5-2011

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American Economic Review: Papers & Proceedings 2011, 101:3, 308–312
http://www.aeaweb.org/articles.php?doi=10.1257/aer.101.3.308

Vertical Linkages and the Collapse of Global Trade

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During the Great Recession of 2008–2009, real world trade fell by roughly four times the decline in real world GDP.[1] A common, but controversial, view is that cross-border vertical linkages—international trade in intermediate goods—played a key role in the decline in trade. The purpose of this paper is to provide systematic evidence on the importance of these linkages. The framework we use draws from Johnson and Guillermo Noguera (2010) and Bems, Johnson, and Yi (2010); it is a global input-output table that links demand to production through bilateral, sectoral trade in intermediate and final goods. With this framework, we perform two exercises.

In our first exercise, we compute the fall in final goods trade and in intermediate goods trade that arises from the actual decline in final demand that occurred between 2008:I and 2009:I. Surprisingly, we find that the fall in final goods trade, 16.9 percent, was more than twice as large as the fall in intermediate goods trade, 7.6 percent. However, because the share of intermediate goods trade in total trade is about two-thirds, the contribution of intermediate goods to the total trade decline is still significant.

In our second exercise, we focus on a subset of vertical linkages, those imported intermediate goods that are embodied in goods that are exported (vertical specialization).[2] To measure vertical specialization, we compute the difference between gross trade and the value-added content of trade. We show that vertical specialization trade fell by more than value-added trade (12.9 percent versus 10.3 percent), because declines in demand were largest in more vertically specialized sectors. Nevertheless, because value-added trade constitutes about three-fourths of total trade, the decline in value-added trade still accounts for more than two-thirds of the decline in total trade.

I. Empirical Framework

We consider a world economy composed of N countries and S goods-producing sectors in each country. Each country produces a differentiated good within each sector that is either used as an intermediate input in production or used to satisfy final demand.[3] Output in each country is produced by combining local factor inputs with domestic and imported intermediate goods. Let the quantity of (gross) output in sector s of country i be denoted by $q_i(s)$. Let the quantity of intermediates from sector s in country i used in production of output in sector t in country j be $q_{ij}^m(s,t)$, and the quantity of final goods from sector s in country i absorbed in destination j be $q_{ij}^d(s)$.

With this notation, the market clearing is given by $q_i(s) = \sum_j \sum_t q_{ij}^m(s,t) + \sum_j q_{ij}^d(s)$. Taking percentage changes across two points in time yields

$$(1)\qquad \hat{q}_i(s) = \sum_j \sum_t \left[\frac{q_{ij}^m(s,t)}{q_i(s)}\right]\hat{q}_{ij}^m(s,t) + \sum_j \left[\frac{q_{ij}^d(s)}{q_i(s)}\right]\hat{q}_{ij}^d(s),$$

where $\hat{x} \equiv ((x_t - x_{t-1})/x_{t-1})$ denotes the percentage change in variable x. To translate this into an empirical framework for analysis, we need

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[1] Between 2008:I and 2009:I, real world trade fell by 15 percent, and real world GDP fell by 3.7 percent (source: IMF Global Data Source database).

[2] See David Hummels, Jun Ishii, and Yi (2001) and Yi (2003).

[3] The definition of final demand here follows the national accounts, including private consumption, government purchases, and investment (including inventory changes).

measures of quantity shares $q_{ij}^m(s,t)/q_i(s)$ and $q_{ij}^d(s)/q_i(s)$ for all i,j,s,t. Because we observe shipment values computed at a common set of prices in our data, we can equate quantity shares to value shares. We also need to link changes in real bilateral final and intermediate goods flows (i.e., $\hat{q}_{ij}^m(s,t)$ and $\hat{q}_{ij}^d(s)$) to observables. To do this, we assume that production functions and consumer preferences are Leontief, which implies that $\hat{q}_{ij}^m(s,t) = \hat{q}_j(t)$ and $\hat{q}_{ij}^d(s) = \hat{q}_j^d(s)$.

With these assumptions, we can then re-write equation (1) as

$$\hat{q}_i(s) = \sum_j \sum_t \left[\frac{m_{ij}(s,t)}{y_i(s)}\right]\hat{q}_j(t) + \sum_j \left[\frac{d_{ij}(s)}{y_i(s)}\right]\hat{q}_j^d(s), \tag{2}$$

where $m_{ij}(s,t)$ and $d_{ij}(s)$ are the value of bilateral intermediate and final goods shipments and $y_i(s)$ is the value of total production.

Combining the market clearing conditions for many countries, we show in Bems, Johnson, and Yi (2010) that changes in output are linear combinations of changes in final demand:

$$\hat{q}_i(s) = \sum_j \sum_t s_{ij}(s,t)\hat{q}_j^d(t), \tag{3}$$

where $s_{ij}(s,t)$ records the share of output from sector s in country i used directly or indirectly to produce final goods of sector t that are absorbed in country j. These shares depend on the entire structure of both final and intermediate goods linkages within and across countries.

We then calculate changes in real aggregate output and trade using Laspeyres quantity indices. For example, aggregate real import growth is

$$\widehat{IM}_i = \sum_{j\neq i} \sum_s \sum_t \left[\frac{m_{ji}(s,t)}{im_i}\right]\hat{q}_i(t) + \sum_{j\neq i} \sum_s \left[\frac{d_{ji}(s)}{im_i}\right]\hat{q}_i^d(s), \tag{4}$$

where im_i are the value of total exports and imports in the base period. Ultimately, aggregate output and trade are linear combinations of demand changes in all countries and sectors.

We make two observations about this framework. First, the framework does not admit the possibility that global supply chains can be broken. Hence, this channel of reduced trade is not captured. Second, suppose that final demand falls by X percent in all sectors and countries. Then, output, total trade, final goods trade, and intermediate goods trade will also all fall by X percent in all sectors and countries. Hence, any deviation from a unit elasticity of trade with respect to final demand in our framework must arise from heterogeneity across sectors or countries in the size of the demand changes.

To operationalize this framework, we need data on bilateral final and intermediate goods flows ($m_{ij}(s,t)$ and $d_{ij}(s)$), as well and final demand changes ($\hat{q}_i^d(s)$).[4] We combine national input-output tables with bilateral trade data from the GTAP 7.1 database to measure final and intermediate flows.[5] As in Johnson and Noguera (2010), we use the bilateral trade data to split imported intermediate and final goods across bilateral sources, assuming that bilateral sourcing is proportional to bilateral imports at the sector level. After splitting the data at the disaggregate level, we aggregate the data to form three composite sectors—durable industrial production, nondurable industrial production, and a composite agriculture and services sector.[6] We use national accounts data from the IMF Global Data Source, the OECD, and national sources to compute changes in real demand for the three composite sectors. In the end, we have real output, trade, and demand data for 55 countries. We examine the time period between 2008:I and 2009:I.

II. Final versus Intermediate Goods Trade

We first examine the relative importance of final and intermediate goods in the decline in trade. A key implication of our framework is that trade in final goods is closely linked to final demand, while trade in intermediate goods is closely linked to output. We feed changes in final demand for all countries and sectors into our parameterized framework; this yields implications for output

[4] See Bems, Johnson, and Yi (2010) for details on the procedure described here.

[5] The 2004 benchmark data are assembled by the Global Trade Analysis Project at Purdue University.

[6] Durables include sectors 38–42 in the GTAP data, covering machinery and equipment. Nondurables include all other industrial production (sectors 15–37 and 43–45).

Table 1—Changes in World Final and Intermediate Goods Trade in Global IO Framework

	Agriculture and services	Nondurables	Durables	Total
Change (percent)				
Actual final demand: $\hat{q}^d(t)$	0.0	−5.6	−27.7	−3.7
Gross output: $\hat{q}(t)$	−1.6	−5.2	−19.4	−4.6
Final goods trade	0.5	−6.7	−31.2	−16.9
Intermediate goods trade	−1.1	−5.6	−19.4	−7.6
Actual shares				
In total final goods trade	0.21	0.31	0.48	
In total intermediate goods trade	0.35	0.40	0.26	

and trade for all countries and sectors. One implication is that world trade declines by 11 percent, which is close to the actual decline of 15 percent. This is a useful diagnostic that indicates that our framework is a reasonable one.

Our discussion of the results focuses on implications for global aggregates. Table 1 presents the results for gross output, final goods trade, and intermediate goods trade in rows 2, 3, and 4.[7] Column 4 of rows 3 and 4 shows that final goods trade falls by 16.9 percent, while intermediate goods trade falls by only 7.6 percent. Two forces drive this result, both related to durable goods. First, column 3 shows that final goods trade in durable goods falls by considerably more than intermediate goods trade in durable goods (31.2 percent versus 19.4 percent). Second, the share of durable goods in final goods trade is both large and almost twice that of the share of durable goods in intermediate goods trade (48 percent versus 26 percent).

Why does final goods trade in durables fall by much more than intermediate goods trade in durables? We mentioned above that final goods trade is tied closely to final demand, while intermediate goods trade is tied closely to gross output. Indeed, Table 1 shows that actual final demand for durables fell by about 28 percent, while gross output of durables fell by about 19 percent. The answer to the question, then, can be found by answering why final demand for durables fell by more than gross output of durables. The change in gross output of durables is a weighted average of the sectoral changes in final demand (see (3)), because durable goods are used as inputs to produce final agriculture, services, and nondurable goods. As Table 1 shows, these categories of goods experienced a much smaller decline in final demand than did durables. Hence, there is a smaller decline in durables gross output than in durables demand.

Finally, we note that, while intermediate goods trade declined by less than final goods trade, because intermediate goods account for 63.5 percent of total trade, these goods contributed 43.9 percent of the fall in total trade.

III. Value Added versus Gross Trade

A second way to assess the role of vertical linkages is to focus on the subset of vertical linkages known as vertical specialization—those intermediate goods that are imported and are embodied in goods that are exported. Vertical specialization is closely related to the value-added content of trade. Johnson and Noguera (2010) define the value-added content of trade (equivalently, value-added exports) as the amount of value added produced in a given source country that is ultimately embodied in final goods absorbed abroad. The value-added content of trade is typically a fraction of total trade owing to "double counting" in trade data. This double counting arises as goods are passed back and forth across international borders through multistage, vertically specialized production processes. By comparing changes in valued-added trade to changes in gross or total trade, we can quantify how vertical specialization trade changed during the Great Recession.

To perform this decomposition, we develop an expression for the change in real

[7] See the online Appendix (http://www.aeaweb.org/articles.php?doi=10.1257/aer.101.3.308) for algebraic details regarding construction of this table.

TABLE 2—CHANGES IN WORLD VALUE ADDED AND VERTICAL SPECIALIZATION (VS) TRADE IN GLOBAL IO FRAMEWORK

	Agriculture and services	Nondurables	Durables	Total
Change(percent)				
Actual final demand: $\hat{q}^d(t)$	0.0	−5.6	−27.7	−3.7
Total (gross) trade	0.6	−6.0	−29.2	−11.0
Value-added trade	0.6	−6.0	−29.5	−10.3
Vertical specialization trade	0.7	−5.8	−28.6	−12.9
Actual shares				
In gross trade	0.41	0.26	0.33	
In value added trade	0.42	0.27	0.30	
In vertical specialization trade	0.34	0.25	0.41	

value-added exports for each country. Note that growth in real value added for country i is $\hat{V}_i = \sum_s (VA_i(s)/VA_i)\hat{q}_i(s)$, where $VA_i(s)$ is value added in sector s and $VA_i = \sum_s VA_i(s)$. Because output in each sector depends on changes in both domestic and foreign demand (as in (3)), we can decompose changes in real value added into components due to domestic and foreign demand changes. The change in real value added induced by changes in foreign demand is then equal to the change in real value-added exports, which we denote $\widehat{VAX}_i$. This is given by

$$\widehat{VAX}_i = \sum_s \sum_t \sum_{j \neq i} \left(\frac{VAX_{ij}(s,t)}{VAX_i} \right) \hat{q}_j^d(t),$$

where $VAX_{ij}(s,t) = VA_i(s)s_{ij}(s,t)$. The ratio $VAX_{ij}(s,t)/VAX_i$ is value added produced by sector s in country i absorbed in sector t final demand in country j expressed as a share of total value added embodied in exports of country i. This means that the change in value-added exports is a weighted average of sectoral final demand changes in foreign destinations, where the weights reflect the extent to which value added from the source country-sector is embodied in final demand in the destination.

Turning to gross exports, the change in real gross exports can be written as $\widehat{EX}_i = \sum_{j \neq i} \sum_t (d_{ij}(t)/ex_i)\hat{q}_j^d(t) + (m_{ij}(t)/ex_i)\hat{q}_j(t)$. Noting, again, that output changes themselves depend on final demand, this can be rewritten as

$$\widehat{EX}_i = \sum_{j \neq i} \sum_t \left(\frac{d_{ij}(t)}{ex_i} \right) \hat{q}_j^d(t) + \sum_{j \neq i} \sum_t \sum_k \sum_u \left(\frac{m_{ij}(t)}{ex_i} \right) s_{jk}(t,u)\hat{q}_k^d(u).$$

Comparing (6) to (5), both gross exports and value-added exports depend ultimately on demand changes. However, the weights differ across the two types of trade. For example, value-added exports depend only on demand changes abroad. By contrast, gross exports depend on both foreign and domestic demand changes, because exported intermediate goods can be used to produce foreign goods that are ultimately consumed at home. Further, note that if demand falls by the same percentage in all countries and sectors, then value-added exports and gross exports fall by an identical percentage. Thus, deviations between value-added exports and gross exports are driven entirely by composition effects in our framework.

For each country, we define "vertical specialization trade" as the difference between gross trade and trade in value added: $VS_i = EX_i - VAX_i$. This implies $\widehat{VS}_i = (EX_i/VS_i)\widehat{EX}_i - (VAX_i/VS_i)\widehat{VAX}_i$. Then, we can aggregate across countries to generate world changes in value-added and vertical specialization trade. We decompose the results by sector, as in the previous section, and then aggregate to form world composites. As before, we also use the index t to denote the destination sector, though now this is the destination in which output or value added is absorbed in final demand, as in (6) and (5).

Table 2 presents the response of total (gross) trade, value-added trade, and vertical specialization trade. Not surprisingly, the largest decline in gross trade is due to the change in demand for durables. Note, also, that within each sector, value-added and vertical specialization trade fall by roughly the same percentage.

Column 4 shows that total vertical specialization trade falls by more than value-added trade

(−12.9 percent versus −10.3 percent). This is because vertical specialization trade is more heavily concentrated in the durables sector, the sector with the largest decline in demand and, therefore, trade. Thus, the interaction of a large decline in demand centered on the most vertically specialized sector raises the global elasticity of trade with respect to realized demand changes. Nevertheless, the difference in declines between the two types of trade is not large. The overall contribution, in an accounting sense, of vertical specialization (*VS*) trade to the decline of total trade is quite significant, 31.6 percent, but the contribution exceeds *VS*'s share of global trade, 26.9 percent, by less than five percentage points. For individual countries that either trade mainly durable goods or have particularly intense vertical linkages, this effect is larger. For Canada and Mexico, for example, vertical specialization exports fall by 17 percent, while value added exports fall by 11.7 percent.

IV. Conclusions

Our paper uses a global input-output framework to assess the role of vertical linkages in the sharp decline in trade during the Great Recession. We give a nuanced interpretation to our findings. Intermediate goods trade fell by considerably less than final goods trade, but, owing to its large share in total trade, it still accounted for more than two-fifths of the decline in global trade. Vertical specialization trade accounted for about one-third of the decline in total trade; this implies, of course, that value-added trade accounted for the bulk of the decline.

The role of durable goods is far less nuanced. Three aspects of durable goods stand out. First, global durable goods demand fell sharply, close to 30 percent. Second, because durable goods rely heavily on services for production, our framework implies that the fall in durable goods output is less than the fall in durable goods demand. Then, because intermediate goods trade is tied to (gross) output and final goods trade is tied to final demand, our framework yields the result that intermediate goods trade falls by less than final goods trade. Third, durable goods tend to have more vertical specialization than nondurables, services, or agriculture goods. Because of this, the contribution of vertical specialization in the decline in trade is larger than its share in trade.

As mentioned above, our framework does not allow for vertical despecialization or "onshoring," the process by which firms have returned some foreign production back home.[8] To the extent this occurred, this would increase the importance of vertical specialization in the trade decline. It would also be useful to compare the actual trade collapse to a simulated collapse in a counterfactual world with less vertical specialization. Additional work in both these areas would be worthwhile.

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[8] See, for example, "Caterpillar Joins 'Onshoring' Trend," *Wall Street Journal*, March 11, 2010.