of value-added to gross exports for each of the top 20 exporters for two time periods. Column 2 records the change in this ratio over the 1995–2008 period, while column 3 records changes over the longer 1970–2008 period. To summarize, some countries have seen declines on the order of 20 percentage points, while others have seen no change—or even increases. In general, declines have been larger in fast-growing emerging markets than other countries, largely due to the rapid increase in the share of manufactures in their gross exports over time (Johnson and Noguera 2014).

Drilling down to the bilateral level, changes in the ratio of value-added to gross exports are also very different across bilateral trade partners. One stylized fact is that the ratio has declined more for nearby countries and countries within the same region (Johnson and Noguera 2012b, 2014). A second fact is that the ratio has declined more for countries that have adopted regional trade agreements with one another (Johnson and Noguera 2014).

## International Macroeconomics

Using value-added export data in place of gross exports sheds new light on some old questions in international macroeconomics. Here, I consider three of those questions. First, how large are the spillover effects of changes in foreign final expenditure on domestic economic activity? Second, how do international relative price changes—for example, due to exchange rate movements—influence competitiveness? Third, how large must price changes be in order to close trade imbalances?

### Tracking Foreign Expenditure Changes Back Home

How much does US GDP fall when foreign final expenditure falls? Would the US economy be hit harder by a fall in expenditure in Italy or Canada? To answer these questions, analysts traditionally look at US gross exports, and assume that those exports are produced entirely within the United States. They use the share of multilateral or bilateral exports in GDP to summarize the exposure of the US economy to foreign expenditure changes.

A value-added perspective on trade highlights several flaws in this approach. First, a dollar of US exports does not generate a dollar of US value added. As a result, the ratio of exports to GDP will overstate how much GDP falls when exports decline. Second, bilateral gross exports do not capture how much value added the United States sells in particular destinations. For example, a significant share of US exports to Canada are used to produce Canadian goods consumed in the United States, so gross exports overstate US exposure to Canadian demand shocks. Alternatively, gross exports may understate exposure in other cases. For example, the US exports inputs to Germany that are used to produce German goods consumed in Italy. Thus, the US economy is more exposed to changes in Italian demand than gross exports would indicate.

Looking directly at value-added exports side-steps these problems. Value-added exports directly link foreign final expenditure to demand for domestic value added, removing gross exports as the “middle man” in the calculation. Though this intuition is straightforward, explaining how it emerges directly from standard macro-models takes some additional effort. There are two alternative theoretical approaches.

The first approach is to write down the model entirely in value-added terms, ignoring trade in intermediate inputs entirely. Though this approach may initially sound strange, it is in fact completely standard—for example, the canonical international real business cycle fits this description (Backus, Kehoe, and Kydland 1994). On the supply side, producers combine primary factors (labor and capital) to produce value added. On the demand side, consumers directly purchase and consume value added originating from different source countries. Given this structure, value-added exports are the appropriate data to use in measuring trade and calibrating preference parameters.<sup>4</sup> And the share of bilateral value-added exports in total value added is the appropriate weight to use in estimating how much demand for domestic value added falls in response to changes in foreign final expenditure.

The second approach is to embrace input trade, and write down the model in gross terms (Ambler, Cardia, and Zimmerman 2002; Johnson forthcoming). In this case, producers would combine primary factors with intermediate inputs to produce gross output, which may be dedicated to either final or intermediate use. And preferences would be defined over consumption of final goods. In Bems

<sup>4</sup> This observation is closely related to a recent point raised by Herrendorf, Rogerson, and Valentinyi (2013). In a closed economy, they argue that expenditure on value added from each sector, rather than expenditure on final goods from each sector, should be used to calibrate preferences in multisector models that feature value-added production functions for sectoral output.

and Johnson (2012), we show that value-added export shares are the appropriate weights to attach to foreign final expenditure changes in this type of model as well.<sup>5</sup>

Using value-added exports in place of gross exports has three implications. First, all countries appear less exposed to foreign expenditure changes, many substantially so. Remember, the ratio of value-added to gross exports is less than one, and these adjustments are getting larger over time due to declines in value-added to export ratios. Second, at the sector-level, the manufacturing sector looks substantially less exposed, and nonmanufacturing sectors look substantially more exposed to foreign shocks, because manufacturing exports are smaller and services exports larger in value-added terms. Third, the importance of shocks originating in particular export destinations differs—with some countries becoming more important, while others are becoming less important, than one would guess based on gross bilateral exports. This follows from differences in bilateral value-added to export ratios across partners.

To illustrate the magnitude of these adjustments, I graph the ratios of gross and value-added exports to GDP for the top four exporters in Figure 2. Aggregating across sectors, the ratio of value-added exports to GDP is generically smaller than the ratio of gross exports to GDP. At the sector level, the ratio of value-added exports from the manufacturing sector to manufacturing GDP is dramatically smaller than the ratio of gross exports from the manufacturing sector to manufacturing GDP, about half as large for these countries. Further, differences in openness across sectors are reduced when measured using the ratio of value-added exports to GDP, rather than the ratio of gross exports to GDP. Manufacturing openness drops a lot, and nonmanufacturing openness rises (doubling in three of the four countries). This convergence in measured openness will be important below in thinking through the mechanics of trade balance adjustment.<sup>6</sup>

Turning to bilateral data, there are also differences between bilateral value-added versus gross exports to GDP ratios, particularly for manufacturing. For the United States, the ratio of bilateral gross manufacturing exports to manufacturing GDP is about 0.17 for Canada and only .07 for value-added exports. For exports to the European Union, the comparable figures are 0.11 for gross exports and 0.06 for value-added exports. Therefore, while Canada looks like a more important export destination in gross terms, the European Union is equally important when we focus on how much US value added is actually being consumed in each country. The reason, of course, is that so much of US gross exports to Canada are embodied in Canadian exports back to the US economy. These value-added adjustments should be taken into account in evaluating the strength of bilateral demand linkages.

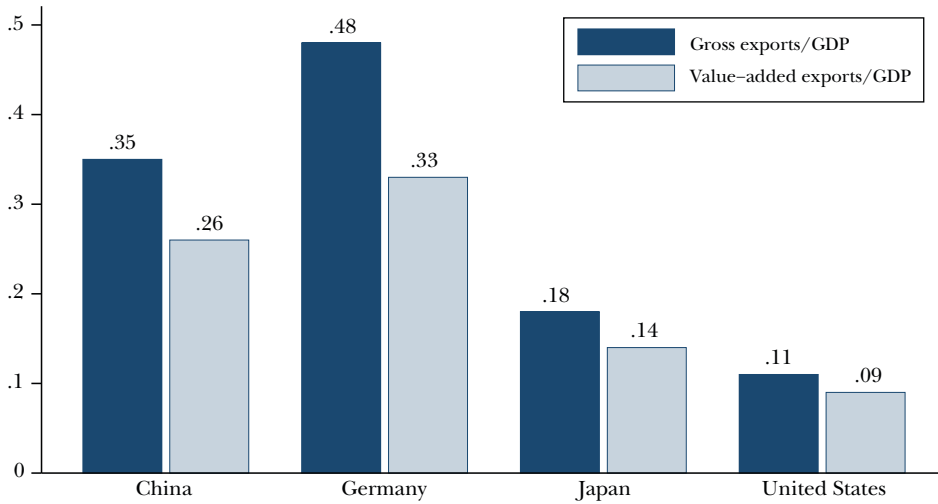
<sup>5</sup> In Bems, Johnson, and Yi (2010, 2011), we use a Leontief assumption to derive the same result from a global input-output accounting framework. This is a special case of the more general model in Bems and Johnson (2012).

<sup>6</sup> In the absence of value-added trade data, one might be tempted to use the ratio of gross exports to gross output in calibrating openness. This is not only wrong in theory, it is also troublesome in practice because it makes the economy and individual sectors look too closed. For example, the aggregate ratio of gross exports to gross output in China is 0.11, less than half the ratio of value-added exports to GDP.

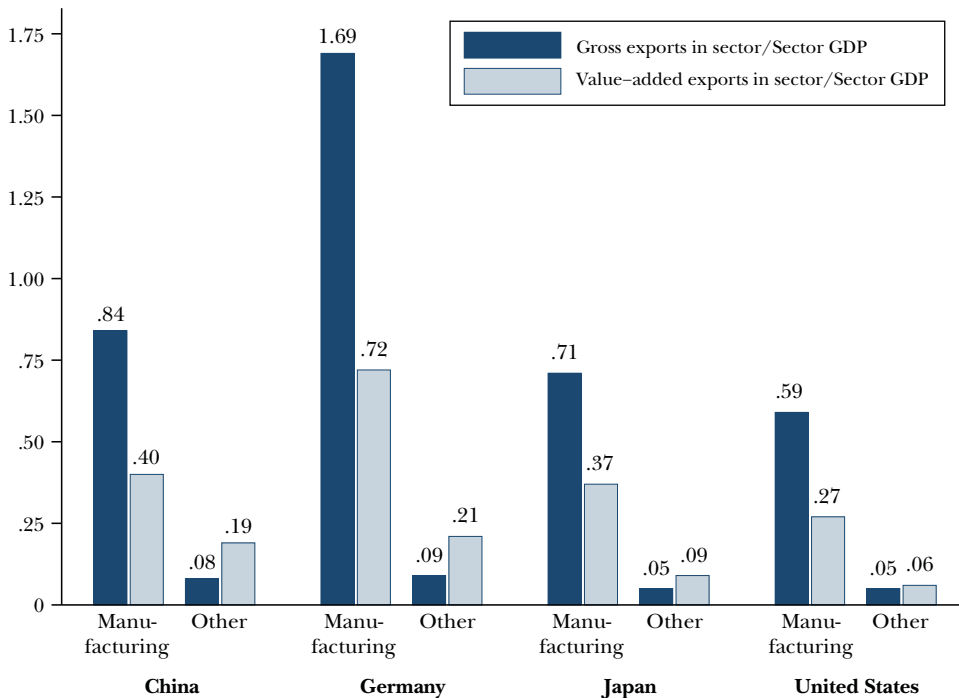
Figure 2

**Aggregate and Sector-Level Openness for Top Four Exporting Countries**

A: Aggregate Exports/GDP



B: Sector Exports/Sector GDP



Sources: World Input-Output Database (WIOD) and author's calculations.

Notes: Data are for 2008. The category labeled "Other" includes all nonmanufacturing industries.

### **Relative Price Changes and Competitiveness**

How do changes in relative prices influence demand for value added from particular source countries? For example, how much would a renminbi appreciation lower demand for Chinese value added? What about if the renminbi appreciates against the yen, but holds its value against the dollar? How should we aggregate those heterogeneous bilateral relative price changes to evaluate Chinese competitiveness?

The answers to these questions can be somewhat different depending on whether one takes a value-added or conventional view of trade. For example, suppose the renminbi appreciates (against all countries) and factor prices in all countries are fixed in producer currencies. How much this appreciation raises the relative price of Chinese exports depends on how much Chinese value added is embodied in them. Since China imports intermediate inputs to produce exports, China's export price depends on both the price of Chinese and foreign value added. As a result, a lower value-added to export ratio means that the appreciation will have a lower pass-through rate into export prices. The less these prices rise, the less demand for Chinese exports, and hence Chinese value added, falls.

Matters become more complicated when three countries are linked via production chains. For example, consider a scenario in which Japan exports computer parts to China, who then assembles them into a laptop and exports the laptop to the United States. If the Japanese yen depreciates against the US dollar (while the Chinese renminbi is fixed against the US dollar), then this brings down the price of Chinese-assembled laptops in the United States. This implies increased demand for laptops, which generates additional demand for value added from the Chinese computer assembly industry. Thus, even though there is no bilateral movement in the renminbi-dollar exchange rate, vertical input trade linkages imply that exchange rates vis-a-vis third-country input suppliers influence export competitiveness and hence demand for one's own value added.

As these examples illustrate, sorting out the effects of exchange rate movements (or other shocks to relative prices) on demand for exports and value added can be complicated. Fortunately, data on value-added exports can help cut through the fog. Since countries ultimately produce and trade value added, a natural approach would be to use price changes for value added originating from different countries, combined with trade weights based on value-added exports, to construct "real effective exchange rates" for value added (Bems and Johnson 2012).<sup>7</sup> These composite exchange rate indexes capture the effect of changes in relative value-added prices on demand for value added from each country.

In practice, this value-added approach to evaluating exchange rate movements leads to quantitatively different conclusions than conventional approaches. For example, in Bems and Johnson (2012), we find that, from 2000 to 2009, China's

<sup>7</sup>Though value-added real exchange rates can be motivated directly by appealing to value-added models, in Bems and Johnson (2012), we derive value-added weights from a constant elasticity of substitution model written in gross terms under the assumption that elasticities of substitution are equal in preferences and production functions.

value-added real effective exchange rate appreciated by 20 percentage points more than the conventional index used by the IMF. We also find that appreciations in value-added exchange rates for the European periphery prior to the euro-crisis were larger than implied by conventional indexes. The value-added perspective thus indicates that China's exchange rate has become less misaligned (consistent with rebalancing) and intra-EU rates were more misaligned (consistent with the build-up of imbalances within the European Union) than conventional indexes would indicate. The most important reason for these differences is that conventional indexes are constructed using consumer price indexes, which are poor guides in practice to how the relative price of value added across countries, and hence demand for value added, changes over time.

### **Adjustment of Trade Imbalances**

The geopolitics of external adjustment are often acrimonious. Not surprisingly therefore, the fact that bilateral trade balances are not equal in gross and value-added terms has attracted substantial attention in policy circles (Xing and Detert 2010; Lamy 2011; Johnson and Noguera 2012a). The value-added view of trade also has important implications for adjustment of multilateral trade balances—an insight that is less commonly appreciated, but perhaps of greater practical importance.

At the outset, it is crucial to emphasize that a country's multilateral trade balance is identical when measured in gross and value-added terms. The national accounts GDP identity states that total value added produced minus total final expenditure (including domestic and imported final goods) is equal to the gross trade balance. Because all final expenditure is ultimately value added purchased from some source, then this is the same as saying that value added produced minus value-added consumed (including domestic and imported value added) equals the gross trade balance. Since value added produced minus value added consumed is equal to value-added exports less value-added imports—that is, the value-added trade balance—the value-added trade balance equals the gross trade balance by construction.

This mechanical equality does not imply that the value-added view has nothing to contribute in analyzing external adjustment. To focus the discussion, consider a standard question asked by Obstfeld and Rogoff (2005, 2007): how much does the consumption real exchange rate—that is, relative consumer price levels—need to change to close the trade imbalance? The answer to this question depends on whether one uses value-added or gross trade data in calibrating the underlying macroeconomic model. Bems (2013) points out three distinct channels that can lead to different results.

First, the economy looks more closed when one uses value-added exports to GDP, rather than the ratio of gross exports to GDP, as the measure of how much output is exported. With a more closed economy (equivalently, stonger home bias in consumption), the “transfer problem” associated with closing imbalances is worse. Specifically, the decline in home expenditure relative to foreign expenditure needed to close home's deficit leads to a larger decline in home's terms of trade (the price of home relative to foreign tradables), thus increasing the size of the required real exchange rate change.

Second, manufacturing and nonmanufacturing sectors look more similar in terms of openness in value-added terms. This tends to reduce the size of the intra-national, cross-sector relative price adjustment associated with closing the external imbalance, and hence reduce the required real exchange rate adjustment. Essentially, reducing the asymmetry in openness across sectors means that demand for output declines more uniformly across sectors (and hence cross-sector relative price changes are smaller) following the decline in home expenditure associated with closing the imbalance.

The third channel concerns elasticities, not openness. Typically, macro-researchers plug elasticities (like the elasticity of substitution between home and foreign goods) that are estimated using gross data into value-added models. Bems (2013) argues this approach overstates the appropriate elasticities for cross-sector or cross-country substitution of value added. Converting the estimated gross elasticities of substitution into levels appropriate for value-added models, he shows that the resulting value-added elasticities are lower than the gross elasticities typically used in the literature. Using these lower value-added elasticities increases the size of the real exchange rate adjustment needed to close imbalances.

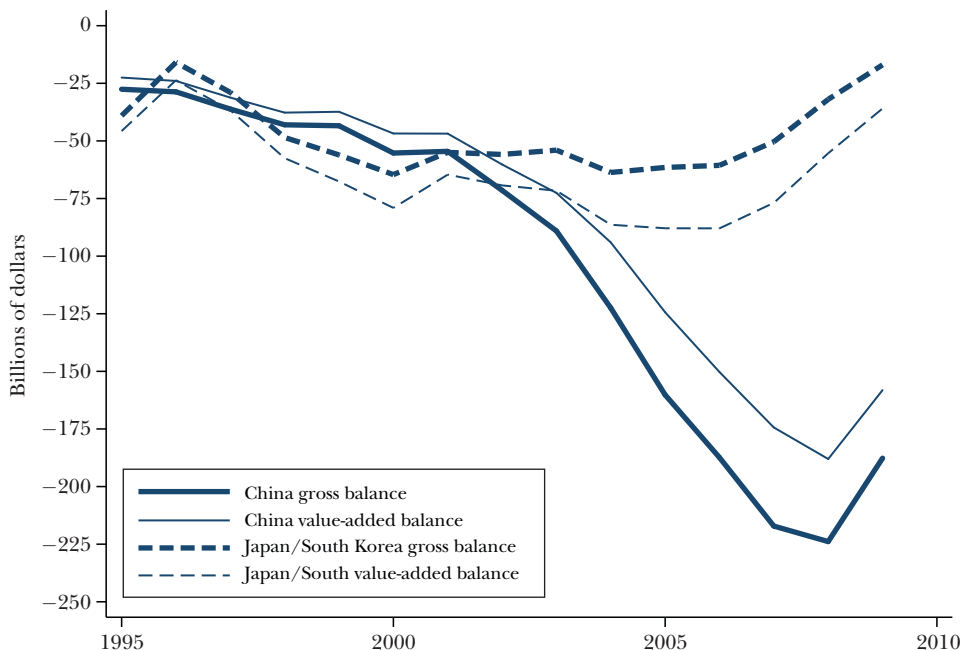
How these channels net out depends on the particular country under examination. Bems (2013) works out the net effects for a range of countries. Not surprisingly, accounting correctly for intermediate inputs in calibration matters most for countries like China, Mexico, or South Korea that are deeply integrated into global supply chains. For a decline in the trade surplus equal to 1 percent of GDP, the real exchange rate appreciates by 15–25 percent more in a model parameterized to be consistent with the value-added data, relative to the conventional approach that mixes value-added and gross data. Specific numbers aside, this analysis points to the usefulness of looking at value-added export data in studying the mechanics of external adjustment.

Shifting our attention to the bilateral level, bilateral trade balances are generally not equal in gross and value-added terms. This is true not only if bilateral gross trade is unbalanced, but holds even if bilateral gross trade is balanced.<sup>8</sup> For illustration, Figure 3 plots United States bilateral gross and value-added trade balances with China and the composite of Japan and South Korea using World Input-Output Database data. The US trade deficit with China looks smaller in value-added terms than it does in gross terms, while the deficit with Japan and South Korea looks correspondingly larger. The maximal difference in percentage terms between the gross and value-added US–China imbalance is about 23 percent in 2004 (\$124.5 billion versus \$94 billion). In terms of absolute values, the gap peaks at \$42 billion in 2007.

Almost surely, this figure understates the true reallocation of trade imbalances. The reason is that the World Input-Output Database (like most other available

<sup>8</sup> With balanced bilateral trade, differences in bilateral value-added to export ratios for exports from country  $i$  to country  $j$  versus from  $j$  to  $i$  can generate imbalanced bilateral value-added trade. With imbalanced bilateral trade, the average level of value added to export ratios for a given country pair will scale up/down the value-added imbalance relative to the gross imbalance (Johnson and Noguera 2012a).

Figure 3

**United States Trade Deficits with China, Japan, and South Korea**

Sources: World Input-Output Database (WIOD) and author's calculations. Deficits for Japan and South Korea are combined in the figure.

input-output data) does not account for the high share of pure “processing trade” in Chinese exports. Specifically, just over half of Chinese exports are produced under its processing trade regime, where firms are allowed to import inputs duty-free if the resulting output is exported. Given these incentives, the imported input intensity of these firms is substantially higher than the average Chinese firm. Standard input-output tables report input requirements for the average firm only, however. Therefore, they understate the import content of exports for China, and thus overstate domestic value-added in Chinese exports.<sup>9</sup>

Adjusting value-added calculations to account for this bias, Koopman, Wang, and Wei (2012) find that the Chinese domestic content in exports from the processing trade sector was only about 25 percent in 2002, as compared to about 90 percent for normal nonprocessing exports. Correctly accounting for these discrepancies

<sup>9</sup> Although I focus on pure processing trade here, the core idea is more general. Micro-data indicate that export and import participation are highly correlated at the firm-level. Therefore, the imported input intensity of exporting firms is likely higher than that of the average firm in most countries. As in the case of processing trade, ignoring this fact (as standard input-output tables do) leads one to overestimate the domestic value-added content of exports.



lowers the ratio of Chinese domestic content exports from about 0.75 to 0.55 in 2002. Drawing on this work, in Johnson and Noguera (2012a), we implement an adjustment for processing trade in China within the global input-output framework and find that it leads the China–US trade balance to shrink by an additional 10 percentage points. Therefore, we find that the difference between the gross and value-added US–China imbalance was actually likely closer to 30–40 percent in 2004, roughly doubling the unadjusted calculation.

These adjustments to bilateral balances suggest that the burden of adjustment associated with closing the US trade balance would be redistributed away from China and toward Japan and Korea, in line with the reallocation of value-added trade balances. To date, however, there has been no work assessing how important these adjustments are quantitatively. This is a topic for future work.

## **International Trade**

Value-added exports also provide a new perspective on traditional topics in international trade. I highlight applications related to the impact of frictions on trade, specialization patterns, the factor content of trade, and trade policy.

### **Trade Frictions**

What is the impact of frictions—tariffs, nontariff barriers, transport costs, and others—on patterns of consumption versus production across countries? This question is typically addressed by examining the effect of frictions on gross production and trade. As a result, we know a lot about where gross output is produced and the destinations to which it is shipped. We know very little, however, about how trade frictions influence trade in value added, and hence differences between where value added is produced versus where it is consumed.

To launch this discussion, it is helpful to refer back to the five facts laid out earlier in this paper. We noted the significant differences between bilateral gross and value-added exports, and that these bilateral differences are systematically related to common proxies for trade costs. For example, the ratio of bilateral value-added to gross exports tends to be lower for country pairs located in the same region, and pairs that are separated by shorter distances. It is also lower for pairs of countries that have adopted regional trade agreements, and even lower for pairs that have adopted “deep” agreements, such as customs unions, common markets, and economic unions.

These underlying patterns all suggest that trade frictions have different effects on value-added trade versus gross trade. One way to think about this is that standard trade frictions impede gross trade, and hence induce the patterns of final and intermediate goods trade that we observe in the data. This trade in final and intermediate goods gives rise to the global input-output structure. As we use that input-output structure to compute value-added trade flows, we are implicitly aggregating the effect of frictions on gross trade to measure the composite impact of

those frictions on value-added trade. The input-output structure is a device to map gross trade frictions into implied value-added trade frictions, which measure the reduced form impact of the full set of gross frictions in determining value-added consumption patterns.

One insight from thinking through this aggregation process is that both bilateral trade costs and trade costs between third countries directly influence bilateral value-added exports, whereas only bilateral trade costs directly influence bilateral gross trade (Noguera 2012). For this reason, value-added trade frictions are a manifestation not only of bilateral frictions, but rather the entire matrix of trade frictions among all countries.

Two points follow. First, one important reason that value-added exports are less sensitive to bilateral distance between countries than gross exports is that value added can be traded via third countries. For example, the United States can export intermediate inputs to Europe that are embodied in final European goods shipped to Russia. In a sense, Russia is then effectively “closer” to the United States than it looks on a map. Second, changes in trade costs between third countries can have a direct impact on bilateral value-added exports to other countries. For example, a tariff cut between Japan and China would have a direct effect on value-added exports from Japan to the United States. This point has interesting implications for policy discussions, which typically focus on bilateral rather than third-country barriers. I return to this point below.

Turning from cross-sectional to time series facts, we have seen large declines in the ratio of value-added to gross exports over the past few decades, with particularly large declines in fast-growing emerging markets. An important question is: do changes in gross trade frictions explain this divergence? The answer, by and large, is yes.

Using a multisector gravity model with trade in both final and intermediate goods, in Johnson and Noguera (2014), we decompose changes in the global input-output structure into components attributable to changes in trade frictions, changes in endowments and productivity, and changes in generic sector-to-sector input linkages or sector-level final expenditure shares. We find that changes in trade frictions explain nearly the entire decline in the ratio of value-added to gross exports for the world as a whole. We also explain differences across countries, where countries with large declines in trade frictions have seen particularly large declines in value-added relative to gross exports.

These results are consistent with the idea that value-added trade frictions have declined more slowly than gross trade frictions, leading to disproportionate growth in gross relative to value-added trade. Together with the discussion of bilateral differences, they point to new ways to think about the impact of frictions on trade.

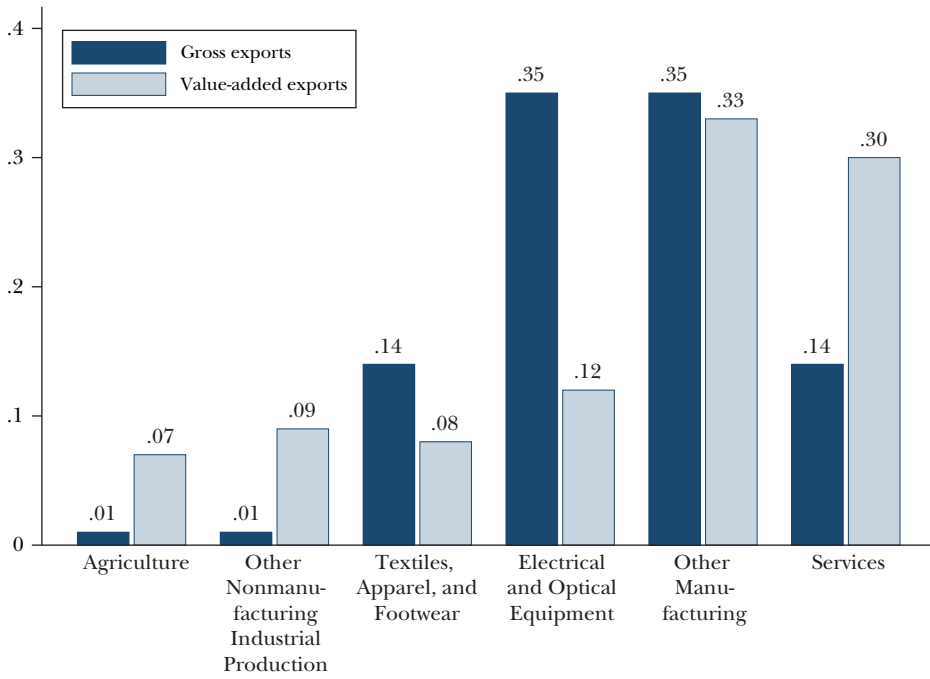
### **Specialization Patterns**

As we have seen, the sector-composition of gross exports can be quite different than the sector-composition of value-added exports. Looking at value-added composition forces us to revisit what we know about patterns of specialization.

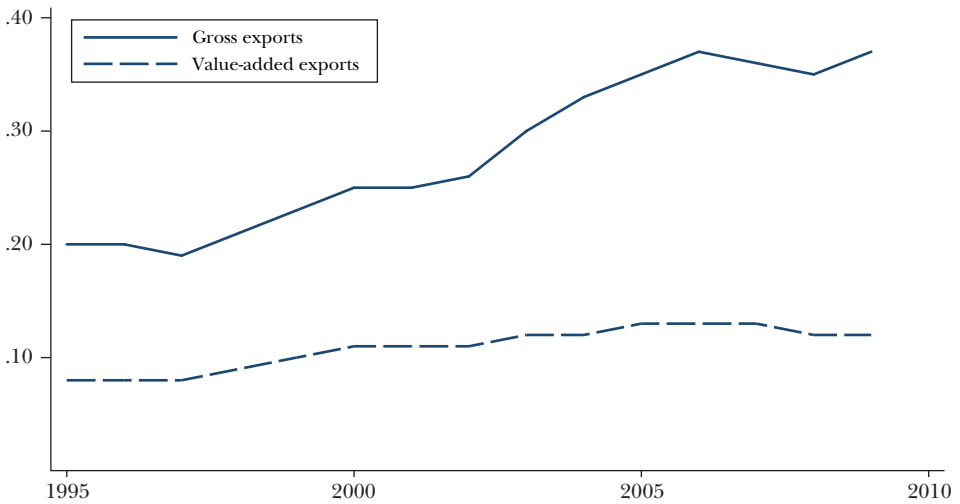
This point is driven home by considering the example of China. The top panel of Figure 4 records the share of individual sectors in Chinese gross and value-added

Figure 4  
Sector-Level Export Shares for China

A: Export Shares, All Sectors



B: Electrical and Optical Equipment Export Shares



Sources: World Input-Output Database (WIOD) and author's calculations. Export shares for all sectors are for 2008.

Note: "Agriculture" means agriculture, hunting, forestry, and fishing.

exports. As in most countries, nonmanufacturing sectors are substantially more important in value-added than gross terms. The more striking fact is that the share of Electrical and Optical Equipment shrinks dramatically, from about one-third of China's exports to just over one-tenth. This difference is of course consistent with the fact that these goods tend to be produced from imported intermediates that are assembled in China. Further, the bottom panel of Figure 4 plots the share of Electrical and Optical Equipment in value-added and gross exports over time. The share of this sector in gross exports has almost doubled since 1995, while the value-added share has barely changed. As such, gross and value-added trade provide very different pictures about what China genuinely produces and sells to the rest of the world.

This example illustrates a general point: what countries export may be very different from what they actually contribute to the production process. Countries that look like dominant exporters in particular sectors may in fact contribute very little value added to those exports. This basic point should be borne in mind in analyses of comparative advantage (Koopman, Wang, and Wei 2014). It should also factor into efforts to evaluate export sophistication across countries (Schott 2008, Wang and Wei 2010), or whether it matters for economic growth what countries export (Hausman, Hwang, and Rodrick 2007).

### **The Factor Content of Trade**

Thus far, we have focused on the value-added content of international trade. Beneath this trade in value added lies trade in primary factors or production tasks. If one knows the quantities of factors needed to produce a unit of GDP in each sector, then one can use these to convert value-added export flows into factor flows. The difference between the quantity of domestic factors needed to produce value-added exports and the quantity of foreign factors needed to produce value-added imports is equal to the net factor content of trade, which measures factors embodied in GDP minus factors embodied in consumption. Moreover, the preceding logic is identical if one uses task contents in place of factor contents.

Value-added export data are useful for performing factor/task content calculations for two reasons. First, using them sidesteps an important conceptual problem with conventional approaches to factor content calculations. Specifically, these approaches made strong, increasingly untenable assumptions—either that gross exports are produced entirely from domestic gross output, or that imported inputs are produced with identical input requirements as domestic output. Relaxing these assumptions requires tracking trade in intermediates across countries and sectors, just as global input-output frameworks are designed to do. Therefore, Reimer (2006) and Trefler and Zhu (2010) proposed methods to compute the multilateral net factor content of trade (that is, the net quantity of factors each country exports to the rest of the world) using global input-output tables. While their approach cannot be used to recover bilateral factor trade, bilateral value-added export data can be used for this purpose. This is another advantage to using value-added data. Measuring bilateral trade in factors enables one to test bilateral predictions of

the factor-contents theory that emerge when factor price equalization breaks down (Debaere 2003; Choi and Krishna 2004).

What are the implications of using value-added exports to compute factor contents? The conventional approach overstates factor trade because it assumes that gross exports of a country are produced using that country's technology alone. Instead, with traded inputs, gross exports of each country are produced using a convex combination of domestic and foreign technologies. By making effective production techniques more similar at home and abroad, traded inputs attenuate measured factor trade (Reimer 2006; Johnson 2011). Thus, appropriately accounting for intermediates lowers the measured factor content of trade relative to measurements that allow for differences in production techniques but do not incorporate traded intermediates. More work is needed to quantify the effect these adjustments have on tests of factor-contents theory.

### **Trade Policy Analysis**

The rise of global supply chains has altered the costs and benefits of protection in a variety of ways (Baldwin 2012; Blanchard 2013). Yet empirical research on two-way interactions between trade policy and global supply chains is sparse. I expect that improvements in global input-output data and new measures of trade in value added will facilitate future work in this area. Therefore, I want to highlight a few specific ways in which the value-added analysis, and global input-output data more generally, can inform trade policy analysis.

First, the fact that gross exports and imports contain both foreign and domestic value-added is a core element of the value-added view of trade. The presence of domestic value added in imports gives rise to domestic constituencies that ought to favor liberalization. For example, exporters of intermediate goods that are then embodied in imported final goods should favor lower tariffs on those final goods imports. On the flip side, the presence of foreign value-added in exports ought to give rise to lobbying by exporters to liberalize imports of intermediates. As global supply chains become more important, these pressures should grow. With the new availability of data on input-output linkages across borders, the time seems ripe to investigate the role of these forces in determining trade policy.

Second, an important benefit of value-added export data is that it tracks value added to the final consumer even as it moves through third countries. This role for third parties has implications for trade policy. For example, a regional trade agreement between countries A and B is likely to increase trade in value added between countries C and A when C is an input supplier to country B. This trade-creating effect of the regional trade agreement, and third-country liberalizations more generally, ought to figure into policy analysis.

Third, global input-output tables and value-added trade data can potentially help quantify the extent to which global supply chains magnify the impact of trade barriers, an effect which is reminiscent of an older literature on the "effective rate of protection" (Yi 2003, 2010). In models of multistage production, trade costs are paid multiple times as goods pass across borders through a global supply chain, and trade

costs imposed on the value of gross output impose a heavy burden when evaluated relative to the actual value added being traded. Building on this intuition, Koopman, Wang, and Wei (2014) call for value-added data to be used in quantifying these effects.

While the potential role of supply chains in magnifying trade barriers deserves attention, several caveats ought to be borne in mind. First, commonly used multisector models with “roundabout production” can match both gross and value-added trade simultaneously, yet they imply zero magnification of trade barriers. Second, in Johnson and Moxnes (2013), we caution that even models with sequential multistage production, which allow for magnification effects, do not deliver significant magnification when calibrated to match observed levels of final and intermediate goods trade. Given the potential importance of amplification effects in understanding the costs of protection, this area demands more research.

## **Concluding Remarks**

The rise of global supply chains has led to far-reaching changes in the nature of international trade. In this article, I have focused on one particular implication: gross trade is not equal to trade in value added. While this fact has been known for some time, gaps between gross and value-added trade have only recently been quantified. These gaps are markers for differences in global supply chain activity across countries and over time. They are also important to keep in mind in quantitative work. Researchers should beware of mixing gross trade data with value-added production data, or using gross trade data in applications where the underlying theory is based on value added concepts. For both these reasons, I expect value-added export data to figure prominently in international macroeconomic and trade research and policy analysis going forward.

Because research using global input-output frameworks is still relatively new, much remains to be done not only in analyzing trade in value added, but also with regard to improving the data underlying its measurement. Enhanced international cooperation to measure global supply chain activity more accurately would be ideal. Even in its absence, however, much could be done to improve measurement on a country-by-country basis. For example, value-added export measurement would be improved by additional work on quantifying differences in imported input use across exporting versus nonexporting firms and incorporating these into input-output tables. Enhanced data collection for countries with large “processing trade” sectors—like China, Mexico, and other emerging markets—would be a good start. Another issue that deserves attention is how we track imported input use behind the border. That is, we need better data on where inputs from particular source countries go (that is, which firms/sectors use them) after they enter the country. Addressing these issues would increase the accuracy of value-added measurements.

Finally, though I have focused on using global input-output frameworks to compute value-added exports, the underlying data is also valuable in other applications. Most obviously, the data can be used to parameterize trade models written in

gross terms with both cross-sector and cross-country input linkages. These models are useful in their own right. For example, trade policy is typically conducted using instruments levied on gross trade, like tariffs, so it is natural to start by analyzing trade policy in gross models. Nonetheless, the deep goal ought to be to better understand how gross policy instruments induce changes in value-added trade, since value added is directly connected to both factor income and final expenditure (and hence welfare). Accomplishing this goal requires a better understanding of the theoretical mapping between gross and value-added representations of international trade.

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