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 somewhat controversial, view is that cross-border vertical linkages — international trade in intermediate goods — played a key role in amplifying 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 Robert C. Johnson and Guillermo Noguera (2010) and Rudolfs Bems, Johnson and Kei-Mu 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 2008Q1 and 2009Q1. Surprisingly, we find that the fall in final goods trade was more than twice as large as the fall in intermediate goods trade. That is, the presence of intermediate goods helped mitigate the fall in total trade during the Great Recession. However, because intermediate goods trade constitutes almost two-thirds of world trade, the contribution of intermediate goods trade to the total 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 value-added trade fell by less than total trade, because demand declines were largest in more vertically specialized sectors. Thus, vertical specialization played a role in amplifying the collapse. 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.

We conclude with a nuanced view on the role of vertical linkages in the trade collapse. On the one hand, vertical linkages (broadly defined) seem to have played a significant dampening

[1] Between 2008Q1 and 2009Q1, real world trade fell by 15 percent, and real world GDP fell by 3.7 percent. Source: IMF Global Data Source database.

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

role, while vertical specialization played a modest amplifying role. On the other hand, from an accounting perspective, vertical linkages did account for a substantial fraction of the decline in trade.

1 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:

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

where $\widehat{x} \equiv (\frac{x_t - x_{t-1}}{x_{t-1}})$ denotes the percentage change in variable x. To translate this into an empirical framework for analysis, we need measures of quantity shares $\frac{q_{ij}^m(s,t)}{q_i(s)}$ and $\frac{q_{ij}^d(s)}{q_i(s)}$ 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., $\widehat{q}_{ij}^m(s,t)$ and $\widehat{q}_{ij}^d(s)$) to observables. To do this, we assume that production functions and consumer preferences are Leontief, which implies that $\widehat{q}_{ij}^m(s,t) = \widehat{q}_j(t)$ and $\widehat{q}_{ij}^d(s) = \widehat{q}_j^d(s)$.[4]

[3] The definition of final demand here follows the national accounts definition of "final goods," including private consumption, government purchases, and investment.

[4] In words, the quantity of inputs shipped from sector s in country i to sector t in country j is proportional

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

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

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:

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

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 $X\%$ in all sectors and countries. Then, output, total trade, final goods trade, and intermediate goods trade will also all fall by $X\%$ 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

to the change in output in sector t, and the change in the quantity of final goods shipped from sector s in country i to country j is proportional to the change in real demand for output from sector s in country j.

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 ($\widehat{q}_i^d(s)$).[5] We combine national input-output tables with bilateral trade data from the GTAP 7.1 database to measure final and intermediate flows.[6] 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.[7] We use national accounts data from the IMF's 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.

2 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 in our system into the framework; this yields implications for output and trade for all countries and sectors. Before discussing our results, we note that our framework generates a decline in world trade of 11%, which is close to the actual decline of 15%. This is a useful diagnostic that indicates that our framework is a reasonable one.[8]

We focus our discussion of the results on global aggregates. Rows three and four in Table 1 show that our framework implies a fall in final goods trade of 16.9%, while it implies a

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

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

[7] 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).

[8] By construction, our framework will replicate the decline in global GDP (3.7%).

	A&S	ND	D	Total
			Change (%)	
Actual final demand: $\widehat{q}^d(t)$	0.0	−5.6	−27.7	−3.7
Gross output: $\widehat{q}(t)$	−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	

Note: A&S is Agriculture and Services; ND is non-durables; D is durables

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

fall in intermediate goods trade of only 7.6%. In other words, intermediate goods helped mitigate the decline in total trade! This finding is surprising, especially in the context of the view that trade with many intermediate goods linkages should increase the income elasticity of trade. To understand this result better, we examine the sectoral composition of trade. The change in global final goods trade is equal to the weighted sum of changes in global sectoral final goods trade, where the sector-level changes are themselves weighted sums of country-specific demand changes. The change in global intermediate goods trade is equal to the weighted sum of changes in global sectoral intermediate goods trade, where the sector-level changes are a weighted sum of country-specific changes in output. See the appendix for algebraic details associated with this decomposition.

Rows three and four of Table 1 present the sectoral changes in trade; the sectoral weights (shares) needed to construct global changes in trade are presented in rows six and seven for reference. Row three shows that durables final goods trade falls substantially more than in the other two sectors. This reflects the fact that the change in final demand for durables was much larger than the changes in final demand for non-durables or services during the recession. Turning to intermediate goods trade, intermediate imports by durables producers also declined by more than intermediate imports by other sectors; however the differences

across sectors are smaller than with final goods trade. This reflects the fact that differences in output changes across sectors are smaller than changes in final demand, as seen in rows one and two. For example, global final demand for durables fell by 27.7%, while global output of durables only fell by 19.4%. On the other hand, global output of agriculture and services fell more than global demand for agriculture and services. The reason for both patterns is that services are heavily used as intermediates to produce durable goods, therefore some of the decline in durables final demand showed up as lower output of services

Aggregating across sectors requires using the trade shares in rows six and seven. The shares play an additional role in explaining why intermediate goods trade falls by less than final goods trade. While trade in durables final goods accounts for nearly half of all final goods trade, imported intermediates by the durables producing sector accounts for only 26% of intermediate imports. As a result, final goods trade places a larger weight on the sector with the larger proportional changes in demand (durables), while intermediate goods imports place more weight on sectors with smaller proportional changes in output (non-durables plus agriculture and services).

Finally, we note that, while intermediate goods helped mitigate the decline in total trade, it is also true that, because intermediate goods trade accounts for 63.5% of total trade, these goods contribute 43.9% of the fall in total trade.

3 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 the border through multi-stage, vertically-specialized production processes in which imports are used to produce exports. By comparing changes in valued-added trade to changes in gross or total trade, we can quantify how vertical specialization trade changed during the collapse.

To perform this decomposition, we develop an expression for the change in real value-added exports for each country. Note that growth in real value added for country i is: $\widehat{V}_i = \sum_s \left(\frac{VA_i(s)}{VA_i}\right) \widehat{q}_i(s)$, 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 $\widehat{VAX}_i$.[9] This is given by:

$$\widehat{VAX}_i = \sum_s \sum_t \sum_{j \neq i} \left(\frac{VAX_{ij}(s,t)}{VAX_i}\right) \widehat{q}_j^d(t), \tag{5}$$

where $VAX_{ij}(s,t) = VA_i(s)s_{ij}(s,t)$. The ratio $\frac{VAX_{ij}(s,t)}{VAX_i}$ 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: $\widehat{EX}_i = \sum_{j \neq i} \sum_t \left(\frac{d_{ij}(t)}{ex_i}\right) \widehat{q}_j^d(t) + \left(\frac{m_{ij}(t)}{ex_i}\right) \widehat{q}_j(t)$. Noting again that output changes themselves depend on final demand, this can be rewritten as:

$$\widehat{EX}_i = \sum_{j \neq i} \sum_t \left(\frac{d_{ij}(t)}{ex_i}\right) \widehat{q}_j^d(t) + \sum_{j \neq i} \sum_t \sum_k \sum_u \left(\frac{m_{ij}(t)}{ex_i}\right) s_{jk}(t,u) \widehat{q}_k^d(u). \tag{6}$$

[9] By construction, $\widehat{V}_i = \left(\frac{VAD_i}{VA_i}\right) \widehat{VAD}_i + \left(\frac{VAX_i}{VA_i}\right) \widehat{VAX}_i$, where VAD_i denotes value added absorbed domestically, VAX_i is value added absorbed abroad and the hat notation denotes real proportional changes.

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 $\widehat{VS}_i = \frac{EX_i}{VS_i}\widehat{EX}_i - \frac{VAX_i}{VS_i}\widehat{VAX}_i$. 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).

	A&S	ND	D	Total
			Change(%)	
Actual final demand: $\widehat{q}^d(t)$	0.0	−5.6	−27.7	−3.7
Gross trade	0.6	−6.0	−29.2	−11.0
Value added trade	0.6	−6.0	−29.5	−10.3
VS 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 VS trade	0.34	0.25	0.41	

Note: For A&S, ND, and D, see note for Table 1; VS is vertical specialization

Table 2: Changes in World Value Added and Vertical Specialization (VS) Trade in Global IO Framework

Table 2 presents the response of 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.

Aggregating across sectors, we find that vertical specialization trade (-12.9%) falls by more than value-added trade (-10.3%). 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, suggesting that the amplification channel is relatively small. Further support for this interpretation is given by the accounting contribution of vertical specialization (VS) trade to the decline of gross trade. It is quite significant, 31.6%, but the contribution exceeds VS's share of global trade, 26.9% 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%, while value added exports fall by 11.7%.

4 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 two main results that intermediate goods trade actually fell by considerably less than final goods trade, and that value-added trade as a share of total trade increased slightly during the recession. As for the role of vertical linkages as an amplification mechanism, we find that vertical linkages overall played a significant dampening role in the decline in trade, while a subset of those linkages associated with vertical specialization played a small amplifying role. At the same time, vertical linkages contributed significantly to the decline in trade from an accounting perspective. Intermediate goods accounted for 44% of the model-implied decline

in trade, and vertical specialization accounted for 32% of the model-implied decline in trade.

The role of durable goods is far less nuanced. Three aspects of durable goods stand out. First, global durable goods demand fell by a huge amount, close to 30%. 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 non-durables, 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 de-specialization or "on-shoring", the process by which U.S. firms for example, have returned some foreign production back to home.[10] To the extent this occurred, this would increase the importance of vertical specialization in the trade decline. Systematic analysis of this channel would be worthwhile.

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

A Final versus Intermediate Goods Decomposition

Looking at trade from the import side,we can rewrite Equation (4) describing the change in imports as:

$$\widehat{IM}_i = \left[\frac{im_i^m}{im_i}\right]\widehat{IM}_i^m + \left[\frac{im_i^d}{im_i}\right]\widehat{IM}_i^d \tag{7}$$

$$\text{with } \widehat{IM}_i^m = \sum_t \left[\frac{m_{Ii}(t)}{im_i^m}\right]\widehat{q}_i(t), \text{ and } \widehat{IM}_i^d = \sum_t \left[\frac{d_{Ii}(t)}{im_i^d}\right]\widehat{q}_i^d(t), \tag{8}$$

where im_i^m and im_i^d are total intermediate and final goods imports for country i, $m_{Ii}(t) = \sum_{j\neq i}\sum_s m_{ji}(s,t)$, and $d_{Ii}(t) = \sum_{j\neq i} d_{ji}(t)$. There are two important differences here between final and intermediate goods imports. First, final goods imports respond directly to changes in final demand ($\widehat{q}_i^d(t)$), while intermediate goods imports respond to changes in production ($\widehat{q}_i(t)$). Second, the import weights placed on each sector may differ for intermediate and final goods.

Aggregating across countries, the proportional change in world trade in final goods is $\hat{T}^d = \sum_i \left(\frac{im_i^d}{T^d}\right)\widehat{IM}_i^d$, and the proportional change in world trade in intermediate goods is $\hat{T}^m = \sum_i\sum_t \left(\frac{im_i^m}{T^m}\right)\widehat{IM}_i^m$, with $T^d = \sum_i im_i^d$ and $T^m = \sum_i im_i^m$. These proportional changes can then be rewritten as:

$$\widehat{T}^d = \sum_t \left(\frac{T^d(t)}{T^d}\right)\widehat{T}^d(t) \quad \text{with} \quad \widehat{T}^d(t) = \sum_i \left(\frac{d_{Ii}(t)}{T^d(t)}\right)\widehat{q}_i^d(t), \tag{9}$$

$$\widehat{T}^m = \sum_t \left(\frac{T^m(t)}{T(t)}\right)\widehat{T}^m(t) \quad \text{with} \quad \widehat{T}^m(t) = \sum_i \left(\frac{m_{Ii}(t)}{T^m(t)}\right)\widehat{q}_i(t), \tag{10}$$

where $T^m(t) = \sum_i m_{Ii}(t)$ and $T^d(t) = \sum_i d_{Ii}(t)$. Note that the index t here identifies the sector in which the goods are imported, for either final or intermediate use. For final goods, the sector in which goods are produced is identical to the sector in which goods are imported by definition. For intermediate goods, goods produced in sector s can be imported by another sector t as intermediates.