International Supply Chains and the Volatility of Trade

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Abstract

The world trade collapsed in the most recent recession. Some analysts have suggested the increasing offshoring of the supply chain, or vertical specialization (VS) trade, can explain the apparent increase in volatility of trade over the business cycle. This paper develops a model of VS trade to examine its impact on the volatility of trade. The model features increased trade volatility as VS trade increases when goods production is more volatile than services production. While the simulated model generates the observed increase in relative volatility of trade to GDP from 1967 to 2002, most of the increase is due to GDP's shift to less volatile services production. VS trade only accounts for a third of the increase. Counterintuitively, VS trade can moderate trade volatility.

JEL classification: E3, F1.

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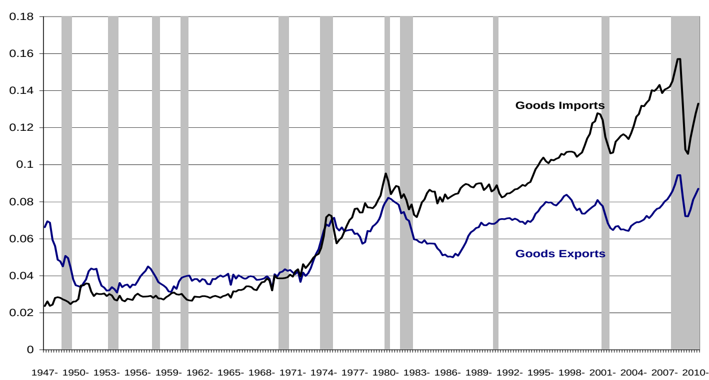
1 Introduction

While the recession beginning in 2007 was quite acute, the collapse in trade that accompanied it was staggering. Since its peak in the third quarter of 2007 to the trough in the second quarter of 2009, the volume of U.S. goods imports fell 24 percent. Exports show a similar decline in an even shorter period. In terms of goods trade share of GDP, this decline undid the trade expansion of the 2000s in less than two years. (See Figure 1.) World trade recorded a similar decline.

Figure 1: U.S. Goods Trade Share of GDP, 1947:Q1-2010:Q2



The recent decline is part of a wider increase in the relative volatility of trade over the business cycle. Real output fell 3.24 percent in the 1973-75 recession, similar to the 3.8 output drop in the 2007 recession (to 2009Q2, the point of trade's largest decline). However, real imports only fell 15.2 percent in the mid-1970s recession. This anecdotal evidence holds up in a more formal examination of the data. As documented in detail below, a shock to GDP - as defined by deviation from a Hodrick-Prescott (H-P) trend - has stronger impact on trade now than it did in the past. Over the last 40 years, the responsiveness of imports to GDP shocks has increased in the United States. From 1967 to 1989, a 1 percent GDP deviation from HP trend led to a 2.4 percent deviation in imports on average. From 1990 to 2009, the responsiveness has increased to 3.2 percent, a 33 percent increase. (See Levchenko, Lewis & Tesar (2010), Eaton, Kortum, Neiman & Romalis (2010) and the citations within for empirical studies of this event.)

Some analysts have suggested that the rise of vertical specialization (VS) trade, trade in goods incorporating imported inputs, has been a cause of the collapse in trade. VS trade has become more important, growing from 6 percent of U.S. exports in 1972 to 14 percent in 1997 (Feenstra 1998, Hummels, Rapoport & Yi 1998, Hummels, Ishii & Yi 2001). The increasing importance of international sources in supply chain was cited frequently in symposia on the collapse in trade. (See Hufbauer & et al. (2009) and Yi (2009).) When the production process is split up across different countries, portions of a product may cross international borders many times since trade is measured in gross output terms. For example, if auto parts made in the United States are shipped to Canada to be assembled into a car that is sent back to the United States, the value parts show up in both exports (as parts) to Canada and imports from Canada (as part of the value of the car). If U.S. car demand falls due to a recession, both parts exports and car imports fall. In contrast, if there is only trade in final goods, a car import from Canada only enters the international accounts once. If U.S. car demand falls, only car imports fall. The amplification from VS trade is stronger as more firms use VS trade or as parts cross a border more times during the production of final goods.

Examining VS trade is important since there has been concern that offshoring has led to mismeasurement of national output (Houseman 2007). Net exports (and national output) will be overstated if offshored inputs are not properly accounted for, since the value of exports will in part incorporate the value of imported inputs. This analysis also holds for imports incorporating exported inputs. If the effect is cyclical, the measured behavior of productivity and other indicators over the business cycle will also be mismeasured.

While the international supply chain explanation has been frequently cited in journalistic and other informal accounts of the trade collapse, I am not aware of a formal examination of whether increasing VS trade is responsible for increasing volatility[1]. This

[1] Bems, Johnson & Yi (2010) examine the impact of VS trade on propagating shocks during the recent recession.

paper seeks to fill this gap by examining whether the unraveling of international supply chains is a quantitatively important source of this increased responsiveness. It presents a tractable general equilibrium model with Ricardian trade in intermediate goods. There are two countries with two layers of goods production: Intermediate goods are inputs to final consumption goods. Both types of goods may be traded, but incur an iceberg transportation cost and may face tariffs. There is a service sector that is not traded. I calibrate the model to match the U.S. economy in 1967 and 2002 using tariff and freight cost data. I then simulate the effect of productivity shocks on trade.

Model simulations generate significant increased volatility. The relative volatility of trade to GDP increases 33 percent from 1967 to 2002 in the baseline simulation, the same increase as in the data. Two thirds of the increase is due to the shift to less volatile services production while imports continue to be dominated by goods trade.

About a third of the volatility increase is attributable to VS trade. However, the mechanism is different than the one in popular accounts. In the model, parts trade is more volatile than final goods trade. Increasing VS trade means that more trade is in volatile parts.

The unwinding of the supply chain does not increase trade volatility. Since nominal trade is proportional to nominal goods production, trade falls by the same percentage as goods production regardless of trade share. While the rising importance of VS trade explains the rapid increase in trade levels, the higher trade share does not directly affect volatility. The higher level does explain the high absolute decline in trade volumes.

Increasing VS trade may even reduce trade volatility. The impact of VS trade is reversed if parts production is less volatile than that of final goods. In an alternative calibration, the model can generate the observed increase in volatility even though increasing parts trade is a moderating influence. While careful data work will be required to determine the exact impact of VS trade, the results indicate that structural change has been a more significant source of increased import volatility relative to GDP.

Alternative theories have been put forth to explain the recent fall in trade. Amiti & Weinstein (2009) and Chor & Manova (2009) suggest the loss of trade credit due to stress on banking system. Alessandria, Kaboski & Midrigan (2010) examine adjustments to inventories. Gamberoni & Newfarmer (2009) cite increasing protectionism. This paper only examines the ability of VS trade and GDP composition changes to explain the trade collapse rather than run a horse race between all of the popular explanations.

Modeling the volatility of trade over the business cycle has received interest recently. Standard international real business cycle (IRBC) models fail to deliver the relative volatility of trade to output. Boileau (1999) and Ercega, Guerrieria & Gust (2008) show that trade will be more volatile when trade is dominated by capital goods. Engel & Wang (2008) augment the standard IRBC model with trade in durable goods. This paper takes a similar approach to these papers: The traded sector is more volatile than overall production. It differs in that it simplifies the shocks and does not contain durable goods to concentrate on VS trade.

A portion of the IRBC literature examines the impact of higher trade share on the co-movement of business cycles, including Backus & Crucini (2000), Bems et al. (2010), Kose & Yi (2001), Kose & Yi (2006) and Burstein, Kurz & Tesar (2008). This paper concentrates on the effects of shocks on trade rather than the degree to which trade transmits shocks to other countries.

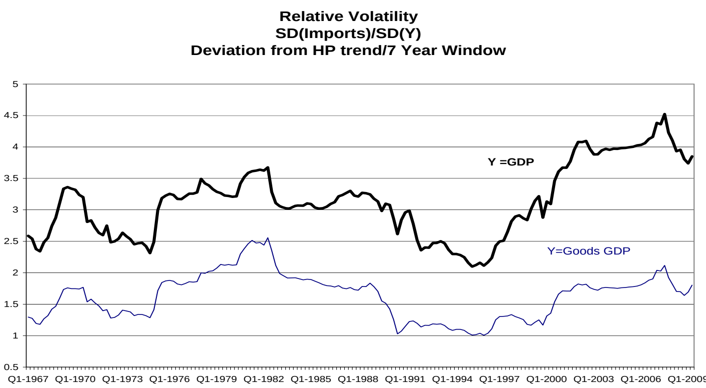
A number of papers have examined the importance of intermediates trade for a number of issues including development (Jones 2008, Goldberg, Khandelwal, Pavcnik & Topalova 2008), firm productivity (Amiti & Konings 2007), trade elasticities (Ramanaryanan 2006) and the border effect in gravity equations (Yi 2010). Grossman & Rossi-Hansberg (2008) examine the growth of trade in intermediate services. Theoretical models of vertical specialization trade include Dixit & Grossman (1982) and Sanyal (1983). Unlike these papers, I examine the volatility of trade over the business cycle.

2 Evidence on Trade and the Business Cycle

This section examines the evidence on U.S. trade over the business cycle in greater detail.

The volatility of trade relative to that of GDP has increased. Figure 2 shows the relative volatility of U.S. trade and output. Volatility is measured as the standard deviation of the percentage deviation from a H-P trend in a seven year moving window ending in the year reported. The ratio of volatilities has increased to its highest sustained levels in the last 20 to 25 years. Prior to the mid to late 1980s, both GDP and trade volatility follow the same pattern: Volatility falls during the 1960s and increases during the 1970s and fall again in the early 1980s. Therefore, the ratio is largely constant. Beginning the later 1980s, trade volatility increases while GDP volatility remains low.

Figure 2: U.S. Relative Volatility



However, relative to goods output, goods imports does not show a significant increase in volatility. The pattern of relative volatility is similar to that relative to overall GDP. It declines in the 1980s and increases again in the 1990s. Unlike the total GDP comparison, volatility only returns to its 1970s level.

The ratio only measures unconditional variance and does not take into account the covariance of the series. I conduct a more formal test of an increase in volatility by regressing trade's deviation from H-P trend (calculated using 1600 as the smoothing parameter, the standard for quarterly data) on output's deviation from 1967Q1 to 2010Q2. I fit the following equation using OLS,

$$Dev(Tr) = \gamma_0 + \gamma_1 Dev(GDP) + \gamma_2 \delta_{t \geq t_{break}} + \gamma_3 \delta_{t \geq t_{break}} * Dev(GDP) \tag{2.1}$$

where $Dev(Tr)$ and $Dev(Y)$ are the deviation from trend for trade and output respectively and $\delta_{t \geq t_{break}}$ is a dummy variable that equals 1 beginning with time t_{break}. If the coefficient on the interaction between the dummy and GDP deviation is significant, it is evidence that GDP shocks have stronger effects on trade now than they did before t_{break}. As a baseline, I select t_{break} as the first quarter of 1990 because trade's relative volatility begins its sustained increase in the seven years ending in 1996.

Table 1: Volatility Regressions

Variable	**(Y=GDP)**	**(Y=Goods GDP)**
$\delta_{t\geq 1990Q1} * Dev(Y)$	0.804**	0.145
(SE)	(0.342)	(0.200)
$Dev(Y)$	2.443**	1.220**
	(0.170)	(0.119)
Constant	0.000	0.000
	(0.003)	(0.004)
$\delta_{t\geq 1990Q1}$	-0.001	-0.001
	(0.005)	(0.005)
Obs.	174	174
$Adj. - R^2$	0.66	0.51
**: Significant at 1 percent level.		

Table 1 reports the results of the regressions using imports as the measure of trade. The regressions show similar results as the unconditional volatility. There is a statistically significant 33 percent increase in the impact of GDP shocks on imports, increasing from 2.4 to 3.2 times as volatile as GDP. This finding is consistent with those of Engel & Wang (2008). There is no significant increase in import volatility relative to goods GDP. These results indicate that the data support the idea that trade has become more volatile relative to the business cycle. Freund (2009) finds collaborating evidence in international data, where the income-trade elasticity has nearly doubled from the 1960s to the 2000s. Levchenko et al. (2010) find that the last two recessions in the United States have led to more severe declines in trade compared to previous post-war recessions.

Since the choice of break date was selected in a rather *ad hoc* fashion, I experimented with changing the break date, moving it both forward and backward. The results show a robust increase in relative volatility beginning some time in the early 1990s. Relative trade volatility has increased between 1960s and the 2000s in a statistically meaningful way, even if the current analysis does not isolate when that increase occurred.

3 Model

3.1 Households

There are two countries each with a representative household. Households have preferences over a final consumption good C_f^i and a service good C_s^i represented by:

$$U = [\gamma(C_f^i)^\psi + (1-\gamma)(C_s^i)^\psi]^{\frac{1}{\psi}} \tag{3.1}$$

The associated prices are P_f^i and P_s^i. Each country is endowed with labor N^i. The wage is W^i.

3.2 Intermediate Goods Sector

There is a continuum of intermediate goods $x^i(z)$ with a price $P_{x,j}^i(z)$ for $z \in [0,1]$. Each country is endowed with technologies that use labor $N_x^i(z)$ to produce intermediates. Total output of intermediate z is given by:

$$Y_x^i(z) = A_x^i(z) N_x^i(z). \tag{3.2}$$

The productivity parameters are given by $A^1(z) = \frac{1}{(1+z)^\theta}$ and $A^2(z) = \frac{1}{(2-z)^\theta}$, a variant of the mirror image technology in Bridgman (2008) which is based on Dornbusch, Fischer & Samuelson (1977) and Eaton & Kortum (2002).

3.3 Consumption Goods Sector

Intermediate goods can be assembled into consumption goods using labor N_c^i. Each country can only produce the good with its name: $j = i$. The total output is given by the technology:

$$Y^i_{c,j} = A^i_c(N^i_c)^\alpha(\int (x^i(z))^\sigma)dz)^{\frac{1-\alpha}{\sigma}} \tag{3.3}$$

for $i = 1, 2$ and $j = i$. The associated price is $P^i_{c,j}$.

3.4 Goods Assembly Sector

The consumption goods from each country are assembled into the final consumption good with the technology:

$$C^i_f = [\sum_{j=1,2} \phi^i_j(C^i_{c,j})^\rho]^{\frac{1}{\rho}} \tag{3.4}$$

where $\phi^i_j = \phi$ if $j = i$ and $\phi^i_j = 1 - \phi$ and if $j \neq i$. The associated price is P^i_f. The final consumption good cannot be traded. This sector is a dummy industry to stand in for household's preferences over the consumption goods to simplify the presentation of the model.

3.5 Service Sector

Each country is endowed with a technology that uses labor N^i_s to produce services $C^i_s = A^i_s N^i_s$. Services cannot be traded.

3.6 Transportation Sector

The countries may trade the goods they produce with each other by incurring an iceberg transportation cost specific to that good: f_k for $k \in \{x, c\}$.

3.7 Government

The countries each have a government that can impose an ad valorem (net of transport fees) tariff τ^i_k on traded goods $k \in \{x, c\}$. The government gives the domestic representative household transfers T^i and maintains budget balance.

4 Equilibrium

4.1 Definition

Households sell labor and purchase goods. They maximize U subject to the budget constraint

$$P_f^i C_f^i + P_s^i C_s^i = W^i N^i + T^i \tag{4.1}$$

Service firms buy labor and sell services. They face competitive markets and solve:

$$Max P_s^i A_s^i N_s^i - W^i N_s^i \tag{4.2}$$

Intermediate goods firms face competitive markets and solve:

$$Max P_i^i(z) A_x^i(z) N_x^i(z) - W^i N_x^i(z) \tag{4.3}$$

For $j = i$, consumption goods firms solve:

$$Max P_{c,i}^i A_c^i (N_c^i)^\alpha \left(\int (x^i(z))^\sigma) dz\right)^{\frac{1-\alpha}{\sigma}} - W^i N_c^i - \int_0^1 P^i(z) x^i(z) dz \tag{4.4}$$

Final goods assembly firms face competitive markets and solve:

$$Max P_f^i \Big[\sum_{j=1,2} \phi_j^i (C_{c,j}^i)^\rho\Big]^{\frac{1}{\rho}} - \sum_j C_{c,j}^i \tag{4.5}$$

Transportation firms buy domestic goods and sell exports. Consumption goods exporters face competitive markets and solve:

$$Max P_{c,i}^{-i} C_{c,i}^{-i} - P_{m,i}^i C_{c,i}^{-i}(1 + f_c) \tag{4.6}$$

where $P_{c,i}^{-i}$ is the price of the consumption good in the other country. Intermediate goods exporters solve a similar problem.

Feasibility for each consumption good requires that for $j = 1, 2$:

$$f_c^j C_{c,-j}^j + \sum_{i=1,2} C_{c,j}^i = Y_c^j \tag{4.7}$$

where $-j$ is the other country. The term $f_c^j C_{-j}^j$ is the amount of consumption used to pay the iceberg cost to ship the good. There is a corresponding feasibility constraint for intermediate goods production. Labor feasibility requires that labor sum to the total population.

$$N^i = N_c^i + N_s^i + \int_0^1 N_x^i(z)dz \tag{4.8}$$

The definition of equilibrium is standard.

Definition 4.1. *Given tariffs, an equilibrium is consumption, parts and materials goods allocations and prices in each period such that:*

1. *Households solve their problem,*
2. *Service, intermediate goods, consumption goods, good assembly and transportation firms solve their problem,*
3. *The government balances its budget,*
4. *The allocation is feasible.*

4.2 Solution

The two countries are mirror images in manufactured parts production. There is a symmetric equilibrium with a closed form solution when the parameters are the same in the two countries. Specifically, if the parameters N^i, τ_k^i, A_k^i for $k \in \{x, c\}$ and are constant across the two countries, there exists an equilibrium where $C_{c,1}^1 = C_{c,2}^2$, $C_{c,1}^2 = C_{c,2}^1$, $P_s^1 = P_s^2$, $W^1 = W^2$, $P_{c,2}^1 = P_{c,1}^2$ and $P_{c,1}^1 = P_{c,2}^2$. Prices and quantities in the intermediate goods sectors across the countries mirror each other: $P_x^1(z) = P_x^2(1-z)$, etc. In the rest of the paper, I examine this symmetric equilibrium.

I denote the common parameters and quantities (for example, N^i and W^i) by omitting the i superscript (for example, $\tau^1 = \tau^2 = \tau$) and normalize price of country one's service good to one ($P_s^1 = 1$). This implies that the wage $W^1 = A_s$. Define $\overline{z}_i$ as the cutoff industry in country i such that manufactured parts $z > \overline{z}_1$ and $z < \overline{z}_2$ will be imported. Given the functional forms, an interior solution is given by:

$$\overline{z}_1 = 1 - \overline{z}_2 = \frac{2(1+\tau_x+f_x)^{\frac{1}{\theta}} - 1}{(1+\tau_x+f_x)^{\frac{1}{\theta}} + 1} \tag{4.9}$$

5 Results

In this section, I use the model to measure the effects of increasing vertical specialization trade on the volatility of trade over the business cycle. I calibrate the model to match moments of the data in 1967 and 2002 and examine the impact of productivity shocks on international trade.

5.1 Model Mechanics

The business cycle is modeled as a productivity shock to the traded sector. Specifically, recessions occur when there is a temporary decline in the productivity parameters A_x, A_c and A_s.

The model generates higher volatility for trade than GDP. Since services production is subject to smaller shocks, the household's demand shifts from consumption goods to services after a negative shock. Demand of imports at a given level of trade costs is linear in demand for final consumption goods. Less demand for consumption goods leads to lower demand for imports. Since the shocks are stronger in the traded sectors, trade is more volatile than overall output.

The model is similar to Engel & Wang (2008) in that the traded sector is more volatile than the non-traded sector. The mechanism is different. In their model, traded goods are durable and shocks are persistent. Negative productivity shock reduce wealth and households cut back on new durable goods purchases. This model abstracts from such forward looking behavior - there are no durable goods and shocks are transitory - to focus on vertical production.

Nominal imports are proportional to output of consumption goods. This proportion is strictly declining in trade costs and is given by:

$$Imports = P_c^i Y_c^i [\underbrace{\frac{1}{1+f_c+(\frac{(1+f_c+\tau_c)\phi}{1-\phi})^{\frac{1}{1-\rho}}}}_{Consumption} + \underbrace{\frac{(1-\alpha)((2-\overline{z}_1)^\eta - 1)}{[(1+\overline{z}_1)^\eta - 1](1+f_x+\tau_x)^{\frac{1}{1-\sigma}} + (1+f_x+\tau_x)[(2-\overline{z}_1)^\eta - 1]}}_{Parts}] \tag{5.1}$$

where $\eta = \frac{\theta\sigma+\sigma-1}{\sigma-1}$.

The first term in the brackets is consumption goods imports and the second is intermediate goods imports. If there are no trade barriers, the second term is equal to $\frac{1}{2}(1-\alpha)$. It can be shown that the second term is strictly increasing as trade barriers τ_x and f_x fall[2].

Nominal quantities need to be deflated into real terms. Real imports are measured by holding prices fixed at base year prices. GDP is deflated by the CES price index:

$$P = [\gamma^{\frac{1}{1-\psi}}(P_f)^{\frac{\psi}{\psi-1}} + (1-\gamma)^{\frac{1}{1-\psi}}(P_s)^{\frac{\psi}{\psi-1}}]^{\frac{\psi-1}{\psi}} \tag{5.2}$$

5.2 Calibration

This section presents the time invariant parameter selection for the model. In the calibration, I follow the convention of Yi (2003) and Bridgman (2008) and interpret the two countries as the United States and the rest of the industrialized countries (the EC plus Japan).

Jones (2008) examines the input-output tables of 35 countries and finds that intermediate goods share of gross output is clustered around 50 percent. (The United States has a value of 0.47.) I set the share of intermediate goods in final goods production α both equal to 0.5. There is little information on materials elasticity σ. I use the value of -1 suggested by Jones (2008), which implies an elasticity midway between Cobb-Douglas and Leontief.

Ruhl (2005) estimates the long run Armington elasticity in response to permanent changes in trade costs to be 6.4, which implies the value of ρ is 0.85. The selection of this parameter is appropriate since ρ only governs the long run changes imports in the model. The import share of goods production is not affected by business cycle shocks.

The relative productivity parameter θ and home bias parameter ϕ are taken from Bridgman (2010). There are selected to match initial VS trade share and import share of GDP respectively given trade costs. I use the trade cost estimates and model of Ricardian comparative advantage from Bridgman (2010) in the simulations, so it is natural to use

[2] When $\eta \neq 0$ this term is strictly decreasing in $\overline{z}_1$. $\overline{z}_1$ is increasing in trade barriers to intermediates trade. When $\eta = 0$, the result follows by inspection.

the same parameter estimates.

The baseline parameters are summarized in Table 2.

Table 2: Baseline Parameters

Variable	ρ	θ	α	σ	ϕ
Value	0.85	0.24	0.5	-1	0.545

5.3 Simulations

This section presents the results of the calibrated model.

Tariffs and freight rates are taken from the estimates in Bridgman (2010). I use manufacturing intermediate goods for intermediate goods and manufacturing final goods for final production. Following Bridgman (2010), I adjust these data to account for trade-weighting bias. I measure of the size of this bias as the ratio of the Mercantilist Trade Resistance Index (MTRI) proposed by Anderson & Neary (2003), the estimated uniform tariff equivalent that generates the observed level of trade, to trade-weighted tariffs. Using the MTRI estimates for the United States in 2002 from Kee, Nicita & Olarreaga (2005), I scale up trade costs by 1.69. While this estimate only covers tariffs, Anderson & van Wincoop (2004) note that transport costs are similar to tariffs in magnitude and variability. Therefore, a tariff based estimate is likely to be a reasonable proxy for bias in transport cost measures.

The remaining parameters as selected to match volatility and production share moments.

Recessions are modeled as productivity shocks. There are three productivity shocks to assign: The two goods producing sectors (A_c and A_x) and the services producing sector (A_s).

Overall goods production (incorporating both A_c and A_x) is about twice as volatile as services. I regressed deviations from H-P trend for real goods GDP on the percent deviation for services GDP from 1967Q1 to 2010Q2. Goods producing industries show a 1.8 percent deviation in response to a 1 percent deviation in the service sector. The relative volatilities have not changed significantly over this period.

The relative shocks to the two goods producing industries are are difficult to recover directly. The data do not separate out final goods and intermediate goods producing industries. The tools used to estimate the split between the two do not work well at business cycle frequencies, since they use very low frequency input-output tables and real trade data are not reported using the I-O classifications. To get some sense of the relative volatilities, I examined U.S. imports by use category. "Non-petroleum industrial supplies" is a classification that is likely to only include intermediate goods while "Consumer goods" is likely to only include final goods. These categories do not show a strong difference in relative volatility. The standard deviation from H-P trend for non-petroleum industrial supplies over the period 1967Q1 to 2010Q2 is 0.070, slightly higher than the 0.069 for consumer goods.

Since the data are imprecise, I set a baseline recession to be when the productivity parameters fall from $A_x = A_c = A_s = 1$ to $A_x = 0.965, A_c = 0.99, A_s = 0.99$. These shocks generate reasonable volatilities given the above facts. In the baseline case, goods production matches the relative volatility of goods to services production (1.8 times in 1967). These shocks imply that intermediate imports are somewhat more volatile than final goods imports: A recession leads to a 4.3 percent decline in intermediates trade and a 3.6 percent decline in final goods in 2002. I discuss alternative shock parameterizations below.

Given these shocks, the household's share parameters on service and final goods γ is set in each period to match the share of GDP that is manufacturing value added. The service sector has become more important as manufacturing industries have fallen from 26 percent of GDP in 1967 to 13 percent in 2002.

Finally, the elasticity between service and final goods ψ is chosen to match the relative volatility of imports to GDP in 1967, as measured by the coefficient on GDP from the regression in Table 1: Imports are 2.4 times as volatile as GDP. The value of ψ is 0.361. This value implies the elasticity between the traded and non-trade sectors is 1.565. This value is somewhat close to that used in Engel & Wang (2008) (1.1) and well within the range reasonable values they cite from Baxter (1996): 0.5 to 2.5. The robustness of the results to this parameter choice is discussed below.

Table 3 shows that the model generates the empirical increase in trade volatility

Table 3: Baseline Simulations

Parameter	1967	2002
f_x	0.1234	0.0659
f_c	0.0980	0.0389
τ_x	0.1200	0.0135
τ_c	0.1453	0.0355
γ	0.461	0.33
Recession Deviation		
Real trade	-3.48%	-3.92%
Real GDP	-1.45%	-1.23%
Ratio Trade/GDP	2.4	3.2
Data	**2.4**	**3.2**

relative to output. The ratio of the deviation of trade to GDP increases from 2.4 to 3.2, the 33 percent increase in relative volatility found in the regression in Table 1. Recall that while the calibration targets the relative volatility in 1967, the model is not constrained to match the 2002 ratio.

There are two forces increasing the volatility of trade relative to GDP. First, output has shifted from volatile manufacturing industries to less volatile services. As more output shifts to the service sector, less of the economy is hit with the larger shocks to the traded sectors. The same shocks lead to a 15 percent smaller decline in real GDP in 2002 compared to 1967[3].

The other force is that increasing VS trade increases trade in volatile intermediate goods. Recall that goods imports were more volatile than final goods imports: A 4.3 versus 3.6 percent decline in a recession in 2002. The stronger shocks to the parts sectors mean that part prices increase more than in the final goods sector and real parts

[3] There is a related but separate literature examining the sources of the "Great Moderation," a fall in the overall volatility of the economy. (See Davis & Kahn (2008) for a survey.) One explanation is the shift to less volatile industries. This paper examines the relative volatility of trade and GDP, but does not attempt to explain why the shocks are smaller. The *ratio* of shocks to the two sectors have been much more stable than the *level* of the shocks.

imports fall more. Since a greater share of imports in 2002 is parts trade, trade volatility increases.

Note that VS trade does not increase volatility by unwinding supply chains, the explanation that figures into popular accounts of the its importance. Nominal trade is proportional to nominal goods output, a proportion that increases as trade costs fall. While a recession reduces trade since there is less goods output, it does not change the share of nominal goods output traded. To see this, note from equation 5.1 imports M are constant share s of nominal consumption goods output: $M = sP_cY_c$. In a recession, the deviation of imports is given by: $\frac{M'}{M} = \frac{sP_c'Y_c'}{sP_cY_c} = \frac{P_c'Y_c'}{P_cY_c}$. Therefore, the volatility of trade does not increase as a result of rising trade share.

We can decompose the impact of the two effects. If we impose 1967 parts tariffs on the 2002 economy, there is no trade in parts. The relative volatility ratio without VS trade falls to 2.9. Therefore, about two thirds of the increase in the volatility ratio is due to structural change and one third is due to VS trade.

These findings are consistent with the decomposition of the trade decline in Levchenko et al. (2010). They find that assuming that trade in each sector fell by the same amount as industrial production would explain 83 percent of the real decline in imports. Eaton et al. (2010) also find that falling demand for manufactures explain the bulk of declining trade. In their regression of different candidate sources, Levchenko et al. (2010) find that a 13 percent share of the decline in imports that are attributable to downstream production linkages. These results are consistent with the model's prediction that the majority of the decline in imports is due to volatility in the traded sector with a smaller role for VS trade.

The model also captures the increase in trade levels. Table 4 shows the model's predicted trade growth from 1967 to 2002. The model generates essentially all of manufactured trade growth relative to GDP and manufactured value added.

Table 4: Trade Growth

Moment	Model	Data
Mfg Exports/GDP growth	103%	104%
Mfg Exports/Mfg VA growth	301%	317%

Since the mechanism for the VS trade to matter for increasing trade volatility is strongly linked to the shocks to the goods producing sectors and these shocks were imprecisely selected, it is important to examine the robustness of the results to these parameter choices. The impact of VS trade is sensitive to the choice of productivity shocks. If the parts sector is less volatile than final goods, then increasing VS trade will reduce trade volatility.

To show this, I change a recession to be the productivity parameters $A_x = 0.97, A_c = 0.98, A_s = 0.99$ and recalibrate the model. The new calibrate sets the goods/services elasticity parameter $\Psi = 0.29$ and $\gamma_{2002} = 0.31$ (with all other parameters the same). The model hits the same targets as in the baseline case. The results are given in Table 5. In this case, relative trade volatility increases from 2.4 in 1967 to 3.1 in 2002.

While the model is able to match the moments well, as was true for the baseline case, the implications for increasing VS trade are very different. Increasing VS trade *reduces* trade volatility. If we repeat the counterfactual exercise of shutting off parts trade, the import/output volatility ratio increases to 3.3. Therefore, contrary to the popular explanation, increasing VS trade could be a source of moderation in trade[4].

Table 5: Alternative Simulations

Parameter	1967	2002
Ψ	0.29	0.29
γ	0.443	0.281
Recession Deviation		
Real trade	-4.20%	-4.15%
Real GDP	-1.72%	-1.32%
Ratio Trade/GDP	2.4	3.1
Data	**2.4**	**3.2**

The key difference that parts trade is now less volatile than final goods trade. In 2002, parts trade falls 3.9 percent in a recession compared to 4.4 percent for final goods. Therefore, increasing VS trade means that more goods from the less volatile sector are

[4]Bems et al. (2010) make this point.

traded.

Other models of the business cycle with intermediate goods, such as Hornstein & Praschnik (1997), have the feature that intermediate goods are less volatile than final goods. However, these studies have identified final output as durable goods and intermediates as nondurables. U.S. trade data by use show that this breakdown does not reflect trade data. About a third of the nominal value of industrial supplies are durable goods. Likewise, a third of consumer goods are non-durable. Disentangling the two uses will require careful data work.

Intersectoral linkages tend to make final goods more volatile than parts, since shocks in the parts sector feed into the final goods sector. Lower parts productivity increases their prices, which tends to reduce parts demand. Higher parts prices raise the cost of producing final goods. Therefore, the cost of final goods is pushed up by both parts and final goods shocks[5]. Parts trade can be less volatile even if it is hit with a bigger productivity shock than final goods.

The findings indicate the rising VS trade is not likely to be a first order cause of increasing trade volatility. Even when parts production is more volatile than final goods, structural change is a much more important factor.

Why is VS trade a relatively unimportant source of trade volatility? Perhaps the result is not surprising. Other examinations of the impact of VS trade on business cycle phenomena, such as Kose & Yi (2001) and Kose & Yi (2006), have not given it a large role. Arkolakis & Ramanaryanan (2009) argue that perfect competition in trade eliminates the impact of productivity shocks in amplifying productivity shocks in international business cycles. They suggest that imperfect competition may increase the impact of productivity shocks.

Since the relative volatility of imports to goods output has not increased by much, the empirical impact of VS trade is limited. Therefore, the data do not support modeling changes that would significantly increase the impact of shocks on the volatility of goods imports relative to good output. While VS trade has expanded, other forces tend to reduce volatility. The rise of Just-in-Time inventories reduce the stock of parts that

[5]The importance of intersectoral linkages has been long known in the real business cycle literature. For example, see Long & Plosser (1983).

firms hold (Dalton 2009). Fewer inventories mean that negative shocks lead to smaller inventory adjustments of the type identified in Alessandria, Kaboski & Midrigan (2008), even if more inputs are imported.

5.4 Robustness

The values of some of the parameters are not assigned with precision. The main finding, that structural change rather than VS trade is more important for increasing trade volatility, is robust to changes in these parameters.

Changing the elasticity between goods and services ψ affects the relative volatility of trade to output. As this elasticity increases, trade becomes more volatile relative to output. As long as the elasticity is greater than one ($\psi > 0$), the relative volatility of trade increases from 1967 to 2002. Changing ψ does not change the relative importance of VS trade. VS trade scales up total trade by the same amount as in the baseline case. Therefore, the contribution of VS trade to increasing volatility is unaffected.

The parts elasticity σ was taken from Jones (2008) who assigned it as a midpoint between Leontief and Cobb-Douglas. The results are nearly unchanged by changing σ. As can be seen in Equation 4.9, the extensive margin for parts trade is not affected this elasticity. It only affects the intensive margin, leading to quantitatively minor changes in parts and total trade.

6 Conclusion

While the internationalization of the manufacturing supply chain has been an important source of increased volume of trade over the last 40 years, it does not appear to be a first order source of the increase in the relative volatility of trade over the business cycle. In fact, it is possible that it reduced trade volatility. The decline of the relatively volatile goods producing sector in GDP has been much more important. The interpretation of the trade collapse beginning in 2007 that the model supports is that the shocks to the economy were unusually strong for the post Great Moderation period. Similar shocks in an economy with a 1960s industrial composition would have led to a very severe recession.

Data Sources

Figure 1 Current dollar GDP, goods exports and goods imports, BEA NIPA Table 1.1.5, lines 1, 16 and 19. Accessed August 18, 2010.

Figure 2 GDP, imports volume index, expenditure approach, OECD.Stat table VIXOBSA, lines B1 GE, P6 and P7. Goods GDP quantity index, BEA NIPA Table 1.2.3, line 4. Accessed April 2nd, 2010.

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