The Rise of Vertical Specialization Trade

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Abstract

Manufacturing and vertical specialization (VS) trade, trade in goods that incorporate imported inputs, has grown rapidly since the 1960s. I argue that declining trade costs are an important explanation for these facts. I present a three stage vertical specialization trade model, with raw materials, manufactured parts and final goods sectors. In the simulated model, falling trade costs explain much of the observed growth in overall and VS trade. Manufacturing trade grows twice as fast as overall trade. Raw materials trade was more important in the 1960s when trade costs were high, since their production is more strongly linked to endowments than manufacturing. Therefore, materials will be traded even when trade costs are high. Trade costs have fallen more for manufactured goods over the last 40 years, leading to a rapid expansion of manufactured parts trade relative to materials.

JEL classification: F1.

Keywords: Trade costs; Vertical specialization; Manufacturing trade.

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1 Introduction

The share of merchandise output that is internationally traded has significantly increased in the last fifty years. The share of U.S. goods output that is exported tripled between 1960 and 2006. At the same time, the structure of trade has changed.

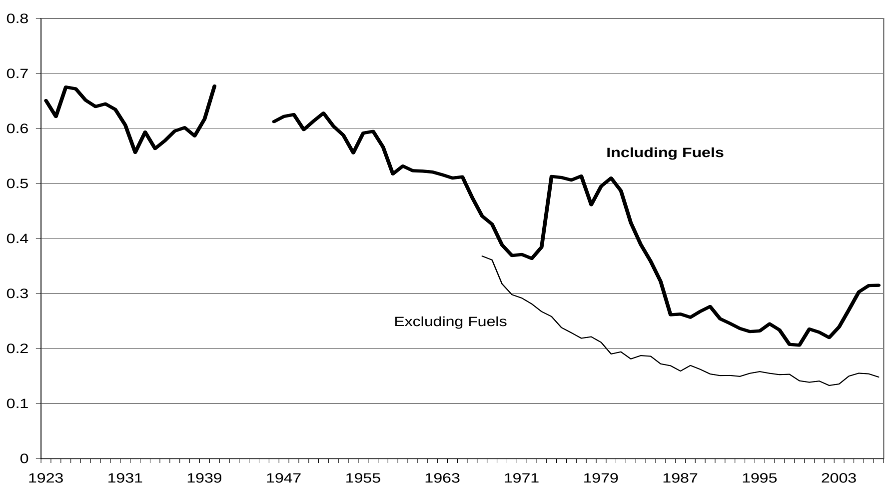
Trade in manufactured goods has expanded rapidly (Bergoeing, Kehoe, Strauss-Kahn & Yi 2004). U.S. manufacturing export share of GDP grew by 140 percent between 1960 and 2006. The share of manufacturing output that is exported quadrupled during that period. This fact is puzzling given that manufacturing has not grown as a nominal share of output. Early on, when manufacturing was a large part of production, there was little trade in manufactured goods. Later, when manufacturing declined in importance, trade became dominated by trade in these goods.

At the same time, vertical specialization (VS) trade, trade in goods incorporating imported inputs, has expanded rapidly. VS trade in the United States grew from 6 percent of exports in 1972 to 14 percent in 1997 (Feenstra 1998, Hummels, Rapoport & Yi 1998, Hummels, Ishii & Yi 2001). As documented by Chen, Kondratowicz & Yi (2005), VS trade growth is not due to a large increase in the share of intermediate goods trade. They find that share of trade accounted for by intermediate goods has been nearly constant since 1972. While this fact may be initially somewhat surprising, a glance at the types of goods traded 50 years ago explains why. Trade in the early postwar period and earlier was dominated by intermediate goods, particularly raw materials such as ores and lumber. In 1963, the only industries with more than 10 percent of domestic supply from imports were mining and forestry industries (Walderhaug 1973).

However, there has been a significant change in the types of intermediate goods traded. Figure 1 shows the share of U.S. imports made up of industrial supplies using the BEA's end use nomenclature. Imports are dominated by such supplies early in the period, making up almost two thirds of imports. In the mid-1960s, the composition of imports began to shift significantly. Industrial supplies fell from over half of imports in the 1965 to less than a quarter in the 1990s. (The spike in share in the mid-1970s is due to the run up in oil prices, as demonstrated by the non-fuel supplies share.)

Accounting for the increase in VS trade is important since there has been concern that offshoring has led to overestimation of productivity growth by undercounting imports. (For example, see Houseman (2007).) Understanding this question is important for determining the degree to which imports and output are mismeasured. Source data for goods trade is measured in gross output terms. With VS trade, a portion of exports consists of imported inputs. If these imported inputs are not properly accounted for, net exports (and national output) will be mismeasured since the value of exports will in part incorporate the value of imported inputs. A similar effect holds for imports incorporating exported inputs. Properly accounting for the degree of offshoring may lead to improvements in the measurement of the net exports by removing the impact of traded inputs on the level of international trade.

Figure 1: U.S. Imports of Industrial Supplies, 1923-2007



This paper examines the importance of changes in trade costs for the changes in the composition of international trade, specifically the increasing importance of VS and manufacturing trade. I argue that the rise of manufacturing and VS trade are related: Both are driven by falling costs of trading manufactured parts. The 1960s coincide with the implementation of the Kennedy Round along with other trade deals, such as the U.S.-Canada Auto Pact, that shifted trade policy away from protecting manufacturers. Tariffs were low on these raw materials and high on manufactured goods. The Kennedy Round focussed on cutting tariffs on manufactures. This round of the GATT was notable both for the size of the tariff reductions and the fact that it widely covered manufactures. Since then, trade policy has gone from being biased against manufactured goods to being more neutral.

Prior to the Kennedy Round, trade was dominated by low value raw materials. Raw materials were imported despite being expensive to ship because the ability to produce them is strongly linked to endowments. Therefore, materials cannot not reliably be replaced domestically and were essential for production. Manufactured goods are easier to replace with a domestic good since they are less dependent on endowments.

This paper presents an expanded version of the tractable general equilibrium model with Ricardian trade in intermediate goods found in Bridgman (2008*a*). There are two countries with three layers of production: Raw materials which are inputs to intermediate goods, which in turn are inputs to final consumption goods. All three types of goods may be traded, but incur an iceberg transportation cost and may face tariffs. I calibrate the model and run simulations using data on freight costs and tariffs.

The simulated model nearly all of the empirical growth in trade and the change in composition, accounting for over two thirds of the increase in both total and manufacturing trade from 1967 to 2002. Manufacturing trade grows much faster than overall trade growth. While overall share of goods output that is traded more than doubles between 1967 and 2002 in the baseline simulation, manufacturing trade share triples. VS trade also grows rapidly, doubling from 1972 to 1997. In the 1960s, manufactured goods faced higher tariffs than raw materials. Beginning with the Kennedy Round of the GATT, manufactured goods tariffs fell more rapidly than non-manufactured goods. Lower trade costs on manufactured parts led to an rapid expansion of VS trade.

While VS trade grows rapidly, the share of trade that is in intermediate goods does not increase. Intermediate goods trade shifts from being dominated by raw materials to manufactured parts. Raw materials production tends to depend on local geographical conditions in a way that manufacturing does not. Mines can only be sited where ore exists naturally. Geography is also important for agricultural and forestry goods. Manufacturing is much less tied geographic conditions. Therefore, raw materials will be traded even when trade costs are high. Combined with the fact that trade costs for raw materials fell less, most of the new trade in goods is due to new trade in manufactured parts.

I find that the rise of offshoring of manufactured parts is due in large part to changes tariffs. Examining the impact of tariffs and transportation costs separately, falling tariffs have a stronger effect on the growth of both manufacturing and VS trade. Specifically, falling tariffs on manufactured parts lead to their trade in international markets while falling freight alone does not.

The paper also contributes to the historical measurement of the structure of trade protection. Examples include Anderson (1972) and Irwin (2007). It presents estimates of trade costs of goods by final and intermediate uses. Supplementary tables used in the calculation of the input-output (IO) tables provide estimates of trade costs by IO commodity. These supplementary tables can be combined with the IO tables to generate estimates of the structure of protection. U.S. foreign trade statistics do not provide detailed data on freight costs before 1974, so historical data on this issue are very thin (Hummels 2007).

This paper contributes to the large literature investigating postwar trade growth, including Rose (1991), Krugman (1995), Baier & Bergstrand (2001), Bergoeing & Kehoe (2003) and Alessandria & Choi (2009). Models incorporating VS trade, such as Yi (2003) and Bridgman (2008*a*) have been successful at resolving the puzzle that tariffs have not fallen enough to generate the observed trade growth given estimates of the Armington elasticity (Armington 1969), the aggregate elasticity of substitution between domestic and foreign goods. (Erkel-Rousse & Mirza (2002) provide a summary of this literature.) However, they have not emphasized the structure of trade expansion. While Bergoeing et al. (2004) speculate that a VS model could generate that change in composition, they do not pursue the issue.

This paper is also part of a literature examining the impact of the structure of protection on economic performance. Estevadeordal & Taylor (2008) argue that openness of inputs and capital goods improved growth in Latin America. Lehman & O'Rourke (2008) argue that high agricultural tariffs reduce growth. Beginning with Balassa (1965), a related literature measures effective protection, the protection on an industry's value added.

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 2008). Grossman & Rossi-Hansberg (2008*a*) and Grossman & Rossi-Hansberg (2008*b*) examine the growth of trade in intermediate services. A number of papers have used input-output tables to examine the factor content of trade, including Trefler & Zhu (2000) and Ravn & Mazzenga (2006). Theoretical models of vertical specialization trade include Dixit & Grossman (1982) and Sanyal (1983). Unlike these papers, I examine the change in the composition of intermediates trade.

2 The Structure of Protection

This section examines the structure of protection from tariffs and transportation costs for intermediate and final goods. One way to distinguish between the two types of goods is to partition goods into one category or the other. This approach is used by Estevadeordal & Taylor (2008), for example. This approach is relatively easy to implement, particularly since the Brussels Tariff Nomenclature used by a large number of countries during the Twentieth Century does this partitioning. In reality, goods are not intrinsically intermediate or final goods: A tire can either depending whether it is sold to a car company or a consumer. Trade statistics do not record to whom goods are sold, so we cannot distinguish directly.

An alternative approach (when the data are available) is to use the input output tables to split goods by use, the approach used by Campa & Goldberg (1997) and Hummels et al. (1998). I use this method to estimate the rates of protection on goods by use. The tariff and transportation margins on imports are calculated as a supplementary table in the compilation of the input-output tables, since the margins need to be allocated to their producing industries: Wholesale trade for tariffs and transportation services for transportation. This table is not reported for all benchmark years, but they are for 1967 (pre-Kennedy Round) and 1972 (post-Kennedy Round). They can also be calculated for 1992, 1997 and 2002.

These margins are matched to the input-outputs tables[1]. I assume that imported commodities are used at the same rate for intermediate and final production as aggregate supply of that commodity. This assumption is equivalent to assuming that the imported share of a commodity is the same for both final and intermediate goods[2]. The trade weighted import cost is given by:

$$\frac{\sum_i \tau_i y_i^{Imp} s_i^{Use}}{\sum_i y_i^{Imp} s_i^{Use}} \tag{2.1}$$

where τ_i is the tariff rate, y_i^{Imp} is imports and s_i^{Use} is the share of the domestic supply of commodity i that for that use (intermediate or final). Freight costs f_i are weighted in a similar fashion.

As can be seen from Table 1, tariffs prior to the Kennedy Round protected manufacturers and allowed raw materials to enter at relatively low tariffs. (The Kennedy Round was agreed to in 1967 and implemented over the next five years, so the 1967

[1] The appendix provides detail on data sources and calculations.

[2] This assumption is widely used in the literature. For example, the OECD uses it to split the IO tables into domestic and foreign sources.

Table 1: Weighted U.S. Import Costs

Variable	1967	1972	1992	1997	2002
All Imports					
Tariff	7.1	5.9	2.6	2.2	0.7
Freight	7.4	5.3	4.0	3.3	3.4
Interm. (Mfg.)					
Tariff	7.1	5.8	2.7	2.0	0.8
Freight	7.3	4.9	4.1	4.4	3.9
Interm. (Non-Mfg.)					
Tariff	4.1	3.1	0.4	0.9	0.1
Freight	10.8	9.9	10.9	7.1	3.5
Final					
Tariff	8.6	6.4	2.6	2.4	2.1
Freight	5.8	4.7	3.4	2.8	2.3

to 1972 comparison gives an indication of its effects.) This tariff structure was a long standing feature of trade policy (Irwin 2007). Since then, trade policy has become more neutral with all goods facing similar, low tariffs.

The discriminatory tariff rates are to a large degree undone by higher freight costs for non-manufactured goods. Most raw materials are bulky and low value. This finding is consistent with the findings of Yeats (1977). As found in Hummels (2007), freight rates have not fallen as rapidly as tariffs. There are significant differences across types of goods. Freight costs for manufactured goods have fallen by much more than for raw materials. Manufactured goods freight costs fell in half while raw materials show no downward trend. This finding is consistent with the containerization revolution reducing the cost of non-bulk items (Levinson 2006).

The overall protection profile (tariffs plus freight) has gone from somewhat protecting manufacturing and final goods producers to protecting raw materials producers.

The tariffs on all goods have declined nearly to zero. Freight for manufacturing has fallen while it has not for materials[3].

Why would tariffs on parts, an input, be high? Firms that produce final goods often produce parts as well. Firms lobbying for protection in final goods may have an incentive to protect upstream production. Whether final goods maker also makes its own parts or outsources the task depends on a number of issues, including government policy and productivity. (For example, General Motors has vertically integrated and disintegrated a number of times over the years.) However, the technology to manufacture parts is likely to be more similar to final goods manufacturing than raw materials production, so is more likely to be vertically integrated. Therefore, firms lobbying for protection for final manufactured goods may also ask for manufactured parts protection.

Since these are trade weighted measures, they suffer from some well-known limitations. High trade cost goods are likely to be traded less than low trade cost goods. (See Anderson & van Wincoop (2004) for a survey of the problems of aggregating trade costs.) A particular issue with this measure in this context is that there has been significant trade growth along the extensive margin: trade in new goods (Kehoe & Ruhl 2002). Therefore, there are a significant number of goods whose trade costs are not measured in the early years. Bridgman (2008*b*) shows that for freight, lower trade costs induce lower value goods to be traded which masks changes in trade costs. In the calibration of the model, I will make an adjustment for this effect.

[3] The significant decline in non-manufacturing intermediate freight costs in 2002 is largely due to the run up in oil prices. Excluding oil products raises the freight rate to 5.7 percent. Bridgman (2008*b*) shows that freight rates for oil are negatively related to oil prices, since rates are charged by volume.

3 Model

3.1 Households

There are two countries each with a representative household. Households have preferences over a consumption good represented by:

$$U = [\sum_{j=1,2} \phi^i_j (C^i_j)^\rho]^{\frac{1}{\rho}} \tag{3.1}$$

where C^i_j denotes consumption good $j \in \{1,2\}$ for country $i \in \{1,2\}$, $\phi^i_j = \phi$ if $j = i$ and $\phi^i_j = 1 - \phi$ and if $j \neq i$. The associated prices are $P^i_{c,j}$. Each country is endowed with labor N^i. The wage is W^i.

3.2 Raw Materials Sector

Each country can use labor N^i_m to produce a raw material good M^i_j with a price $P^i_{m,j}$. Each country can only produce the good with its name: $j = i$. Output is given by $Y^i_m = A^i_m N^i_m$.

3.3 Manufactured Parts Sector

There is a continuum of manufactured parts $x^i(z)$ with a price $P^i_{x,j}(z)$ for $z \in [0,1]$. Each country is endowed with technologies that combine materials inputs $M^i_j, j \in \{1,2\}$ and labor $N^i_x(z)$ to produce parts. Total output of part z is given by:

$$Y^i_x(z) = A^i_x(z)(N^i_x(z))^\alpha((\sum_j (M^i_j(z))^\sigma)^{\frac{1}{\sigma}})^{1-\alpha}. \tag{3.2}$$

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*a*) which is based on Dornbusch, Fischer & Samuelson (1977) and Eaton & Kortum (2002).

3.4 Consumption Goods Sector

Manufactured parts can be assembled into consumption goods using labor N^i_c. As with material goods, each country can only produce the good with its name: $j = i$. The total output is given by the technology:

$$Y^i_{c,j} = A^i_c (N^i_c)^{\alpha_c} (\int_0^1 ln(x^i(z))dz)^{1-\alpha_c} \tag{3.3}$$

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

3.5 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 $k \in \{m, x, c\}$.

3.6 Government

The countries each have a government that can impose an ad valorem (net of transport fees) tariff τ^i_k on traded goods $k \in \{m, x, c\}$. 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

$$\sum_j P^i_{c,j} C^i_j = W^i N^i + T^i \tag{4.1}$$

Materials firms buy labor and sell materials. They face competitive markets and solve:

$$Max P^i_{m,i} A^i_m N^i_m - W^i N^i_m \tag{4.2}$$

Manufactured parts firms face competitive markets and solve:

$$MaxP_i^i(z)A_x^i(z)(N_x^i(z))^\alpha((\sum_j(M_j^i(z))^\sigma)^{\frac{1}{\sigma}})^{1-\alpha} - W^iN_x^i(z) - \sum_j P_j^iM_j^i(z) \tag{4.3}$$

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

$$MaxP_{c,i}^iA_c^i(N_c^i)^{\alpha_c}(\int_0^1 ln(x^i(z))dz)^{1-\alpha_c} - W^iN_c^i - \int_0^1 P^i(z)x^i(z)dz \tag{4.4}$$

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

$$MaxP_{m,i}^{-i}M_i^{-i} - P_{m,i}^iM_i^i(1+f_m) \tag{4.5}$$

where $P_{m,i}^{-i}$ is the price of the materials in the other country. Parts and consumption goods exporters solve a similar problem.

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

$$f_c^jC_{-j}^j + \sum_{i=1,2} C_j^i = Y_c^j \tag{4.6}$$

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

$$N^i = N_c^i + N_m^i + \int_0^1 N_x^i(z)dz \tag{4.7}$$

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. *Materials, parts, consumption goods 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 $k \in \{m, x, c\}$ and are constant across the two countries, there exists an equilibrium where $C_1^1 = C_2^2$, $C_1^2 = C_2^1$, $P_{m,1}^1 = P_{m,2}^2$, $W^1 = W^2$, $P_{c,2}^1 = P_{c,1}^2$ and $P_{c,1}^1 = P_{c,2}^2$. Prices and quantities in the parts and materials 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 material good to one ($P_{m,1}^1 = 1$). This implies that the wage $W^1 = \frac{1}{A_m}$. 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,

$$\overline{z}_1 = 1 - \overline{z}_2 = \frac{2(1+\tau_x+f_x)^{\frac{1}{\theta}} - 1}{(1+\tau_x+f_x)^{\frac{1}{\theta}} + 1} \tag{4.8}$$

Parts exports are given by:

$$\frac{\overline{z}_2}{(1+\tau_x+f_x)} \frac{(A_mN+T)[1+f_x+(1+\tau_x+f_x)^{\frac{1}{1-\rho}}]}{[1+\tau_x+f_x+(1+\tau_x+f_x)^{\frac{1}{1-\rho}}]}. \tag{4.9}$$

Consumption goods exports are given by:

$$C_2^1 = C_1^2 = \frac{A_mN+T}{P_c[1+\tau_c+f_c+((1+\tau_c+f_c)\frac{\phi}{1-\phi})^{\frac{1}{1-\rho}}]} \tag{4.10}$$

where $P_{c,1}^1 = P_{c,2}^2 = P_c$.

Tariffs in the United States are collected on the FOB value of goods (the value before transport costs are added). Therefore,

$$T = \frac{\tau_m A_m N(\frac{1}{1+\tau_m+f_m})^{\frac{1}{1-\sigma}}}{[1++(\frac{1}{1+\tau_m+f_m})^{\frac{\sigma}{1-\sigma}}]}(1-\alpha)(\overline{z}_1+(1+f_x)\overline{z}_2) + NA_m\tau_x(1-\overline{z}_1) + \frac{A_m N\tau_c}{[1+\tau_c+f_c+((1+\tau_c+f_c)\frac{\phi}{1-\phi})^{\frac{1}{1-\rho}}]} \quad (4.11)$$

5 Results

5.1 Calibration

This section presents the parameter selection for the model. In the calibration, I follow the convention of Yi (2003) 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 parts and consumption production α and α_c 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.

The Armington parameter ρ is set to match the long run trade elasticity of 6.4 estimated in Ruhl (2005). The relative productivity parameter θ and home bias parameter ϕ are selected by grid search to match the level of VS trade in 1972 and share of manufacturing output that is exported in 1967 respectively given the other parameters. Model VS trade is measured as the sum of the three sources of VS trade: Materials imports that are exported in parts ($(1-\overline{z}_2)P_1^{m,2}M_1^2$), imported parts in exported final goods ($(1-\overline{z}_2)P_2^1C_2^1$) and imported materials in domestic parts used in exported final goods ($P_1^1C_2^1\frac{P_1^{m,2}M_1^2}{P_x^1(0)x^1(0)}\overline{z}_2$). Note that this definition does not include goods that are exported that are reimported. While this is an important source of VS trade (see Johnson & Noguera (2008)), it is omitted from the data sources I use.

Tariffs and freight rates are taken from Table 1. I use non-manufacturing intermediate goods for raw materials, manufacturing intermediate goods for parts and manufacturing final goods for final production.

As discussed above, it is well known that trade-weighted measures underestimate total costs since the goods that are the most costly to trade are traded the least. A measure of the size of this bias for tariffs is the Mercantilist Trade Resistance Index (MTRI) proposed by Anderson & Neary (2003), which is the estimated uniform tariff equivalent that generates the observed level of trade. I scale up trade costs by 1.69, the ratio of MTRI that Kee, Nicita & Olarreaga (2005) estimates to trade-weighted tariffs for the United States in 2002[4]. These estimates only cover tariffs. I am not aware of any MTRI estimates for transport costs. Anderson & van Wincoop (2004) note that transport costs are similar to tariffs in magnitude and variability, so a tariff based estimate is likely to be a reasonable proxy for bias in transport cost measures.

The baseline parameters are summarized in Table 2.

Table 2: Baseline Parameters

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

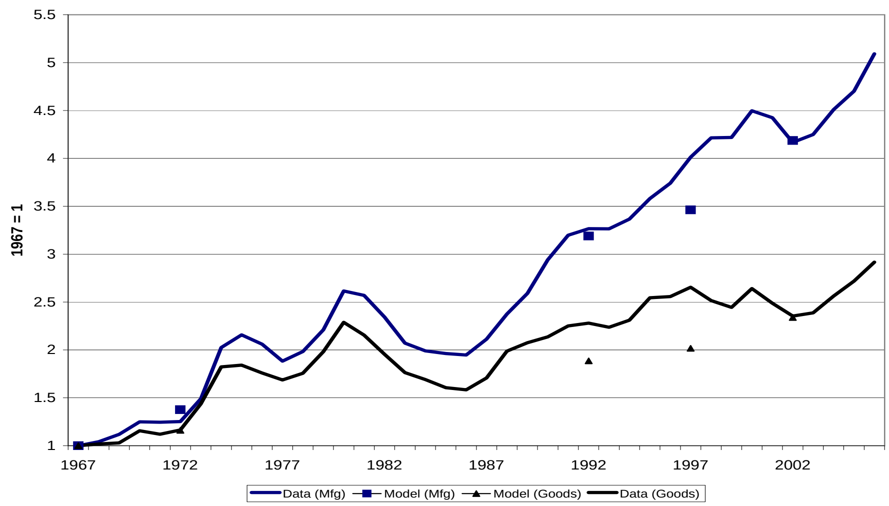
5.2 Simulations

This section presents the results of the calibrated model. In interpreting the results, I identify the raw materials sector as non-manufacturing output and the manufactured parts and final goods sectors as manufacturing output.

The model is able to match a number of trade growth facts. It generates both the empirical growth in trade and the change in composition.

[4] Irwin (2007), using the closely related Trade Resistance Index, estimates the ratio in 1960 was 1.74 which suggests the bias hasn't changed too much over the sample period.

Figure 2: U.S. Exports/Value Added, Model and Data 1967-2006



As can be seen from Figure 2, the model does a good job of matching the empirical trade growth. The share of goods production that is exported in the model grows 133 percent from 1967 to 2002, nearly identical to the actual growth in export share of 135 percent. Even in 1997, the year that the model misses the data the most, it predicts 76 percent of total and 86 percent of manufactured trade growth in the data. Both tariffs and freight costs fall, leading to expanding trade. The model is able to generate a doubling the trade share with a relatively modest the fall in trade costs and Armington elasticity. As noted above, most standard models (that exclude VS trade) are unable to generate such significant trade growth.

The model is able to generate such strong growth because of the rapid expansion of manufacturing trade. The share of manufacturing output that is exported in the model grows much faster than total trade, growing by 319 percent between 1967 and 2002. This growth is very close to the 317 percent empirical growth in the share of manufacturing output. This growth is mostly due to increasing trade in manufactured parts. Of the three types of goods, manufactured parts grows the fastest. In 1967, there is no trade in parts. By the 1990s, this category is over half of manufacturing trade.

Table 3: Results

Variable	**Model**	**Data**
VS Trade 1997	18.9	14.1
Mat. trade share (67-02)	12.1%	26.0%
Interm. Trade Share 1972	53.4%	50.4%
Interm. Trade Share 1997	55.9%	51.9%
Interm. Share Mfg. Trade 1997	42.5%	30.7%

As a consequence of the rapid rise in manufactured goods trade, VS trade also grows rapidly. VS trade increases from 6 percent in 1972 to almost 19 percent in 1997. The model is not too far off from the estimate in Chen et al. (2005). In the 1960s, manufactured goods faced higher tariffs than raw materials. Beginning with the Kennedy Round of the GATT, manufactured goods tariffs fell more rapidly than non-manufactured goods. Lower trade costs for manufactured parts led to an rapid expansion of VS trade.

While VS trade grows rapidly, intermediate goods trade does not increase significantly. This prediction matches the data in that intermediate goods share of trade is roughly constant over most of the period. The model predicts that 61 percent of trade is in intermediate goods in 1967 which is close to its prediction of 56 percent in 2002. Therefore, the rise of VS trade in the model is not driven by a relative increase in intermediates trade. The level is similar to estimates of Chen et al. (2005). They estimate intermediates were about half of trade (50.4 percent in 1972 and 51.9 in 1997), close to the model's predictions (53.4 percent in 1972 and 58.6 in 1997).

Intermediate goods trade shifts from being dominated by raw materials to manufactured parts. The share of materials output that is exported grows by only 12 percent, even lower than the 26 percent in the data. Almost all the growth in VS trade is due to the rise of parts trade. Raw materials production tends to depend on local geographical conditions in a way that manufacturing does not. The lack of strong comparative advantage is represented by the low value of θ. Mines can only be sited where ore exists naturally. A steel plant can be placed anywhere. Therefore, raw materials will be traded even when trade costs are high. Combined with the fact that trade costs for raw materials fell less, most of the new trade in goods is due to new trade in manufactured parts. This feature of the model is consistent with empirical finding that goods lower down the supply chain have lower price-trade elasticities (Balassa & Kreinin 1967).

The model is consistent with the finding that parts and component trade has grown more rapidly than manufacturing trade (Yeats 2001). Parts are a growing part of manufacturing exports. From only 1992 to 1997, they went from 27 to 31 percent of U.S. manufacturing exports (Athukorala & Yamashita 2006). The model predicts that 43 percent of manufacturing trade is in parts in 1997, which is a good deal higher. However, the measure of parts trade is only that with is labeled as such in the trade data, either because it was coded as part of an Offshore Assembly Program or was classified in a parts category. Therefore, there may be unmeasured parts trade that do not fall into these categories.

It is not the case that geography does not matter for manufacturing. Manufacturing plants are more likely to be built within a country close to cheap transportation hubs, such as ports, rivers or rail centers. However, manufacturing is less tied to geographic endowments relative to raw materials. Even industries that use inputs that are closely tied to natural endowments, such as steel and refined sugar, are often placed far from the sources of those inputs. For example, Japan became a major steel producer despite not producing iron ore domestically. It imports the ore from Australia. The center for cane sugar refining in the United States was New York City. New Orleans, a major port close both to domestic and imported raw sugar sources, was a minor producer (Glaeser 2005).

The results may explain why trade among industrial countries has increased, despite having similar industrial structures. In the 1960s, when trade is dominated by goods that depend heavily on endowments, less developed countries (LDCs) whose economies are dominated by raw materials production make up more of world trade. Since they do not have a significant industrial base, they are less able to take part in the rise of VS trade. In addition, the early rounds of the GATT did not include many LDCs, further isolating them from VS trade. This explanation does not rely on increasing returns or agglomeration economies, as in Krugman (1980), to explain the concentration of trade among similar countries.

In fact, it is precisely because productivity differences in parts production between industrialized countries are small that causes relatively small declines in trade costs to have such a large impact on trade growth. Since the productivity differences in tradeable goods between rich and poor countries are large (Herrendorf & Valentinyi 2007), even high trade barriers (such as those used by import substitution programs) are not sufficient to prevent poor countries from specializing in materials production.

5.2.1 Offshoring: Policy or Technology?

An issue that has generated significant interest is the process of offshoring, the shift of production from domestic to foreign sources. (For example see Bhagwati, Panagariya & Srinivasan (2004).) The model provides a laboratory for examining this issue since the model generates offshoring in parts production. The process of Ricardian specialization concentrates output in fewer industries. The amount of offshoring is measured by the cut-off $\overline{z}$. The measure of offshored industries in the symmetric equilibrium is given by $1 - \overline{z}_1 = \overline{z}_2$.

The model provides clues as to why concern over the impact of offshoring has grown recently. The baseline model predicts that all possible domestic industries operate in 1967. As trade expands, the set of industries that a country operates contracts. By 2002, 26 percent of domestic parts manufacturing industries have closed. (In terms of the model, $\overline{z}_1(2002) = 0.74$.) The process accelerates over the period. In the 25 years between 1967 and 1992, 17 percent of parts industries close ($\overline{z}_1(1992) = 0.83$), or 0.68 percent a year. Another 11 percent of the remaining parts industries close in the final ten years from 1992 to 2002, over 1 percent a year.

In the model, shifting labor from one sector to another is frictionless which abstracts from the costs that workers and capital owners face in reality. For example, Kletzer (1998) finds that displaced workers earn about 15 percent lower wages. (See Davis & Harrigan (2008) for a model that incorporates these frictions explicitly in a trade model.) The increased concern over "globalization" may reflect recent increasing pressure on certain manufacturing industries. More workers and capital owners in these industries are faced with the adjustment costs as production shifts overseas.

The model allows us to decompose the importance of the various trade costs for the increase in offshoring. Falling tariffs brought about by World Trade Organization and regional trade pacts such as NAFTA are widely cited as the primary reason for increasing trade and offshoring. Others, such as Levinson (2006), have suggested that improvements in shipping technology such as containerization are a first order source of increasing trade[5].

Table 4: Counterfactuals

Variable	**1967 Tariffs**	**1967 Freight**	**1967 Parts Tariffs**
Total Trade Growth 1967-2002	18.6%	65.4%	71.1
Mfg. Trade Growth 1967-2002	35.6%	156.9%	157.1
$\overline{z}_1$	1	0.89	1

To examine the relative importance of these two forces, I run a number of counterfactual simulations holding trade costs at their 1967 levels. The first counterfactual simulation (1967 Tariffs) reported in Table 4 holds all tariffs at their 1967 levels. Freight costs fall as they do in the baseline simulation. We can see that falling tariffs are essential for generating the observed trade expansion. Falling freight costs alone generate very little trade growth.

[5]Technological change may improve transportation is ways that are not reflected in price, such as increasing reliability (Hummels 2007). The importance of timeliness is emphasized by Harrigan & Venables (2006).

The next simulation (1967 Freight) does the opposite: It holds freight rates at their 1967 levels while tariffs fall as they do in the baseline. Trade growth is much stronger, indicating a stronger role for tariffs.

There is an interaction effect between the two trade costs. Trade growth in baseline is much higher than the sum of the two counterfactuals. Total trade grows 134 percent in the baseline as opposed to a sum of 84 percent across the counterfactuals. An important source of trade growth is trade in new manufactured parts. Falling freight or tariffs alone are insufficient to cause some of the goods to be traded.

These results indicate that trade liberalization had a significant role in changing industrial structure. Tariffs are a more important source of extensive margin trade growth. Falling freight costs alone cannot induce parts trade while falling tariffs do. Table 4 shows that the 1967 Tariffs counterfactual does not cause any of the manufactured parts to be traded, while there is parts trade in the 1967 Freight counterfactual. In terms of model quantities, $\overline{z}_1$ does not fall from one in the 1967 Tariffs counterfactual while it falls to 0.89 in the 1967 Freight counterfactual. In fact, simply maintaining tariffs on manufactured parts at their 1967 levels (the counterfactual named "1967 Parts Tariffs" in Table 4) is sufficient to prevent trade in parts through 2002 ($\overline{z}_1 = 1$). While manufactured goods trade still grows significantly due to growing finished goods trade, there is no trade in parts.

6 Conclusion

This paper shows that trade costs can explain the change in the composition of international trade. However, it does not consider alternative causes of VS trade growth. Improvements in technology, both production (allowing better standardization) and communication (allowing better coordination across locations), may have had a role. Financial liberalization has encouraged foreign direct investment, allowing firms to offshore while keeping production within the firm. Trade among affiliated firms within multinationals has been an important source of trade growth. However, the strength of the results suggest that trade costs would remain a significant source of the rise in VS and manufacturing trade even if other sources were considered.

A Data

A.1 Figure 1

Imports One digit end use category. 1923-1966: Lechter (1971), Table 2. 1967-2007: NIPA Table 4.2.5.

A.2 Figure 2

Exports NIPA Tables 1.2.5 and 4.1.

A.3 Table 1

IO Tables Benchmark Input-Output tables are drawn from the BEA Industry Economic Accounts website. The 1967 and 1972 tables are the 85-industry total requirements tables. The 1992, 1997 and 2002 are the Use Tables at the detailed level after redefinition.

Import Margins: 1967 & 1972 The imports and trade costs are reported in U.S. Department of Commerce (1977), Table 1b for 1967 and Ritz, Roberts & Young (1979), Table D for 1972.

Import Margins: 1992, 1997 & 2002 Import, duties and freight data come from Feenstra (1994) and U.S. International Trade Commission (dataweb.usitc.gov). This data is concorded into the IO classification. The 1992 concordance is an unpublished concordance provided by BEA's Industry Economic Accounts. The 1997 and 2002 concordances are taken from the BEA website.

Calculation Commodities originating from service industries and government are excluded: Two digit IO Industries 65-79 (1967/72/92) and one digit industries 4-9 and two digit industry 22 (Utilities) (1997/2002). Manufacturing industries are two digit IO industries 13-64 (1967/72/92) and one digit industry 3 (1997/2002).

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