Trade and the Global Recession*

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PRELIMINARY AND INCOMPLETE

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Abstract

The ratio of global trade to GDP declined by nearly 30 percent during the global recession of 2008-2009. This large drop in international trade has generated significant attention and concern. Given the severity of the recession, did international trade behave as we would have expected? Or alternatively, did international trade shrink due to factors unique to cross border transactions? This paper merges an input-output framework with a gravity trade model and solves numerically several general equilibrium counterfactual scenarios which quantify the relative importance of changes in demand, trade frictions, and other shocks in the current recession. Our results suggest that the relative decline in demand for manufactures was the most important driver of the decline in manufacturing trade. Changes in demand for durable manufactures alone accounted for 65 percent of the cross-country variation in changes in manufacturing trade/GDP. The decline in total manufacturing demand (durables and non-durables) accounted for more than 80 percent of the global decline in trade/GDP. Trade frictions increased and played an important role in reducing trade in some countries, notably China and Japan, but decreased or remained relatively flat in others. Globally, the impact of these changes in trade frictions largely cancel each other out.

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1 Introduction

According to the World Trade Organization, the value of global merchandise trade in 2009 contracted by 23 percent: four times the size of the second largest annual percentage drop since World War II. Peak to trough, estimates suggest that the ratio of global trade to GDP declined by nearly 30 percent.\footnote{The global trade index was obtained by multiplying the world trade volume index by the world trade price index available from the Netherlands Bureau for Economic Policy Analysis. This index was divided by our own estimations of world GDP.} The four panels of Figure 1 plot the average of imports and exports relative to GDP for the four largest countries in the world: U.S. Japan, China, and Germany. Trade to GDP ratios sharply declined in the recent recession in each of these economies.

This large drop in international trade has generated significant attention and concern, even against a backdrop of plunging final demand and collapsed asset prices. For example, Eichengreen (2009) writes, "The collapse of trade since the summer of 2008 has been absolutely terrifying, more so insofar as we lack an adequate understanding of its causes." International Economy (2009) asks in its symposium on the collapse, "World trade has been falling faster than global GDP – indeed, faster than at any time since the Great Depression. How is this possible?" Dozens of researchers posed hypotheses in Baldwin (2009), a timely and insightful collection of short essays aimed at the policy community and titled, "The Great Trade Collapse: Causes, Consequences and Prospects."

Given that the share of spending on tradables typically drops during recessions, it is not surprising that the ratio of trade to GDP also typically declines in recessions. Figures 2 and 3 show proxies for growth in manufacturing spending relative to GDP in the left columns, and growth in non-oil imports relative to GDP in the right columns, for these same four largest countries.\footnote{Due to data limitations, China's plots are of manufacturing production / GDP and manufacturing imports / GDP.} These ratios are highly procyclical. The datapoints from the recent recession are plotted with red squares, distinguishing them from historical data plotted with blue circles. The squares in the plots of imports/GDP are often right along the regression line, such as for the United States and Germany, and are occasionally below the line, particularly for Japan and China, indicating a surprisingly large drop in trade. These simple summary relationships suggest cyclical factors are...
crucial in understanding the decline in global trade flows. Given the relationships are quite noisy, however, it is difficult to determine whether the unprecedentedly large decline in trade is simply a reflection of the unprecedentedly large drop in GDP, or whether additional forces are driving down global trade flows.

What is at stake in determining the culprit? Imagine that nothing unique to cross-border trade occurred, so that international trade behaved as expected given the severity of the recession. In this version of events, international trade data could only contribute to our understanding of the cross-country transmission, but not the amplification, of the recent global recession. Now, instead, imagine that an increase in international trade frictions, such as the reduced availability of trade credit, protectionist measures, or the home-bias implicit in stimulus measures, were largely to blame for the decline in trade flows in the recent episode. In this scenario, in addition to the initial shock that led to a decline in final demand, there would be negative effects from the higher prices of imported goods. The decline in international trade would itself be important to understanding the mechanics and welfare consequences of the recent recession.

This paper aims to quantify the relative contributions of these explanations, both globally and at the country level. Our conclusion is that the bulk of the decline in international trade is attributable to the decline in the share of demand for tradables. Changes in demand for durable manufactures alone accounted for about 65 percent of the cross-country variation in changes in manufacturing trade/GDP from the first quarter of 2008 to the first quarter of 2009, a period encompassing the steep decline in trade. The decline in total manufacturing demand (durables and non-durables) accounted for more than 80 percent of the global decline in trade/GDP over that same period.

The decline in trade for some countries (and between some country pairs) did exceed what one would expect simply from the changing patterns of demand. Hence, increasing trade frictions reflected an independent contribution to the troubles facing the global economy and played an important role in some countries, particularly China and Japan. Our calculations suggest, however, that other countries saw reductions in trade frictions over this period. Globally, these effects largely cancel out. This result need not be the case in our framework, and is driven by the data over this
period, not the model. When we perform related calculations on data from the Great Depression, we find evidence suggesting a dramatic increase in trade frictions in the early 1930s.

Our analytic tool is a multi-sector model of production and trade, calibrated to detailed global data from recent quarters. We run counterfactuals to determine what the path of trade would have been without the shift in demand away from the manufacturing sectors and without the increase in trade frictions. The spirit of our exercise is similar to that of growth accounting. One might also think of it as an analog for international trade to the "wedges" approach for business cycle accounting in Chari, Kehoe, and McGratten (2007). Just as growth accounting builds and uses a theoretical framework to decompose output growth into the growth of labor and capital inputs as well as a Solow residual term, we build and use our model to decompose changes in trade flows into changes in several factors like demand, deficits, and productivity, as well as changes in trade frictions. Closer to Chari, Kehoe, and McGratten (2007), however, our decomposition relies on model-based general equilibrium counterfactual responses to various shock scenarios.

In theory, our exercise is simple: we wish to tie the decline in final demand for tradable goods to the decline in trade flows in the recent global recession. In practice, we must first deal with three measurement issues: (1) countries have different input-output structures tying trade and production flows to final demand; (2) the country-level accounting must be consistent with changing patterns in bilateral trade flows; and (3) high frequency data are needed.

We solve the first problem by building a multi-sector model with a global input-output structure incorporating country differences. Guided by results such as Engel and Wang (2009) and Lewis, Levchenko, and Tesar (2009) that stress the different cyclical properties of durables and non-durables (generally as well as during the recent recession), we define our sectors as durable manufacturing, non-durable manufacturing, and non-manufacturing. We solve the second problem by merging our global input-output structure with a gravity model of trade. Thus we account for bilateral trade flows between each of 22 countries and the rest of the world, separately for durables and non-durables. Third, we base our measures on monthly data. The decline in trade steepened in the summer of 2008, and reversed sometime in mid-to-late 2009. Annual data would likely miss
the key dynamics of the episode (and complete data for 2009 are just now starting to become available). Using a procedure called "temporal disaggregation," we infer monthly production values from annual totals using information contained in monthly industrial production (IP) and producer price (PPI) indices, both widely available for many countries.

We calibrate our multi-country general equilibrium model to fully account for changes in macroeconomic and trade variables over 4-quarter periods to eliminate seasonal effects. Some global results are shown for many periods, but most of our analyses are done on the period from the first quarter of 2008 to the first quarter of 2009. We focus on trade in the durable and non-durable manufacturing sectors. To quantify the impact of global or country-specific shocks on trade flows in our model, we run counterfactual scenarios and relate the outcomes with what we observe in the data.

2 Trade Decline: Hypotheses

The shorter pieces mentioned above and other academic papers have generated several potential explanations for the decline in trade flows relative to overall economic activity. Levchenko, Lewis, and Tesar (2009), for example, use U.S. data to show that the recent decline in trade is large relative to previous recessions. They present evidence of a relative decline in demand for tradables, particularly durable goods.

Given that many economies’ banking systems have been in crisis, another leading hypothesis is that a collapse in trade credit has contributed to the breakdown in trade. Amiti and Weinstein (2009) demonstrate, with earlier data, that the health of Japanese firms’ banks significantly affected the firms’ trading volumes, presumably through their role in issuing trade credit. Using U.S. trade data during the recent episode, Chor and Manova (2009) show that sectors requiring greater financing saw a greater decline in trade volume. McKinnon (2009) and Bhagwati (2009) also focus on the role of reduced trade credit availability in explaining the recent trade collapse.

In addition to the negative shock to trade credit availability, there are other explanations that suggest something unique is happening to international trade, per se. For example, there are
unsettling signals that protectionist measures have, and may continue, to exert an extra drag on trade.\(^3\) Brock (2009) writes, “...many political leaders find the old habits of protectionism irresistible ... This, then, is a large part of the answer to the question as to why world trade has been collapsing faster than world GDP.” Another hypothesis is that, since trade flows are measured in gross rather than value added terms, a disintegration of international vertical supply chains may be driving the decline.\(^4\) In addition, dynamics associated with the inventory cycle may be generating disproportionately severe contractions in trade, as in Alessandria, Kaboski, and Midrigan (2009, 2010). All of these potential disruptions can be broadly construed as reflecting trade frictions.

Results such as Levchenko et al. and Chor and Manova only analyze U.S. data in partial equilibrium, but are able to use highly disaggregated data which allow for clean identification of various effects. We view our work as complementary to these U.S.-based empirical studies. Our framework has the benefit of being able to evaluate hypotheses for the trade decline in a multi-country quantitative general equilibrium model.

### 3 A Framework to Analyze the Global Recession

We now turn to our general equilibrium framework, which builds upon the models of Eaton and Kortum (2002), Lucas and Alvarez (2008), and Dekle, Eaton, and Kortum (2008). Our setup is most closely related to recent work by Caliendo and Parro (2009), which uses a multi-sector generalization of these models to study the impact of NAFTA.\(^5\) Our paper is also related to Bems, Johnson, and Yi (2010), which uses the input-output framework of Johnson and Noguera (2009) to link changes in final demand across many countries during the recent global recession to changes in trade flows throughout the global system. One crucial difference is that we endogenize changes in bilateral trade shares, an important feature to match the recent experience.

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\(^3\)See www.globaltradealert.org for real-time tracking of protectionist measures implemented during the recent global downturn.

\(^4\)Eichengreen (2009) writes, “The most important factor is probably the growth of global supply chains, which has magnified the impact of declining final demand on trade,” and a similar hypothesis is found in Yi (2009).

\(^5\)Their model contains significantly more sectors and input-output linkages, but unlike our work, does not seek to "account" for changes in trade patterns with various shocks.
We start by describing the input-output structure. Next, we merge this structure with trade share equations from the class of gravity models.

### 3.1 Demand and Input-Output Structure

Consider a world of $i = 1, \ldots, I$ countries with constant return to scale production and perfectly competitive markets. There are three sectors indexed by $j$: durable manufacturing ($j = D$), non-durable manufacturing ($j = N$), and non-manufacturing ($j = S$). The label $S$ was chosen because “services” are a large share of non-manufacturing, although our category also includes petroleum and other raw materials. We let $\Omega = \{D, N, S\}$ denote all sectors and $\Omega_M = \{D, N\}$ the manufacturing sectors.

We only model international trade explicitly for the manufacturing sectors. Net trade in raw materials (themselves not manufactures) is exogenous in our framework. Within manufactures, we distinguish between durables and non-durables because these two groups have been characterized by shocks of different sizes, as documented in Levchenko, Lewis, and Tesar (2009).

Let $Y^j_i$ denote country $i$’s gross production in sector $j \in \Omega$. Country $i$’s gross absorption of $j$ is $X^j_i$ and $D^j_i = X^j_i - Y^j_i$ is its deficit in sector $j$. The overall deficit is:

$$D_i = \sum_{j \in \Omega} D^j_i,$$

while, for each $j \in \Omega$,

$$\sum_{i=1}^I D^j_i = 0.$$

Denoting GDP by $Y_i$, aggregate spending is $X_i = Y_i + D_i$. The relationship between GDP and sectoral gross outputs depends on the input-output structure, to which we now turn.

Sector outputs are used both as inputs into production and also to satisfy final demand. Value-added is a share $\beta^j_i$ of gross production in sector $j$ of country $i$, while $\gamma^j_l$ denotes the share of sector $l$ in among intermediates used by sector $j$, with $\sum_l \gamma^j_l = 1$ for each $j \in \Omega$. Formally, we are
assuming a Cobb-Douglas aggregator of sectoral inputs, with time-invariant parameters.\textsuperscript{6} We offer empirical support for this assumption below.

We can now express GDP as the sum of sectoral value added:

$$Y_i = \sum_{j \in \Omega} \beta^j_i Y^j_i.$$  \hspace{1cm} (1)

We ignore capital and treat labor as perfectly mobile across sectors so that:

$$Y_i = \sum_{j \in \Omega} w_i L^j_i = w_i L_i.$$  

Finally, we denote by $\alpha^j_i$ the share of sector $j$ consumption in country $i$’s aggregate final demand, so that the total demand for sector $j$ in country $i$ is:

$$X^j_i = \alpha^j_i X_i + \sum_{l \in \Omega} \gamma_{ij} (1 - \beta^j_i) Y^l_i.$$  \hspace{1cm} (2)

To interpret (2), consider the case of durables manufacturing, $j = D$. The first term represents the final demand for durables manufacturing as a share of total final absorption $X_i$. A disproportionate drop in final spending on automobiles, trucks, and tractors in country $i$ can be captured by a decline in $\alpha_i^D$. Some autos, trucks, and tractors, however, are used as inputs to make additional durable manufactures, non-durable manufactures, and even services. The demand for durable manufactures as intermediate inputs for those sectors is represented by the second term of (2). The sum of these two terms – demand for durable manufactures used as final consumption and demand for durables manufactures used as intermediates – generates the total demand for durable manufactures in country $i$, $X_i^D$.

It is helpful to define the 3-by-3 matrix $\Gamma_i$ of input-output coefficients, with $\gamma_{ij} (1 - \beta^j_i)$ in the

\textsuperscript{6}To avoid uninteresting constants in the cost functions that follow, we specify this Cobb-Douglas aggregator as:

$$B^j_i = \left( \frac{l^j_i}{\beta^j_i} \right)^{\beta^j_i} \prod_{k \in \Omega} \left( \frac{y^{jk}^i}{\gamma_i^j (1 - \beta^j_i)} \right)^{\gamma_i^j (1 - \beta^j_i)}$$

where $B^j_i$ are input bundles used to produce sector $j$ output. Here $l^j_i$ is labor input in sector $j$, and $y^{jk}^i$ is sector-$k$ intermediate input used in sector-$j$ production.
\(l\)'th row and \(j\)'th column, where we’ve ordered the sectors as \(D\), \(N\), and \(S\). We can now stack equations (2) for each value of \(j\) and write the linear system:

\[
X_i = Y_i + D_i = \alpha_i X_i + \Gamma_i^T Y_i, \tag{3}
\]

where \(\Gamma_i^T\) is the transpose of \(\Gamma_i\) and the boldface variables \(X_i\), \(Y_i\), \(D_i\), and \(\alpha_i\) are 3-by-1 vectors, with each element containing the corresponding variable for sectors \(D\), \(N\), and \(S\). We can thus express production in each sector as:

\[
Y_i = (I - \Gamma_i^T)^{-1} (\alpha_i X_i - D_i). \tag{4}
\]

Through the input-output structure, production in each sector depends on the entire vector of final demands across sectors, net of the vector of sectoral trade deficits.

The input-output structure has implications for the cost of production in different sectors. We first consider the cost of inputs for each sector and then introduce a model of sectoral productivity, that, in turn, determines sectoral price levels and trade patterns for durable and non-durable manufactures.

For now we take wages \(w_i\) and sectoral prices, \(p_l^j\) for \(l \in \Omega\), as given. The Cobb-Douglas aggregator implies that the minimized cost of a bundle of inputs used by sector \(j \in \Omega\) producers is:

\[
c_j = w_j^\beta_j \prod_{l \in \Omega} (p_l^j)^{\gamma_l^j(1-\beta_l^j)}. \tag{5}
\]

As noted above, we do not explicitly model trade in sector \(S\). Instead we simply specify productivity for that sector as \(A_i^S\) so that \(p_i^S = c_i^S / A_i^S\). Taking into account round-about production we get:

\[
p_i^S = \left( \frac{1}{A_i^S} w_i^\beta_i \prod_{l \in \Omega_M} (p_l^j)^{\gamma_l^S(1-\beta_l^S)} \right)^{\frac{1}{1-\gamma_i^S(1-\beta_i^S)}}.
\]

We can substitute this expression for the price of services back into the cost functions expressions (5) for \(j \in \Omega_M\). We are treating the manufacturing sectors as if they had integrated the production of
all service-sector intermediates into their operations. After some algebra we can write the resulting expression for the cost of an input bundle in a way that brings out the parallels to (5):

$$c_j^i = \frac{1}{A_j^S} w_i^j \prod_{l \in \Omega_M} \left( \frac{\tilde{\beta}_j^i}{\tilde{\beta}_j^i} \right)$$

for \( j \in \Omega_M \). Here, the productivity term is

$$A_j^S = (A_j^S)^{\gamma_j^S(1-\beta_j^i)/[1-\gamma_j^S(1-\beta_j^i)]},$$

while the input-output parameters become

$$\tilde{\beta}_j^i = \beta_j^i + \frac{\gamma_j^S(1-\beta_j^i)\beta_j^i}{1-\gamma_j^S(1-\beta_j^i)},$$

and

$$\tilde{\gamma}_j^i = \gamma_j^i + \gamma_j^S \frac{\gamma_j^S(1-\beta_j^i) + \gamma_j^j \beta_j^i}{1-\gamma_j^S(1-\beta_j^i)}.$$
\[ \bar{\alpha}^j_i = \alpha^j_i + \delta^j_i \alpha^S_i. \]

All that remains of the service sector is its trade deficit, if any, which we treat as exogenous.

### 3.2 International Trade

Any country’s production in each sector \( j \in \Omega_M \) must be absorbed by demand from other countries or from itself. Define \( \pi^j_{ni} \) as the share of country \( n \)’s expenditures on goods in sector \( j \) purchased from country \( i \). Thus, we require:

\[ Y^j_i = \sum_{n=1}^{I} \pi^j_{ni} X^j_n. \]  

To complete the picture, we next detail the production technology across countries, which leads to an expression for trade shares.

Durable and non-durable manufactures consist of disjoint unit measures of differentiated goods, indexed by \( z \).\(^7\) We denote country \( i \)'s efficiency making good \( z \) in sector \( j \) as \( a^j_i(z) \). The cost of producing good \( z \) in sector \( j \) in country \( i \) is thus \( c^j_i / a^j_i(z) \), where \( c^j_i \) is the cost of an input bundle, given by (6).

With the standard “iceberg” assumption about trade, delivering one unit of a good in sector \( j \) from country \( i \) to country \( n \) requires shipping \( d^j_{ni} \geq 1 \) units, with \( d^j_{ii} = 1 \) for all \( j \in \Omega_M \). Thus, a unit of good \( z \) in sector \( j \) in country \( n \) from country \( i \) costs:

\[ p^j_{ni}(z) = c^j_i d^j_{ni} / a^j_i(z). \]

The price actually paid in country \( n \) for this good is:

\[ p^j_n(z) = \min_k \left\{ p^j_{nk}(z) \right\}. \]

Country \( i \)'s efficiency \( a^j_i(z) \) in making good \( z \) in sector \( j \) can be treated as a random variable.

\(^7\)Goods from different sectors with the same index \( z \) have no connection to one another. On the other hand, goods from different countries in the same sector with the same index are perfect substitutes.
with distribution: \( F_i^j(a) = \Pr[a_i^j(z) \leq a] = e^{-T_i^j a^{-\theta_j}} \), which is drawn independently across \( i \) and \( j \). Here \( T_i^j > 0 \) is a parameter that reflects country \( i \)'s overall efficiency in producing any good in sector \( j \). In particular, average efficiency in sector \( j \) of country \( i \) scales with \( \left( T_i^j \right)^{1/\theta_j} \). The parameter \( \theta_j \) is an inverse measure of the dispersion of efficiencies.

We assume that the individual manufacturing goods, whether used as intermediates or in final demand, are combined in a constant-elasticity-of-substitution aggregator, with elasticity \( \sigma^j > 0 \). As detailed in Eaton and Kortum (2002), we can then derive the price index by integrating over the prices of individual goods to get:

\[
p_n^j = \varphi^j \left[ \sum_{i=1}^I T_i^j \left( c_i^j d_{ni} \right)^{-\theta_j} \right]^{-1/\theta_j},
\]

where \( \varphi^j \) is a function of \( \theta_j \) and \( \sigma^j \), requiring \( \theta_j > (\sigma^j - 1) \). Substituting (6) into (9), we get:

\[
p_n^j = \varphi^j \left[ \sum_{i=1}^I \left( w_i^j p_i^j \left( z_i^j \right)^{(1-\beta_i^j)} \right) \left( \left( p_i^j \right)^{\beta_i^j} \left( 1-\beta_i^j \right) c_i^j d_{ni} A_i^j \right)^{-\theta_j} \right]^{-1/\theta_j},
\]

where \( l \neq j \) is the other manufacturing sector and

\[
A_i^j = A_i^{jS} \left( T_i^j \right)^{1/\theta_j},
\]

captures the combined effect on costs of better technology in manufacturing sector \( j \) and cost reductions brought about by productivity gains in the services sector. Expression (10) links sector-\( j \) prices in country \( n \) to the prices of labor and intermediates around the world.

Imposing that each destination purchases each differentiated good \( z \) from the lowest cost source, and invoking the law of large numbers, leads to an expression for sector-\( j \) trade shares:

\[
\pi_{ni}^j = \frac{T_i^j \left[ c_i^j d_{ni} \right]^{-\theta_j}}{\sum_{k=1}^I T_k^j \left[ c_k^j d_{nk} \right]^{-\theta_j}}.
\]
We can use (9) and (6) to rewrite the trade-share expression as:

\[ \pi_{ni}^j = \left[ w_i \left( \frac{\varphi^j}{A_j} \right) \left( \frac{\varphi_{ni}}{p_n} \right) \left( \frac{\varphi_{nj}}{p_j} \right) \left( \frac{\varphi_{nl}}{p_l} \right) \right]^{\theta^j} \] . \tag{11}

### 3.3 Global Equilibrium

We can now express the conditions for global equilibrium. Substituting (8) into (7) we obtain “global input-output” equations linking spending in each sector \( j \in \Omega_M \) around the world:

\[ X_i^j = \bar{\alpha}_i^j (w_i L_i + D_i) - \delta_i^j D_i^S + \sum_{l \in \Omega_M} \bar{\gamma}_{ij}^l (1 - \bar{\beta}_j^l) \left( \sum_{n=1}^I \pi_{ni}^l X_n^l \right) . \tag{12} \]

Summing (8) across the two manufacturing sectors gives “global market clearing” equations for each country:

\[ X_i^D + X_i^N - (D_i - D_i^S) = \sum_{l \in \Omega_M} \sum_{n=1}^I \pi_{ni}^l X_n^l . \tag{13} \]

We take world GDP as the numeraire. The global equilibrium is a set of wages \( w_i \) for each country \( i = 1, ..., I \) and, for sectors \( j \in \Omega_M \), spending levels \( X_i^j \), price levels \( p_i^j \), and trade shares \( \pi_{ni}^j \) that solve equations (12), (13), (10), and (11) given labor endowments \( L_i \) and deficits \( D_i \) and \( D_i^S \).

Production, deficits, and employment by country for sectors \( j \in \Omega_M \) are then implied by (8).

### 3.4 Interpretation of Shocks

Trade flows for each sector in our model are driven entirely by four categories of shocks: (i) demand shocks (or more precisely, shocks to a sector’s share in final demand), (ii) deficit shocks, (iii) productivity shocks, and (iv) trade-friction shocks. We emphasize, however, that while we derived our system from a particular model, these shocks are consistent with a variety of different structural interpretations.

The first category of shocks in our model is the country-specific share \( \alpha_i^j \) of final demand that is spent on sector-\( j \) goods. Fluctuations in \( \alpha_i^j \) are consistent with any changes in the domestic absorption of good \( j \) that are not attributable to the current demand for intermediate inputs.
For example, non-homothetic preferences over consumption may imply a relative decline in final consumption demand for durables during recessions. In our model, this type of effect – such as a reduction in the purchase of automobiles – would manifest as a decline in $\alpha_i^D$. Similarly, any shocks which reduce final investment activity would map to a change in $\alpha_i^D$ because that term reflects the purchase of machinery or capital goods that are not used up in the production of intermediates. A reduction in durable inventories, since inventories have not yet been used up in the production of intermediates, will also produce a decline in $\alpha_i^D$.

The second category of shocks in our model is deficits. In particular, equilibrium is a function of each country’s overall deficit $D_i$ and its non-manufacturing deficit $D_i^S$. Of our four categories of shocks, this is the only one without a flexible interpretation.

The third and fourth categories of shocks are productivity and trade friction shocks and are isomorphic to many different structural representations. We derived the price index (10) and trade share expression (11) from a particular Ricardian model, but emphasize that any model generating these two aggregate equations would be equally valid in our analysis. For instance, Appendix A shows that these expressions emerge in, among others, the Armington (1969) model elaborated in Anderson and Van Wincoop (2003), the Krugman (1980) model implemented in Redding and Venables (2004), the Ricardian model of Eaton and Kortum (2002), and the Melitz (2003) model expanded in Chaney (2008). In the Armington setup, for example, one would simply re-interpret shocks to $A_{ij}$ as preference shocks for that country’s goods. For instance, a world-wide decline in demand for cars produced in Japan would map to a reduction in Japan’s durable-good productivity in our framework.

Finally, the shocks $d_{ni}^j$ can be interpreted as trade frictions in a broad sense. Anything causing an increase in home-bias, or a reduction in absorption of imports relative to absorption of domestic production, will map in our framework to a change in $d_{ni}^j$. The simplest examples of such shocks would be changes in shipping costs (relative to domestic shipping costs), changes in tariffs, and changes in non-tariff trade barriers, such as the so-called "Buy America" provision in the U.S.

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8 The deep similarity in the predicted trade patterns from such seemingly disparate models is striking and is the subject of Arkolakis, Costinot, and Rodriguez-Clare (2009).
fiscal stimulus package. Difficulties in obtaining trade finance relative to other types of credit, as in Amiti and Weinstein (2009), would also influence the $d^j_{ni}$ term in our model. Even the highly plausible scenario where importers reduce inventories in recessions more than the average firm (because importing has additional fixed costs), as detailed in the model of Alessandria, Kaboski, and Midrigan (2010), would map to a change in $d^j_{ni}$.  

4 The Data

As described above, one challenge in studying the recent trade decline is the need for timely high-frequency data. We need such data both to capture the timing of the recession and also because translating production flows into a common currency is problematic at an annual or quarterly frequency.

Trade flow data are readily available at a monthly frequency – we use monthly bilateral trade flows from the Global Trade Atlas Database. These data are not seasonally adjusted and are provided in dollars. We aggregate appropriate 2-digit HS categories to generate the total bilateral and multilateral trade flows in each manufacturing sector.

Production data present a greater challenge. A limited number of countries, including the United States, report monthly estimates of the level of manufacturing production, but such data are not generally available. Annual production data are available as are monthly indicators of production. The difficulty is in finding a suitable way to disaggregate these annual totals into internally consistent monthly values, as well as to generate out-of-sample predictions that reflect all up-to-date information for the months subsequent to the previous year’s end.  

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9 To reiterate, a uniform reduction in inventories – whether the goods are imported or not – will appear in our model as a decline in demand for that sector. A disproportionately large decline in imported good inventories, however, would appear in our framework as an increase in trade frictions.

10 This problem, referred to in the econometrics and forecasting literature as temporal disaggregation, was studied as early as the 1950s by, among others, Milton Friedman. See Friedman (1962).
4.1 Temporal Disaggregation

Appendix B details our econometric procedure for disaggregating and extrapolating the annual production data in country \( i \) using the estimated relationship with several high frequency variables.\(^{11}\) For intuition, think of a linear regression of the annual gross production of manufacturers on the annual sum of the monthly totals of the high frequency variables. At its most basic, Chow and Lin (1971) uses the coefficient estimates from such a regression to generate predicted monthly values. Next, the Chow-Lin procedure would distribute the regression residuals equally to each of these monthly predicted values for any given year. This procedure creates an internally consistent monthly series that sums up to the actual annual data. However, it generally creates artificial jumps from December to January since the corrections for residuals are different only from year to year. Our procedure makes two additional changes to this basic structure.

First, we follow Fernandez (1981) and allow for serial correlation in the monthly residuals, which eliminates spurious jumps between the last period of one year and the first period of the subsequent year. Second, we follow Di Fonzi (2002) in adjusting the data so the procedure works for a log-linear, rather than linear, relationship. The monthly indicators used are the index of industrial production (IP) and the producer price index (PPI), so a relationship in logs is clearly most sensible. IP and PPI are available for the vast majority of large countries and are released with a very short time lag.

[Note: We we ultimately do this in two ways, first with the procedure automatically picking the beta coefficients for the relationship between production and IP/PPI and a second in which we automatically set these beta values to equal 1. The results below are generally generated from the second of these procedure types. Future drafts will use the former as a robustness check.]

4.2 Disaggregating Manufacturing Sub-Categories

To actually implement this procedure in our multi-sector model and with our data, we first need IP and PPI indices at the sector level. Some countries explicitly provide indices for durable and non-

\(^{11}\)The procedure was adapted from the code in Quilis, Enrique. “A Matlab Library of Temporal Disaggregation and Interpolation Methods: Summary,” 2006.
durable manufacturing production, while others produce the indices separately for capital goods, consumer durables, consumer non-durables, and intermediate goods. [There are some exceptions and we will offer further details in an appendix in the next draft on how we use these sub-categories to form durables and non-durable manufacturing. For now, a weighted average of capital goods, consumer durables, and intermediates are used for durables, while a weighted average of consumer non-durables and intermediates are used for non-durables. We will have the capacity to also disaggregate intermediates.]

We concord International Standard Industrial Classification (ISIC Rev. 3) 2-digit manufacturing production data to the appropriate sector definition (whatever is required to match the IP/PPI indices) to get annual totals for each of these categories. Our definition of manufacturing comprises ISIC industries 15 through 36 excluding 23 (petroleum). We further divide goods into the above sub-categories using the U.S. import end use classification. Harmonized System (HS) trade data are simultaneously mapped into the end use classification using a concordance from the U.S. Census Bureau and into the ISIC classification using the concordances from the World Bank’s World Integrated Trade Solution (WITS) website. World trade volumes at the 6-digit level for 2007-2008 are again used to estimate what proportion of each ISIC classification belongs in each of the categories.

We then apply our procedure to generate monthly series of these disaggregated categories, from which we obtain a monthly series of the share of durables in manufacturing. Given the highest quality production data from these databases are for the total manufacturing sector, we then multiply these shares by total manufacturing production, which is interpolated in exactly the same way but with IP/PPI indices for the whole of manufacturing. We then have monthly series for durable and non-durable manufacturing production which are consistent with published annual (and implied monthly) levels of total manufacturing production.

The annual data on manufacturing production used in the procedure are from the OECD Structural Analysis Database (STAN) and the United Nations National Accounts and Industrial Statis-

\[12\] Occasionally, a 2-digit sector will be dropped for one year, so we impute an alternative series where production levels are "grown" backward from the more recent and most complete data, only using the growth rates from categories reported in both years.
tics Database (UNIDO). For China, Chang-Tai Hsieh provided us with cross-tabs from 4-digit manufacturing production data from the census of manufacturing production. We used these data to determine the durables/non-durables split and got manufacturing totals from http://chinadataonline.org. Monthly data on the manufacturing industrial production and producer price indices are primarily from the OECD Main Economic Indicators Database (MEI) and the Economist Intelligence Unit (EIU) Database. The exceptions here are Argentina, Chile, China, and Thailand. Data for these countries are from Argentina’s National Institute of Statistics and Census (INE), the Federation of Chilean Industry (SOFOFA), chinadataonline.org, and the Bank of Thailand. Monthly data on these indices for manufacturing sub-categories, such as capital goods, are obtained from Datastream.

To check the quality of the procedure, we compared the monthly fitted series produced using this algorithm and the actual monthly data released by the U.S. Census Bureau on the value of shipments in durable and non-durable manufacturing. The U.S. monthly data are collected as part of the M3 manufacturing survey.\(^{13}\) In the rest of the paper, our monthly series will sum to the annual production totals found in the UN and OECD data, but for this test of the algorithm we re-run the procedure using annual totals from the M3 survey. Though M3 data are available through 2009, we only use annual totals for 1995-2007 to ensure the procedure uses the same amount of data as we would have for other countries in our sample. We test both a procedure which estimates the relationship between annual production and the monthly indicators as well as one in which we set the coefficients in the relationship equal to one.

Appendix Figure B1 demonstrates that both procedures do an excellent job of matching movements in the time series for non-durables, including the out-of-sample decline in production during the recent recession. Our "Beta equals 1" procedure does an excellent job both in-sample and out-of-sample. The procedure with estimated coefficients underestimates the decline in production of durables during the recent recession. Both procedures are promising for our purposes, but in

\(^{13}\)The monthly totals are extrapolated from a sampling procedure that covers a majority of manufacturers with $500 million or more in annual shipments as well as selected smaller companies in certain industries. See http://www.census.gov/indicator/www/m3/m3desc.pdf for additional details.
future drafts we will formally compare all results using each procedure.\footnote{Further, we note that there are essentially no large in-sample deviations, implying that once annual data is available, both procedures will do the job.}

### 4.3 Concordances Linking Trade and Production

A many-to-many concordance was constructed to link the 2-digit harmonized system (HS) trade data to the International Standard Industrial Classification (ISIC) codes used in the production data. We start by downloading the mapping of 6-digit HS codes (including all revisions) to ISIC codes from the WITS website. This concordance was then merged with COMTRADE data on the volume of world trade at the 6-digit level for 2007-2008 (also accessed through WITS). We estimate the proportion of each HS 2-digit code that belongs in each ISIC category using these detailed worldwide trade weights. Then we can use the same concordance in the last step to map production and trade to our sectors \( j \in \Omega_M \).

### 4.4 Input-Output Coefficients

The input-output coefficients – \( \beta_i^j \) and \( \gamma_i^j \) – were calculated from the 2009 edition of the OECD’s country tables.\footnote{The only exception is China’s input-output table, which was obtained from Robert Feenstra and is analyzed in Feenstra and Hong (2007).} We concord and combine the 48 sectors used in these tables to form input-output tables for the three sectors \( j \in \Omega \). Table 1 shows how we classified these 48 sectors into durables, non-durables, and non-manufactures. To determine \( \beta_i^j \), we divide the total value added in sector \( j \) of country \( i \) by that sector’s total output. To determine the values for \( \gamma_i^j \), we divide total spending in country \( i \) by sector \( j \) on inputs from sector \( l \) and divide this by that sector’s total intermediate use at basic prices (i.e. net of taxes on products).

The OECD input-output tables are often available for the same countries for multiple years. In such cases, we use the most recent year of data available. Figure 4 includes examples of the input-output coefficients for several large economies for both 2000 and 2005. Note that there are important differences in the levels of these coefficients across countries. For example, Korea’s value added share in durable manufacturing is significantly lower than the U.K.’s (i.e. \( \beta_{Korea}^D < \beta_{U.K.}^D \)).
On the other hand, the time-series information provides empirical support for our assumption that these technological parameters change little over time. For example, the share of non-durables in the production of non-durable intermediates in the United States ($\gamma_{U.S.}^{NN}$) was 39.5 percent in 2000 and 37.8 percent in 2005. There are a few exceptions, but this degree of stability in the time-series dimension is typical.

4.5 Additional Macro Data

Exchange rates to translate local currency production values into dollars (to match the dollar-denominated trade flows) are from the OECD.Stat database and from the International Financial Statistics database from the IMF. Other standard data used in the paper, such as quarterly GDP and trade deficits, are taken from the EIU. Trade and production data are translated using exchange rates at the monthly frequency before being aggregated to the quarterly frequency that we use in our regressions and counterfactuals.

4.6 Measuring the Shocks

We can now use the data to examine various measures of the shocks that drive the model.

4.6.1 Demand Shocks

The demand shocks can be calculated through a manipulation of (4):

$$\alpha_i = \frac{1}{X_i} (X_i - \Gamma_i Y_i),$$

where data for all the right hand side terms have been described above.\footnote{Service sector production is imputed as: $Y_i^S = (Y_i - \beta_i^D Y_i^D - \beta_i^N Y_i^N) / \beta_i^S$, as implied by (1). For the rest of the world ($i = ROW$) we first need to construct sectoral production for $j \in \Omega_M$. We start by averaging sectoral value added as a fraction of GDP $\beta_i^j Y_i^j / Y_i$ across the countries in our sample. We then multiply the result by $Y_{ROW}$ to estimate value added by sector for rest of world. We divide by $\beta_i^{ROW}$ to estimate $Y_i^{ROW}$, where $\beta_i^{ROW}$ is estimated as the median value of $\beta_i^j$ across the countries in our sample.} Figure 5 plots the paths of $\alpha_i^D$ and $\alpha_i^N$ for four large countries since 2000. The dashed vertical lines on the right of the plot correspond to the period starting in the first quarter of 2008 and ending in the first
quarter of 2009. We highlight this window because it will be the period we use for many of our
counterfactual analyses. The recent recession has led to a steep decline in the share of final demand
for manufactures in all these countries, with a particularly steep decline in durables. This share
begins to increase again in most countries toward the end of 2009.

4.6.2 Trade Deficits

Trade deficits are treated as being exogenous in our framework, and are thus one of the shocks in the
model. This shock can be measured directly. Trade deficits changed dramatically over the current
recession. Figure 6 shows overall and non-manufacturing trade deficits for several key countries.
The sharp reduction in the overall U.S. trade deficit during the recession is balanced by reduced
surpluses for Japan, Germany, and China.

4.6.3 Trade Frictions: Head-Ries Index

Trade frictions are not as easily measured as the macro aggregates above. Hence, in this section,
we derive the Head-Ries index, an inverse measure of trade frictions implied by our trade share
equation (11), or any gravity model. The index will be an easily measurable object that reflects
changes in trade frictions and is invariant to the scale of tradable good demand or the relative
size and productivity of trading partners. Head and Ries (2001) use this expression – equation (8)
in their paper – to measure the border effect on trade between the U.S. and Canada for several
manufacturing industries. Jacks, Meissner, and Novy (2009) studies a very similar object for a span
of over 100 years to analyze long-term changes in trade frictions.

Denote country $n$’s spending on manufactures of type $j$ from country $i$ by $X_{ni}^j$, measured in
U.S. Dollars. All variables are indexed by time (other than the elasticity $\theta^j$), though we generally
omit this from our notation. We have:

$$\frac{X_{ni}^j}{X_{nn}^j} = \frac{\pi_{ni}^j}{\pi_{nn}^j} = \frac{T_i^j \left[c_i^j d_n^j \right]^{-\theta^j}}{T_n^j \left[c_n^j \right]^{-\theta^j}}, \tag{14}$$
where we normalize $d_{nn}^j = 1$. Domestic absorption of goods of type $j$, $X_{nn}^j$, is equal to gross production less exports: $X_{nn}^j = Y_n^j - \sum_{i=1}^T X_{in}^j$.\(^{17}\)

Multiplying (14) by the parallel expression for what $i$ buys from $n$ in sector $j$ and taking the square root, we generate:

$$
\Theta_{ni}^j = \left( \frac{X_{ni}^j X_{in}^j}{X_{nn}^j X_{ii}^j} \right)^{1/2} = \left[ d_{nn}^j d_{in}^j \right]^{-\theta_i/2}.
$$

This index implies that, for given trade costs, the product of bilateral trade flows in both directions should be a fixed share of the product of the countries’ domestic absorption of tradable goods.

This index will change only in response to movements in the trade frictions. Other measures which might have been used to capture these movements include “openness” indices, similar to the left-hand side of (14), or the summation of bilateral trade flows relative to the summation of any pair of countries’ final demands. These other measures, however, have the disadvantage of being unable to isolate trade frictions.

To characterize historical trends in trade frictions at the country level, we apply a regression framework to these bilateral indices. We start with the assumption that each directional transport cost reflects aggregate ($\eta_i^j$), exporter ($\delta_i^j$), and importer ($\mu_i^j$) components that change over time, as

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\(^{17}\)Grouping together country-level terms as $S_{ij}^i = T_{ij}^i (c_{ij}^i)^{-\theta_i}$ and taking logs of both sides of (14), we could run a regression at date $t$ on country fixed effects. We might do this hoping to sweep out the components $S_{ij}^i$ so that we would be left with $(d_{ni}^j)^{-\theta_i}$, which is the object we would like to input into our analysis. Such a procedure would be misleading, however, due to a fundamental identification problem. For any set of parameters $\{S_{ij}^i, d_{ni}^j\}$ we can fit the same data with another set of parameters $\{\tilde{S}_{ij}^i, \tilde{d}_{ni}^j\}$ where:

$$
\tilde{S}_{ij}^i = \phi_i^j S_{ij}^i,
$$

and

$$
\tilde{d}_{ni}^j = \left[ \frac{\phi_i^j}{\phi_n^j} \right]^{1/\theta_i} \tilde{d}_{ni}^j.
$$

The problem is that there are no restrictions on $\phi_i^j$, so this procedure would be unable to determine whether the $d_{ni}^j$ changed or the $S_{ij}^i$ changed. Going back to the primitives of the model, any change in trade shares can be explained by an infinite number of combinations of changes in $\{T_{ij}^i\}$ and $\{d_{ni}^j\}$. There is hope, however. Notice that if we multiply $d_{ni}^j$ by $d_{in}^j$, the ambiguity goes away. This fact is the key motivation for our use of the Head-Ries index. In our counterfactual analysis below, we obtain additional restrictions by confronting the model’s implications for prices.

---
well as a bilateral term \((\gamma^{ij}_{ni})\) that is fixed, and finally a shock \((\epsilon^{ij}_{ni})\):

\[
d^{ij}_{ni}(t) = e^{\rho^{ij}(t)} + \delta^{ij}_{ni}(t) + \gamma^{ij}_{ni} + \epsilon^{ij}_{ni}(t).
\]

Equation (16)

We think of the exporter effect \(\delta^{ij}\) as reflecting, for example, the difficulties potentially imposed on exporting firms in obtaining trade credit and the importer effect \(\mu\) captures, for example, an import tariff. Equations (15) and (16) imply:

\[
\ln \Theta^{ij}_{ni}(t) = \frac{\theta^{ij}}{2} \ln \left( d^{ij}_{ni}(t) d^{ni}_{in}(t) \right) = \theta^{ij} \eta^{ij}(t) + \frac{\theta^{ij}}{2} (\delta + \mu)^{ij}_{ni}(t) + \frac{\theta^{ij}}{2} (\delta + \mu)^{ni}_{i}(t) + \frac{\theta^{ij}}{2} (\epsilon^{ni} + \epsilon^{in})(t),
\]

which shows that, even though there might be distinct importer and exporter frictions, we can only learn about their combination \((\beta^{ij}_{ni} = \theta^{ij} \left( \delta^{ij}_{ni} + \mu^{ij}_{ni} \right) / 2)\) when looking at an individual Head-Ries index, since importers and exporters enter the index calculation symmetrically. To extract these distinct effects, we estimate the pooled regression for all \(i, n, \) and \(t:\)

\[
\ln \Theta^{ij}_{ni}(t) = \beta^{ij}_{ni}(t) + \beta^{ij}_{i}(t) + \gamma^{ij}_{ni} + \epsilon^{ij}_{ni}(t).
\]

Equation (17)

We do this separately for each manufacturing industry, \(j = D, N\). Note that each regression contains only \(N\) country dummy variables each period, any given observation will be influenced by two of these country dummies, and each dummy represents the sum of the trade frictions experienced by that country’s exporters and importers.

Figures 7 and 8 plot the four-quarter moving average of the country-time effects \(\beta^{ij}_{i}\) from a weighted estimation of (17) for selected countries. We use a moving average due to the strong seasonal effects in the data. The coefficients are normalized to zero in the first quarter of 2000 and extend through the fourth quarter of 2009. The country-time effects act proportionally on the Head-Ries indices for all bilateral pairs involving any given country. For instance, if the series for country \(i\) increases from 0 to 0.1, it implies that the index would increase 10 percent for all pairs in which \(i\) is an exporter or an importer.

Looking at Figure 7, we see examples of countries where the recession did not bring with it
marked increases in trade frictions. Only a small share (or a negative share) of any declines in trade flows for Germany, the U.S., Mexico, and Italy should, according to this measure, be attributed to declining trade frictions. Figure 8, by contrast, includes only countries for which there is a steeper increase in trade frictions (a decline in the index) during the recession. These countries include Japan, China, Austria, and Finland, among others not shown. One important conclusion is that, while there is evidence of a potentially important contribution from trade frictions to the trade collapse, this contribution appears to be quite heterogenous across countries. Some countries, in fact, exhibit evidence that reduced trade frictions ameliorated the trade collapse.

The implied changes in trade frictions for durable and non-durables need not be the same for any given bilateral trading pair. First, this may reflect differences in the within-country trade costs for the two types of goods. Given we normalize $d^{i,j}_{ii} = 1$ for all countries and sectors, changes in international trade costs must interpreted as relative to domestic trade costs. Different modes of transport for durable and non-durable goods, for example, could generate different changes in within-country trade costs across the sectors. Further, the elasticities, $\theta^j$, may be different across sectors, and since the Head-Ries index includes this term, similar proportional changes in trade costs can generate different magnitude fluctuations of the Head-Ries index across sectors. Finally, each of the possible stories driving changes in trade frictions, such as difficulties in acquiring trade financing, could plausibly differ across sectors. For example, if one sector is performing worse than another – due to differences in the demand shocks $\alpha^j$, say – there might be differential increases in the higher cost of trade credit.

4.6.4 Trade Frictions During the Great Depression

To check the ability of the Head-Ries index to pick up changes in trade frictions, as well as to give a benchmark for the scale of any such changes, we calculate (15) using data from the Great Depression, which also coincided with a major collapse in trade. The lack of availability of data on bilateral manufacturing trade restricts our analysis to flows between the United States and 8 trading partners: Austria, Canada, Finland, Germany, Japan, Spain, Sweden, and the United Kingdom.
We obtained data on bilateral and multilateral manufacturing trade as well as exchange rates for 1926-1937 from the annual *Foreign Commerce Yearbooks*, published by the U.S. Department of Commerce.\(^{18}\) The gross value of manufacturing, required for the denominator of (15), were obtained from a variety of country-specific sources.\(^{19}\) The U.S. ratio of gross output to value added in manufacturing, found in Carter (2006), was applied to foreign manufacturing value added when output data were unavailable.

The bilateral trade and the manufacturing totals often reflect changing availability of data for disaggregated categories. For example, one year’s total growth may reflect both 20% growth in Paper Products as well as the initial measurement (relative to previous missing values) of Transportation Equipment. Since inspection suggests that such missing values do not simply reflect zero values, we calculate year-to-year growth rates using only the common set of recorded goods. For manufacturing production, we not only need the growth rate, but the level also matters because we subtract the level of exports to measure absorption. We apply the growth rate backwards from the most complete, typically also the most recent, series value.

[Future drafts will present these results. Our preliminary analysis suggests the HR drops dramatically in all these countries starting in about 1930, corroborating our results here.]

## 5 Calibration

Having set up the model, discussed the four categories of shocks that can change trade flows, and given historical context on the path of these shocks, we now calibrate the model to perfectly match the period from the first quarter of 2008 to the first quarter of 2009. The calibration exercise only includes a balanced panel of countries for which we have good data on input-output structure,

\(^{18}\)Total U.S. multilateral manufacturing imports and exports were taken from Carter et al. (2006).

\(^{19}\)Where needed, U.S. Department of Commerce (1968) was used to convert currency or physical units into U.S. dollars. Austria: Bundesamt fur Statistik (1927-1936) was used to obtain product-specific production data, either in hundreds of Austrian schilling or in kilograms. Canada: Value of manufacturing data were available in U.S. dollars from Urquhart (1983). Germany: Data were obtained from Statistisches Reichsamt (1931, 1935, 1940). Finland, Japan, Spain, and Sweden: Value added in manufacturing, in local currency units, were taken from Smits (2009). Peru: Output data in Peruvian pounds and soles obtained from Ministerio de Hacienda y Comercio (1939). United Kingdom: Data were obtained from United Kingdom Board of Trade (1938). These annual numbers combined less frequent results from the censuses in 1924, 1930, and 1935, with industrial production data, taken yearly, from 1927-1937.
production, and imports from and exports to all other included countries. After constructing trade, production, GDP, deficit, and input-output information for each country, and balancing this panel, we are left with a dataset containing complete data for 22 countries responsible for about 75 percent of global manufacturing trade and global GDP. We use all available countries for which we have the data with the only exceptions being Belgium and the Netherlands [Explain other omissions here]. They are omitted because their manufacturing exports often exceed their manufacturing production (due to re-exports), and our framework is not capable of handling this situation. Table 2 lists the included countries, shares in trade, and shares in global GDP, before and after the crisis, as well as a residual category "rest of world."

First, we re-formulate the model to facilitate computing its implications for changes in endogenous variables. Next we describe how we parameterize the model for calculating changes.

5.1 Change Formulation

For any time-varying variable $x$ in the model we denote its beginning-of-period or baseline value as $x$ and its end-of-period or counterfactual value as $x'$, with the "change" over the period (or counterfactual change) denoted $\hat{x} = x'/x$. In our counterfactual experiments, $x$ would be the variable’s value in a particular quarter, $x'$ its value four quarters later, and $\hat{x}$ the gross four-quarter change in that variable. We will take labor supply as fixed so that $Y'_i = \hat{w}_i Y_i$.

In terms of counterfactual levels and changes, the global input-output equations (12), for sectors $j \in \Omega_M$ and countries $i = 1, 2, \ldots, I$, become

$$
\left( X^j_i \right)' = \left( \alpha^j_i \right)' \left( \hat{w}_i Y_i + D'_i - \delta^j_i (D^S_i) \right)' + \sum_{l \in \Omega_M} \gamma^{lj}_i (1 - \beta^l_i) \left[ \sum_{n=1}^{I} \left( \pi^{li}_n \right)' \left( X'^n_l \right)' \right].
$$

(18)

The global market clearing conditions (13) become:

$$
(X^D_i)' + (X^N_i)' - \left[ D'_i - (D^S_i) \right]' = \sum_{n=1}^{I} \left( \pi^{D}_n \right)' \left( X'_n \right)' + \sum_{n=1}^{I} \left( \pi^{N}_n \right)' \left( X'^N_n \right)'.
$$

(19)

\[20\] These shares are highly similar before and after the crisis, suggesting we have a representative sample in terms of the declines in trade and output.
The price equations (10) become:

\[
\hat{p}_i^j = \left( \sum_{i=1}^{I} \pi_{ni}^j \hat{w}_i^{\omega_j} \left( \hat{p}_i^j \right)^{-\theta_j^i \gamma_j^i (1-\beta_i^j)} \left( \hat{p}_i^j \right)^{-\theta_j^i \gamma_j^i (1-\beta_i^j)} \left( \frac{\hat{d}_i^j}{\hat{A}_i^j} \right) \right)^{-1/\theta_j^i},
\]

where \( l \neq j \) is the other manufacturing sector. The trade share equations (11) become:

\[
\left( \pi_{ni}^j \right)' = \pi_{ni}^j \hat{w}_i^{\omega_j} \left( \hat{p}_i^j \right)^{-\theta_j^i \gamma_j^i (1-\beta_i^j)} \left( \hat{p}_i^j \right)^{-\theta_j^i \gamma_j^i (1-\beta_i^j)} \left( \frac{\hat{d}_i^j}{\hat{A}_i^j \hat{p}_n^j} \right)^{-\theta_j^i}.
\]

Equations (18), (19), (20), and (21) determine the changes in endogenous variables implied by a given set of shocks. We solve this set of equations for: (i) changes in wages \( \hat{w}_i \), (ii) counterfactual levels of spending \( (X_i^j)' \), (iii) changes in prices \( \hat{p}_i^j \), and (iv) counterfactual trade shares \( \left( \pi_{ni}^j \right)' \) for countries \( i = 1, ..., I \) and sectors \( j \in \Omega_M \). Baseline trade shares and GDPs are used to calibrate the model. The forcing variables are the end-of-period or counterfactual demand shocks \( \left( \alpha_i^j \right)' \) and deficits \( (D_i^S)' \) and \( D_i^l \), changes in trade frictions \( \hat{d}_i^j \), and changes in productivity \( \hat{A}_i^j \).\(^{21}\)

The system can be solved as follows. Given a vector of possible wage changes, (20) is solved for price changes. Wage and price changes then imply counterfactual trade shares via (21). Given counterfactual trade shares and wage changes, (18) can be solved as a linear system for counterfactual levels of spending. If these levels of spending satisfy (19), then we have an equilibrium. If not, we adjust wage changes according to where there is excess demand (with world GDP fixed) and return to (20). Details are described in Appendix C.

Given the solution described above, we can use equation (8), as it applies to the counterfactual levels:

\[
\left( Y_i^j \right)' = \sum_{n=1}^{I} \left( \pi_{ni}^j \right)' \left( X_i^j \right)',
\]

to obtain counterfactual levels of sectoral production and deficits.

\(^{21}\)As described in Appendix D, equilibrium outcomes for everything but price changes are invariant to productivity shocks of a labor-augmenting form, i.e. \( \hat{A}_i^j = \lambda \hat{A}_i^j \) for some \( \lambda > 0 \). Such shocks lead to price changes equal to \( 1/\lambda \). Furthermore, shocks to service-sector productivity, given \( \hat{A}_i^j \), do not perturb the equilibrium outcomes. Either type of productivity shock will likely alter welfare, but is irrelevant to the model’s implications for international trade.
5.2 Parameter Values and Shocks

We start by setting $\theta^D = \theta^N = 2$. This value is between the smaller values typically used in the open-economy macro literature and the larger values used in Eaton and Kortum (2002).

We have described above our procedure for backing out end-of period demand shocks $(\alpha^j_i)'$. We use them to construct the demand shocks as they enter the model through equation (18):

$$
(\tilde{\alpha}^j_i)' = (\alpha^j_i)' + \frac{\gamma^S_i (1 - \beta^S_i)}{1 - \gamma^S_i (1 - \beta^S_i)} (\alpha^S_i)',
$$

for $j \in \Omega_M$. End of period deficits $D^j_i$ and $(D^S_i)'$ can be read directly from the data. They enter the model via equations (18) and (19).

We have described the Head-Ries index above. Calculating squared changes of it yields:

$$
(\tilde{\Theta}^j_{ni})^2 = \frac{\hat{\sigma}^j_{ni} \hat{\sigma}^j_{in}}{\hat{\sigma}^j_{ni} \hat{\sigma}^j_{in}} = (\hat{\sigma}^j_{ni})^{-\theta^j} (\hat{\sigma}^j_{in})^{-\theta^j}.
$$

Here we need to decompose this measure to isolate $(\hat{\sigma}^j_{ni})^{-\theta^j}$. Dividing both sides of (21) by $\hat{\sigma}^j_{ni}$ we get an expression for $\hat{\sigma}^j_{ni}$. Dividing by the corresponding expression for $\hat{\sigma}^j_{ii}$ and rearranging yields:

$$
(\hat{\sigma}^j_{ni})^{-\theta^j} = \frac{\hat{\sigma}^j_{ni}}{\hat{\sigma}^j_{ni}} \left( \frac{\hat{\sigma}^j_{ii}}{\hat{\sigma}^j_{ii}} \right)^{\theta^j}.
$$

We implement this equation using the changes in sectoral PPI’s we constructed earlier.22

We can also retrieve productivity changes by rearranging (21) as it applies to $n = i$:

$$
\hat{A}^j_i = \left( \frac{\hat{\sigma}^j_{ii}}{\hat{\sigma}^j_{ii}} \right)^{1/\theta^j} \hat{w}^{\hat{\beta}^j_i} \left( \hat{p}^j_i \right)^{\hat{\gamma}^j_i (1 - \hat{\beta}^j_i) - 1} \left( \hat{p}^j_i \right)^{\hat{\gamma}^j_i (1 - \hat{\beta}^j_i)}.
$$

The trade-friction and productivity shocks both enter the model through equation (20) and (21).

We present cross-country evidence on these shocks, together with some of the underlying variables used to construct them, from the first quarter of 2008 to the first quarter of 2009. We begin

---

22We estimate $\hat{p}^j_{ROW}$ for $j \in \Omega_M$ by simply averaging $\hat{p}^j_i$ across the countries in our sample.
with the demand and deficit shocks shown above as they varied over time within countries. The four panels in Figure 9 plot on the y-axis the changes in the durables and non-durables demand shocks and the overall and non-manufacturing deficits. The change in trade to GDP ratios during the crisis are plotted along the x-axis. Figure 10 plots the corresponding changes in the durable and non-durable productivity shocks, calculated according to equation (24), and changes in prices in the two sectors (measured in U.S. dollars and relative to our numeraire of world GDP).

The trade-friction shocks, constructed according to equation (23), have both an importer and exporter dimension. The two panels of Figure 11 contain histograms of the durable and non-durable trade friction changes, in particular, the changes in \( \left( \frac{\bar{d}_{ni}}{\bar{d}_{ni}^{0}} \right)^{-\theta^i} \). The histograms exclude the largest and smallest 5 percentile values (generally small country-pair outliers).

Table 3 lists the combined impact (on imports and exports relative to GDP) of all the shocks associated with the recession, across all the countries used in our counterfactual exercises. By construction, the combined effect of our shocks fully accounts for the actual decline in trade from the first quarter of 2008 to the first quarter of 2009. The top row of data in the table, in boldface and labeled "World," shows that in global trade declined by 19 percent relative to GDP, with durables dropping by 22 percent and non-durables dropping by 11 percent.

6 Counterfactuals

We now discuss our counterfactual exercises. Given values for the changes in the forcing variables we solve (18), (19), (20), and (21), using an algorithm adapted from Dekle, Eaton, and Kortum (2008). Throughout, we take world GDP, measured in U.S. dollars, as given. It is our numeraire, hence, we will have nothing to say about the drop in world GDP over the past year. Formally, we could express every nominal variable in the model as a fraction of world GDP.\(^{25}\) In the results

\(^{23}\)To back out the implied change in the trade friction itself, these changes should be divided by \( \theta^i = 2 \).

\(^{24}\)It is again worth noting that our measure of trade frictions must be interpreted as relative to domestic trade costs.

\(^{25}\)In practice, the issue of numeraire arises in three places. First, the end-of-period deficits that we feed the model need to be divided by a factor equal to the change in world GDP over the period, \( \bar{Y} \). Similarly, country-specific changes in GDP \( \bar{Y}_i \), used to measure changes in wages \( \bar{w}_i \), also need to be divided by \( \bar{Y} \). Finally, for consistency with this measure of wage change, we must express prices changes relative to the change in world GDP.
that follow we treat all end-of-period deficits as exogenous, so that wage changes are endogenous.

In future drafts we will consider a case of exogenous wage changes and endogenous end-of-period manufacturing deficits.

It will be convenient to define the set of all shocks:

\[ \Xi' = \left\{ \{ \tilde{\alpha}^D_i \}, \{ \tilde{\alpha}^N_i \}, \{ \tilde{D}_i \}, \{ \tilde{D}^S_i \}, \{ \tilde{d}^D_{ni} \}, \{ \tilde{d}^N_{ni} \}, \{ \tilde{A}^D_i \}, \{ \tilde{A}^S_i \} \right\}, \]

for all countries \( i, n \in I \). For any given four-quarter period and any given set of shocks \( \Xi' \), we can solve our model to generate changes in all values and flows in the global system relative to the base period. As an example, consider the case where we choose the first quarter of 2008 as the base period. If we solve the model with all shocks in \( \Xi' \) equal to one, implying the shocks did not change at all relative to this base period, the model would generate outcome variables (such as production, trade, GDP, etc.) precisely equal to those seen in the first quarter of 2008, as if the recession never occurred. If, on the other hand, we solve the model with the set of shocks \( \Xi' = \text{data} \), where "data" means that the shock values are those for 2008:Q1 to 2009:Q1 as given in the previous tables and plots, the model would generate values precisely equal to those seen in the first quarter of 2009.

It will be convenient to define these two special cases of the shock matrices as \( \Xi'^{08Q1} \) and \( \Xi'^{09Q1} \), respectively.

### 6.1 Accounting for the Profile of the Global Trade Decline

We start by considering a series of four-quarter changes, beginning with the period from 2006:Q1 to 2007:Q1 all the way through to the period from 2008:Q4 to 2009:Q4. We run the model for each of these 12 four-quarter periods under various counterfactual assumptions and consider the implications at the global level. For instance, when we run the simulation after inputing all observed shocks, the counterfactual in each period shows the actual gross percentage change in world trade/GDP over the previous four quarters, as would be found in the raw data. Figure 12 plots these results.

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\(^{26}\)We note that while we write \( \tilde{D}^D_i \) and \( \tilde{D}_i \), we really only need information on \( (D^D_i)' \) and \( D_i' \), and so do not run into problems if \( \tilde{D}^D_i \) and \( \tilde{D}_i \) are undefined because initial deficits are zero.
as the boldfaced black line labeled "Data." (The 12 overlapping four-quarter changes are plotted as a continuous line, but it should be remembered that each calculation is done independently of those that came before. The changes are not cumulative.)

One sees that after mild rates of growth in the periods ending in 2007, global manufacturing trade/GDP was essentially unchanged until the fourth quarter of 2008, when it dropped nearly 10 percent relative to its value four quarters earlier. The drop continued and world trade/GDP in the first and second quarters of 2009 were about 20 percent below its respective levels in the first and second quarters of 2008. By the end of the dataset, annual growth in global trade/GDP had flattened, as represented by the black line approaching the value 1.0. We expect the line to exceed one in future quarters as trade levels recover.

Next, we consider the question of what might have happened to global trade/GDP if we did the identical exercise, but instead of introducing all shocks, we only introduce the shocks to the share of durable and non-durable manufacturing. Formally, for each of the 12 simulations, we input the shock matrix

$$\begin{bmatrix}
\alpha_i^D \\
\alpha_i^N
\end{bmatrix}
$$

for all countries I and generate the counterfactual change in the global trade/GDP ratio. These counterfactual results are plotted in the red line and demonstrate that the model with demand shocks alone performs quite well in capturing the magnitude of the decline across all of the four-quarter windows. When we consider the same exercise inputing only productivity shocks, only trade friction shocks, or only deficit shocks, the implied paths of global trade/GDP are essentially flat. None of the other shocks, on their own, come close to matching the actual pattern of declines. It is this result that leads us to conclude that demand shocks are the most significant driver of the decline in global trade/GDP. The fact that the red line dips down more than 80 percent of the way toward the black line during the recession leads us to characterize these shocks as explaining more than 80 percent of the decline.

### 6.2 Decomposing Changes Across Countries

Heterogeneity in the Head-Ries indices found earlier, suggest that trade friction shocks may be more successful in explaining the experiences of some countries. In Figure 13, we examine the profiles for
some large countries that display different qualitative patterns. The figures for the United States and Germany largely mirror the World, with a pure demand shock explaining most of the profile of changes in trade to GDP. For Japan, the actual declines are larger in the depths of the recession, and no shock on its own can account for the severity of these declines. In China, the decline started earlier and, like Japan, no single shock captures it. For both Japan and China, the trade friction shock is arguably the largest single factor.

To get a better sense for the experiences of all 23 countries (including "rest of world"), we now focus on the period from the first quarter of 2008 to the first quarter of 2009. We saw in Table 3 that world trade dropped 19 percent relative to economic activity over this period. Compared to this 19 percent, Table 4 shows that a 15 percent decline is generated from a counterfactual recession in which manufacturing demand dropped as it did but with no other shocks. Table 5 shows that a counterfactual recession in which the only change is the shock to trade frictions produces only a 1 percent decline in global trade. In addition to these aggregate results, Tables 3 through 5 list separately the experiences of each country in the data, in the counterfactual with only demand shocks, and in the counterfactual with only trade friction shocks.

We now introduce a measure to summarize the ability of our counterfactuals to match the cross-country pattern. We write the gross change in any particular outcome variable $\xi$ for country $i$ as $\tilde{\xi}_i(\Xi') = \xi_i^{08Q1}/\xi_i^{08Q1}$ to represent its value when the system is solved using the set of shocks $\Xi'$ relative to the value that was observed in the first quarter of 2008. For example, if $\xi_i$ is country $i$’s overall trade to GDP ratio, then $\tilde{\xi}_i(\Xi^{00Q1})$ is the gross percentage change in trade to GDP observed from 2008:Q1 to 2009:Q1 in that country. (Note that with this base period, $\tilde{\xi}_i(\Xi^{08}) = 1$ for any variable $\xi_i$, by definition.)

We construct the following measure:

$$ v(\Xi') = \sum_i w_i \left( \tilde{\xi}_i(\Xi') - \tilde{\xi}_i(\Xi^{00Q1}) \right)^2. $$

\footnote{It is somewhat misleading to say manufacturing demand "dropped" since this experiment does include several countries where it increased.}
It is a weighted sum of squared deviations of the vector \( \hat{\xi}(\Xi') \) from the vector \( \hat{\xi}(\Xi^{09Q1}) \), with each element’s deviation weighted by \( w_i \), with \( \sum_i w_i = 1 \). An important feature of this measure is that it does not net out the mean value of the deviation. For instance, if \( \xi \) is the trade to GDP ratio, then \( v(\Xi^{08Q1}) \) measures total squared changes across countries in trade to GDP ratios during the recession. To measure the share of these total changes in \( \xi \) over the recession that are captured by a set of shocks \( \Xi' \), we define:

\[
V(\Xi') = 1 - \frac{v(\Xi')}{v(\Xi^{08Q1})}.
\]

Imagine running a counterfactual scenario with all shocks equal to 1, except for changes in countries’ non-manufacturing trade deficits, which are set equal to what was observed in the data. The scenario would generate a counterfactual vector of changes in trade to GDP ratios. The x-axis in the top-left plot of Figure 14 plots the vector \( \hat{\xi}(\Xi^{09Q1}) \), while the y-axis plots the vector \( \hat{\xi}(\Xi') \).\(^{28}\) If all the points were on the 45 degree line, it would indicate that the observed changes in the non-manufacturing deficits alone can fully explain the cross-country changes in trade to GDP during that four-quarter period. In such a case, \( V(\Xi') \) would equal 1. As is easy to see, however, this counterfactual was far from aligning the points along the 45 degree line. Using shares of pre-recession global trade as our weights (\( w_i \)), we calculate \( V(\Xi') = 0.05 \). Thus Figure 14’s subtitle says "Share of Trade-Weighted Variance Explained: 5%," and we conclude that the non-manufacturing deficit shocks can explain very little of the pattern of trade changes in the recession.\(^{29}\)

Figures 14 and 15 include plots of various counterfactual scenarios, simulated with only one shock at a time. The most notable result – the shock with greatest explanatory power – is the durable demand shock on the bottom left panel of Figure 14. The durable demand shocks, on their own, explain 64 percent of the trade-weighted variance.\(^{29}\)

Figures 16 and 17 considers various combinations of shocks and demonstrates that, for example, both manufacturing shocks together explain 65 percent of the variation and only little additional power is gained by simultaneously adding other shocks. Trade friction and productivity shocks

\(^{28}\) The plots actually show the net rates of change, that is, \( \hat{\xi}(\Xi) - 1 \).

\(^{29}\) Note that this calculation can very well be negative. We would expect this with any shock that pushes the vector of outcome variables even further away from the post-recession data.
together can explain about 20 percent the pattern of variation. As shown in the bottom right panel of Figure 17, when all shocks are implemented, they perfectly explain changes in the economic system. This result is, of course, true by construction.

6.3 Other Counterfactuals

Given the heterogeneity in the shocks impacting countries in the recent recession, we also consider counterfactuals run at the country- or region-level. As an example, imagine one wants to know the global impact of the decline in durables demand just in the U.S. The top panel of Table 6 shows simulated trade flows at the country and global level (for selected countries) when the only shock we introduce into the system is \( \alpha_{DUS}^0 \). The impact of this single shock on the world is large – it reduces global durables trade by about 3 percent relative to GDP. One also notes the impact of geography. Mexico and Canada are impacted very significantly, while Germany, for example, is relatively insulated.

The bottom panel of Table 6 shows an alternative exercise where the only shocks introduced are the changes in trade frictions observed in China and Japan. These reduce total global trade by about 3 percent relative to GDP, but also have interesting cross-country implications. For example, the counterfactual produces trade diversion as manifest in the increase in South Korea’s trade to GDP ratio.

7 Conclusion

A prominent characteristic of the recent global recession was a large and rapid drop in trade relative to economic activity. Motivated by these dramatic changes in the cross-country pattern of trade, production, and GDP, we build an accounting framework relating them to shocks to demand, trade frictions, deficits, and productivities across several sectors. Applying our framework to the recent recession, we find that the bulk of the decline in trade/GDP can be explained by the shocks to manufacturing demand, with a particularly important role for the shocks to durable manufacturing demand. We do observe that in several countries, trade fell by more than what would be predicted.
by demand shocks alone. The trade declines in China and Japan, for example, reflect a moderate contribution from increased trade frictions. Although we developed this approach with the recent recession in mind, the framework can be applied quite generally to study the geography of global booms and busts.
References


### Durable Manufacturing

1. Wood and products of wood and cork
2. Other non-metallic mineral products
3. Iron & steel
4. Non-ferrous metals
5. Fabricated metal products, except machinery & equipment
6. Machinery & equipment, nec
7. Office, accounting & computing machinery
8. Electrical machinery & apparatus, nec
9. Radio, television & communication equipment
10. Medical, precision & optical instruments
11. Motor vehicles, trailers & semi-trailers
12. Building & repairing of ships & boats
13. Aircraft & spacecraft
14. Railroad equipment & transport equip n.e.c.
15. 50 percent of: Manufacturing nec; recycling (include Furniture)

### Non-Durable Manufacturing

1. Food products, beverages and tobacco
2. Textiles, textile products, leather and footwear
3. Pulp, paper, paper products, printing and publishing
4. Chemicals excluding pharmaceuticals
5. Pharmaceuticals
6. Rubber & plastics products
7. 50 percent of: Manufacturing nec; recycling (include Furniture)

### Non-Manufacturing

1. Agriculture, hunting, forestry and fishing
2. Mining and quarrying (energy)
3. Mining and quarrying (non-energy)
4. Coke, refined petroleum products and nuclear fuel
5. Production, collection and distribution of electricity
6. Manufacture of gas; distribution of gaseous fuels through mains
7. Steam and hot water supply
8. Collection, purification and distribution of water
9. Construction
10. Wholesale & retail trade; repairs
11. Hotels & restaurants
12. Land transport; transport via pipelines
13. Water transport
14. Air transport
15. Supporting and auxiliary transport activities; activities of travel agencies
16. Post & telecommunications
17. Finance & insurance
18. Real estate activities
19. Renting of machinery & equipment
20. Computer & related activities
21. Research & development
22. Other Business Activities
23. Public admin. & defence; compulsory social security
24. Education
25. Health & social work
26. Other community, social & personal services
27. Private households with employed persons & extra-territorial organisations & bodies

**Table 1:** Sector definitions in the OECD Input-Output tables

**Notes:**
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<th>Country</th>
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**Table 2: Country Coverage in Data**

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**Table 3:** Imports/GDP and Exports/GDP over Recession

Notes: All variables expressed relative to global GDP. Calculations using $\beta = 1$ restricted interpolations and extrapolations.
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**Table 4:** Counterfactual Results with Demand Shocks Only

Notes: $\theta^D = \theta^N = 2$. All variables expressed relative to global GDP. Calculations using $\beta = 1$ restricted interpolations and extrapolations.
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<tr>
<td>Rest of World</td>
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<td>1.02</td>
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**Table 5:** Counterfactual Results with Trade Friction Shocks Only

Notes: $\theta^D = \theta^N = 2$. All variables expressed relative to global GDP. Calculations using $\beta = 1$ restricted interpolations and extrapolations.
\begin{table}
\centering
\begin{tabular}{ccccccc}
\hline
& \multicolumn{2}{c}{No Recession} & \multicolumn{4}{c}{Only U.S. Durables Demand Shock} \\
Shocks: & None & Durable Demand Shock for U.S. Introduced & & & & \\
\hline
\multirow{2}{*}{Exports / GDP} & \multicolumn{4}{c}{Imports / GDP} & & \\
\hline
All Vars & All & Non-Durables & All & Non-Durables & All & Non-Durables \\
\hline
World & 1.00 & 0.98 & 0.97 & 1.00 & 0.98 & 0.97 & 1.00 \\
Canada & 1.00 & 0.97 & 0.92 & 1.07 & 0.98 & 0.97 & 0.98 \\
China & 1.00 & 1.00 & 0.99 & 1.03 & 0.99 & 0.99 & 0.99 \\
Germany & 1.00 & 1.00 & 1.00 & 1.01 & 1.00 & 1.00 & 1.00 \\
Japan & 1.00 & 1.00 & 0.99 & 1.03 & 0.98 & 0.98 & 0.99 \\
Mexico & 1.00 & 0.96 & 0.94 & 1.09 & 0.97 & 0.97 & 0.96 \\
South Korea & 1.00 & 1.00 & 0.99 & 1.02 & 0.99 & 0.99 & 0.99 \\
United Kingdom & 1.00 & 0.99 & 0.99 & 1.01 & 1.00 & 1.00 & 1.00 \\
United States & 1.00 & 0.89 & 0.89 & 0.88 & 0.91 & 0.85 & 1.05 \\
Rest of World & 1.00 & 0.99 & 0.98 & 1.02 & 1.00 & 0.99 & 1.00 \\
\hline
\multirow{2}{*}{No Recession} & \multicolumn{2}{c}{Only Trade Friction Shocks in China and Japan} & & & & \\
Shocks: & None & Both Trade Frictions Shocks in China and Japan & & & & \\
\hline
\multirow{2}{*}{Exports / GDP} & \multicolumn{4}{c}{Imports / GDP} & & \\
\hline
All Vars & All & Non-Durables & All & Non-Durables & All & Non-Durables \\
\hline
World & 1.00 & 0.97 & 0.97 & 0.97 & 0.97 & 0.97 & 0.97 \\
Canada & 1.00 & 1.01 & 1.03 & 0.97 & 1.01 & 1.01 & 1.02 \\
China & 1.00 & 0.87 & 0.81 & 1.04 & 0.83 & 0.90 & 0.61 \\
Germany & 1.00 & 1.01 & 1.02 & 0.99 & 1.01 & 1.01 & 1.01 \\
Japan & 1.00 & 0.84 & 0.83 & 0.93 & 0.82 & 0.79 & 0.88 \\
Mexico & 1.00 & 1.03 & 1.04 & 0.95 & 1.02 & 1.02 & 1.03 \\
South Korea & 1.00 & 1.12 & 1.15 & 0.96 & 1.13 & 1.13 & 1.15 \\
United Kingdom & 1.00 & 1.01 & 1.02 & 1.00 & 1.01 & 1.01 & 1.02 \\
United States & 1.00 & 0.96 & 0.98 & 0.93 & 0.98 & 0.95 & 1.03 \\
Rest of World & 1.00 & 0.97 & 0.98 & 0.97 & 0.99 & 0.98 & 1.00 \\
\hline
\end{tabular}
\caption{Country/Region-specific Counterfactuals}
\end{table}

Notes: $\theta^D = \theta^N = 2$. All variables expressed relative to global GDP. Calculations using $\beta = 1$ restricted interpolations and extrapolations.
Figures

Figure 1: Trade as a Share of Output in the Four Largest Economies
Notes: All data through the end of 2009. United States quarterly data taken from BEA national accounts. Japan quarterly data taken from IMF’s IFS database. Germany’s quarterly data taken from Source.OECD database. China data only available annually. China’s data taken from IFS through 2008. 2009 Trade data for taken from WTO database and GDP estimate from IMF’s WEO for China. Trade for United States, Germany, and Japan is goods and services, China is just goods.
Figure 2: The Cyclical Properties of Tradable-Sector Activity and Trade

Notes:
Figure 3: The Cyclical Properties of Tradable-Sector Activity and Trade

Notes:
**Figure 4:** Sample Input-Output Coefficients ($\beta_i^D$, $\beta_i^N$, $\gamma_i^{ND}$, and $\gamma_i^{NN}$)

Notes: Input-Output coefficients taken from OECD input-Output database, version 2009. See Table 1 for sectoral definitions.
Figure 5: Shares of Manufacturing in Final Demand

Notes: Generated using interpolation procedure with elasticities set to equal one.
Figure 6: Overall and Non-Manufacturing Trade Deficits

Notes:
Figure 7: Countries without Large Negative Shock to Trade Frictions
Notes: Generated using interpolation procedure with endogenous elasticites.
Figure 8: Countries with Large Negative Shock to Trade Frictions

Notes: Generated using interpolation procedure with endogenous elasticites.
Figure 9: Sector Shares, Deficit Shocks, and Trade from 2008:Q1 to 2009:Q1

Notes: Changes in deficit levels are relative to global GDP.
Figure 10: Shocks to Productivity, Prices, and Trade from 2008:Q1 to 2009:Q1

Notes:
Figure 11: Shocks to Bilateral Trade Frictions from 2008:Q1 to 2009:Q1

Notes: Histograms exclude largest and smallest 5 percentile shocks
Figure 12: Global Trade/GDP Across Many Four-Quarter Periods in Data and Counterfactuals

Notes:
Figure 13: Country Trade/GDP Across Many Four-Quarter Periods in Data and Counterfactuals

Notes: $\theta^D = \theta^N = 2$
Figure 14: Explanatory Power of Deficit and Demand Shocks

Notes: $\theta^D = \theta^N = 2$
Figure 15: Explanatory Power of Trade Friction and Productivity Shocks

Notes: $\theta^D = \theta^N = 2$
Figure 16: Explanatory Power of Combinations of Shocks

Notes: $\theta^D = \theta^N = 2$
Figure 17: Explanatory Power of Combinations of Shocks

Notes: $\theta^D = \theta^N = 2$
**Figure B1**: Checking Accuracy of Temporal Disaggregation Procedure for U.S.

Notes: Checking procedure with durable (AMDMVS) and non-durable (AMNMVS) series from Federal Reserve M3 survey (note this is different source from analysis in paper). Annual totals included from 1995-2007 only, even though data starts earlier and is available through 2009, to mirror extent of data used for other countries.
Appendix A: Derivations of Expression (11)

In this appendix, we demonstrate that one can derive the Head-Ries index from many classes of trade models, such as a structure with Armington preferences, as in Anderson and van Wincoop (2003), monopolistic competition as in Redding and Venables (2004), the Ricardian structure in Eaton and Kortum (2002), or monopolistic competition with heterogeneous producers, as in Melitz (2003) and Chaney (2008). To do so, we need only show that each theory of international trade lead to a bilateral import share equation with the same form as equation (11). From there, the derivation of (15) follows exactly as in Section 2. This implies that for the first sections of the paper, we need not specify a particular trade structure, so long as it is in this larger set of models.

1. Consider the model of Armington (1969), as implemented in Anderson and van Wincoop (2003). Consumers in country $i$ maximize:

$$
\left( \sum_i \beta_i^{(1-\sigma)/\sigma} c_{ni}^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}
$$

subject to the budget constraint $\sum_i p_{ni}c_{ni} = y_n$, where $\sigma$ is a preference parameter representing the elasticity of substitution across goods produced in different countries, $\beta_i > 0$ is a parameter capturing the desirability of of country $i$’s goods, $y_n$ is the nominal income of country $n$, and $p_{ni}$ and $c_{ni}$ are the price and quantity of the traded good supplied by country $i$ to country $n$. In their setup, prices reflect a producer-specific cost and a bilateral-specific trade cost: $p_{ni} = p_it_{ni}$. Solving for the nominal demand of country $i$ for goods from country $j$ then yields their equation (6):

$$
x_{ni} = \left( \frac{\beta_it_{ni}}{P_n} \right)^{1-\sigma} y_n,
$$

where $P_n = \left[ \sum_k (\beta_k p_k t_{nk})^{1-\sigma} \right]^{1/(1-\sigma)}$ is the price index of country $n$. Substituting this definition and with goods markets clearing, $y_n = \sum_j x_{nj}$, we obtain:

$$
\pi_{ni} = \frac{x_{ni}}{\sum_j x_{nj}} = \frac{(\beta_it_{ni})^{1-\sigma}}{\sum_k (\beta_k p_k t_{nk})^{1-\sigma}}.
$$

Relabeling $\theta = \sigma - 1$ and $T_i = \beta_i^{-\theta}$, we recover an expression equivalent to (11).

2. Consider the model of Krugman (1980), as implemented in Redding and Venables (2004). Like Anderson and van Wincoop, they use a constant elasticity formulation, but they include a fixed cost for firms operating in each country. They express, in their equation (9), the total value of imports to country $n$ from $i$:

$$
x_{ni} = (n_i p_i^{1-\sigma}) t_{ni}^{1-\sigma} \left( E_n G_n^{\sigma-1} \right),
$$

where they refer to $\left( E_n G_n^{\sigma-1} \right)$ as the "market capacity" of the importing country $n$ because it refers to the size of $n$’s market, the number of competing firms that can cover the fixed cost of operation, and the level of competition as summarized by the price index $G$. They refer to the term $\left( n_i p_i^{1-\sigma} \right)$ as the "supply capacity" of the exporting country $i$, because fixing the market capacity, the volume of sales is linearly homogeneous in that term. Finally, $T_{ni}^{1-\sigma}$ is the iceberg trade cost for shipping from $i$ to $n$. Hence, this model too leads to an expression:

$$
\pi_{ni} = \frac{x_{ni}}{\sum_j x_{nj}} = \frac{(n_i p_i^{1-\sigma}) T_{ni}^{1-\sigma}}{\sum_k (n_k p_k^{1-\sigma}) T_{nk}^{1-\sigma}}.
$$

Again, this expression can be relabeled and made equivalent to (11).

3. Consider the competitive model of Eaton and Kortum (2002), where $\theta$ and $T_i$ are parameters of a Fréchet distribution of producer efficiency capturing, respectively, heterogeneity across producers (inversely) and country $i$’s absolute advantage. The property of this distribution is such that the probability that country $i$ is the lowest price (production plus transport costs) provider of a good to
country $n$ is an expression identical to (11), their equation (8). Given that average expenditure per good in their model does not vary by source and invoking the low of large numbers, it follows that this probability is equivalent to the trade share.

4. Consider Chaney (2008), which builds on Melitz (2003). Firm productivities are distributed Pareto with shape parameter $\gamma$ and in addition to iceberg costs $\tau_{ni}$, to sell in market $n$ also requires employing $f_{ni}$ units of local labor. This leads to an expression for total imports by country $n$ from country $i$, his equation (10) (where we’ve dropped sectoral terms indexed by $h$):

$$x_{ni} = \frac{Y_i Y_n}{Y} \theta_n w_i^{-\gamma} \tau_{ni}^{-\gamma} f_{ni}^{-\gamma/(\sigma-1)} f_{ni}^{[1/(\sigma-1)-1/\gamma]},$$

where notation is similar to the examples above, and $\theta_n$ measures what he refers to as country $n$’s "remoteness" from the rest of the world. Summing this over all bilaterals implies:

$$\pi_{ni} = \frac{x_{ni}}{\sum_j x_{nj}} = \frac{Y_i w_i^{-\gamma} \left( \tau_{ni} f_{ni}^{[1/(\sigma-1)-1/\gamma]} \right)^{-\gamma}}{\sum_k Y_k w_k^{-\gamma} \left( \tau_{nk} f_{nk}^{[1/(\sigma-1)-1/\gamma]} \right)^{-\gamma}},$$

which, again, is clearly in the same form as (11).
Appendix B: Temporal Disaggregation Procedure

In this appendix, we describe the procedure used to generate an estimate of the monthly series for gross manufacturing production \( Y^M(t) \) when we only have the annual totals for this series:

\[
Y^M(\tau) = \sum_{t=12(\tau-1)+1}^{12\tau} Y^M(t),
\]

where \( \tau = 1..T \) denotes the year and \( t = 1..12T \) denotes the month. Consider related series \( Z_q \) where \( q = 1..Q \) that are available at a monthly frequency and contain information on the underlying gross production series. Examples of \( Z_q \) are industrial production (IP), the producer price index (PPI), the exchange rate (ER), and potential combinations of these series. Represent the related series data in a \((12T)\times Q\) matrix \( Z \) with elements \( f_{z_{tq}} \).

Write the annual data in vector form as

\[
Y^M = [Y^M_1; \ldots; Y^M_T]^0,
\]

and the estimates for \( Y^M(t) \) in vector form as

\[
dY^M = [dY^M_1; \ldots; dY^M_{12T}]^0.
\]

Assume a linear relationship between the related series and series we wish to estimate:

\[
Y^M = Z \beta + \varepsilon
\]

where \( \beta = [\beta_1; \ldots; \beta_q]^\prime \) and \( \varepsilon \) is a random vector with mean 0 and covariance matrix \( E[\varepsilon \varepsilon^\prime] = \Omega \). We can write (26) as:

\[
\hat{Y}^M = B'Y^M = B'Z\hat{\beta} + B'\varepsilon,
\]

where

\[
B = I_T \otimes \Psi,
\]

and \( I_T \) is the \( T \)-by-\( T \) identity matrix and \( \Psi \) is a 12-by-1 column vector of ones. Hence, \( \hat{\beta} \) and \( \hat{Y}^M \) can be obtained using GLS as:

\[
\begin{align*}
\hat{\beta} &= [Z'B(B'\Omega B)^{-1}B'Z]^{-1}Z'B(B'\Omega B)^{-1}Y^M \\
\hat{Y}^M &= Z\hat{\beta} + \Omega B(B'\Omega B)^{-1}[Y^M - B'Z\hat{\beta}]
\end{align*}
\]

(27)

Consider the simplest assumption that there is no serial correlation and equal variance in the monthly residuals, or \( \Omega = \sigma^2 I_{12T} \). Then, equation (27) simplifies to:

\[
\hat{Y}^M = Z\hat{\beta} + B[Y^M - B'Z\hat{\beta}] \frac{1}{12}
\]

because \((B'B)^{-1} = 1/12\). This implies that the annual discrepancy \( B'\varepsilon \) be distributed evenly across each month of that year. Given the failure of the zero serial correlation assumption in the data, this would create obvious and spurious discontinuities near the beginning and end of each year.

We now follow Fernandez (1981) and consider a similar procedure, but with a transformation designed to transform a model with serially correlated residuals into one with classical properties, and then to apply a procedure similar to the one above, to deal with the disaggregation of annual values. Consider the case where the error term from equation (26) followed a random walk:

\[
\varepsilon_t = \varepsilon_{t-1} + \mu_t,
\]

where \( \mu_t \) has no serial correlation, zero mean, and constant variance \( \sigma^2 \). Consider the first difference transformation \( D \):

\[
D_{12T \times 12T} = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 \\
-1 & 1 & 0 & 0 & 0 \\
& 0 & -1 & 1 & 0 & 0 \\
& & & & & \\
& & & & & \\
& & & & & \\
& & & & & \\
& & & & & \\
0 & 0 & 0 & -1 & 1
\end{bmatrix}.
\]

One can premultiply the error in equation (26) by this matrix to generate: \( DY^M - DZ\beta \), which converts the both left and right hand sides of the model into first-difference form, with the exception being the first terms given the upper left hand element equals one. With these first-differenced series, we can re-write the
model as:

$$DY^M = DZ\beta + D\varepsilon.$$ 

Note that $\Omega = E[D\varepsilon'\varepsilon'] = E[\mu\mu'] = \sigma^2 I_{12T}$, so errors in this reformulated model have classical properties. Fernandez shows that the expression for the best linear estimator in this context is the same as (27), but with $\Omega = (D'D)^{-1}$:

$$\hat{\beta} = \left[ Z'B'(D'D)^{-1}B\right]^{-1} Z'B' \left( B'(D'D)^{-1}B\right)^{-1} Y^M$$

$$\hat{Y}^M = Z\hat{\beta} + (D'D)^{-1}B(B'(D'D)^{-1}B)^{-1}(Y^M - B'Z\hat{\beta})$$

(28)

The relationship (26) is written in levels, but it is clearly more appropriate for our purposes to write the relationship between production and production indicators in log-levels, such that a given percentage change in one variable leads to a percentage change in the other:

$$\ln Y^M = (\ln Z) \beta + \varepsilon.$$ 

(29)

This can be somewhat difficult to handle in the above framework, however, because the sum of the log of monthly totals will not equal the log of the annual total when the adding-up constrain does hold in levels. We deal with this by running the algorithm on annual data that has been converted such that the sum of fitted monthly data will approximate the original annual levels. This cannot be achieved exactly, so a second-stage procedure is then implemented to distribute the residuals across the months and ensure the aggregation constraints bind exactly.

Following Di Fonzi (2002), we consider the first order Taylor series approximation of $\ln Y^M$ around the log of the arithmetic average for the monthly totals, $\ln(Y^M/12)$. We write:

$$\ln Y^M = \bar{Y}^M \approx \ln \frac{\sum_{j=1}^{12} Y^M_j}{12} + \frac{12}{12} \left( Y^M - \frac{1}{12} \sum_{j=1}^{12} Y^M_j \right) = \ln \bar{Y}^M - \ln 12 + \frac{12}{12} \frac{Y^M}{\bar{Y}^M} - 1.$$ 

Summing this expression up over the twelve months, we get:

$$\sum_{j=1}^{12} \bar{Y}^M_j = 12 \ln \bar{Y}^M - 12 \ln 12.$$ 

Hence, we can follow the above procedure, except we replace the left hand size of (29) with $\bar{Y}^M = 12 \ln \bar{Y}^M - 12 \ln 12$ and the right hand size with $\sum_{j=1}^{12} \ln Z_j$.

This approximation should come close to satisfying the temporal aggregation constraints, but will fail to do so exactly. Hence, the final step is to adjust the estimates following Denton (1971). Denoting the initial fitted values as $\bar{Y}^M$ and the residuals $\bar{Y}^M - \sum_{t=1}^{12} \bar{Y}_t^M = R$ (in vector form), we make the final adjustment:

$$\bar{Y}^* = \bar{Y}^M + (D'D)^{-1}B'(B'(D'D)^{-1}B')^{-1}R.$$ 

64
Appendix C: Solving for the Equilibrium

In this appendix, we explain in more detail how we solve for the system’s equilibrium. Given a vector of wage changes \( \hat{\omega} \), we solve (20) and (21) jointly for changes in trade shares and prices. Denote the solution for changes in trade shares by \( \pi_{ni}^j(\hat{\omega}) = \left( \pi_{ni}^j \right)' \).

Second, we can substitute the service sector out of equation (3) to get
\[
\begin{bmatrix}
(X_P^D)' \\
(X_N^N)'
\end{bmatrix}' = \tilde{\alpha}_i' (Y_i' + D_i') - \delta_i (D_i^S)' + \tilde{\Gamma}_i' \begin{bmatrix}
(Y_i^D)' \\
(Y_i^N)'
\end{bmatrix},
\]
where the 2 by 1 vector \( \tilde{\alpha}_i \) has elements
\[
\left( \tilde{\alpha}_i^j \right)' = \left( \alpha_i^j \right)' + (\alpha_i^S)^j \delta_i^j,
\]
the 2 by 1 vector \( \delta_i \) has elements
\[
\delta_i^j = \frac{\gamma_{ij}^S (1 - \beta_i^S)}{1 - \gamma_{ij}^S (1 - \beta_i^S)},
\]
and the 2 by 2 matrix \( \tilde{\Gamma}_i \) contains
\[
\tilde{\gamma}_{ij}(1 - \tilde{\beta}_i^j)
\]
in its \( j \)'th row and \( l \)'th column for all \( j, l \in \Omega_M \).

Third, we follow the approach of Caliendo and Parro (2009) and substitute (22) into the right hand side of (30). Given wage changes, we obtain a linear system in the \( (X_i^j)' \)'s by stacking (30) across all countries:
\[
X' = (\tilde{\alpha} X)' - (\delta D^S)' + \tilde{\Gamma}_i^T (\Pi(\hat{\omega}))^T X'.
\]
Here
\[
X' = \left[ (X_P^D)', (X_2^P)', ..., (X_P^N)', (X_2^N)', ..., (X_N^N)' \right]^T,
\]
\[
(\tilde{\alpha} X)' = \left[ (\tilde{\alpha}_1^D X_1)' , (\tilde{\alpha}_2^D X_2)' , ..., (\tilde{\alpha}_1^N X_1)' , (\tilde{\alpha}_2^N X_2)' , ..., (\tilde{\alpha}_N^N X_1)' \right]^T,
\]
with
\[
(\tilde{\alpha}_i^j X_i)' = (\tilde{\alpha}_i^j)' (\hat{\omega}, Y_i + D_i'),
\]
\[
(\delta D^S)' = \left[ \delta_1^D (D_1^S)' , \delta_2^D (D_2^S)' , ..., \delta_1^N (D_1^S)' , \delta_2^N (D_2^S)' , ..., \delta_N^N (D_2^S)' \right]^T,
\]
\[
\tilde{\Gamma}_i = \begin{bmatrix}
\tilde{\gamma}_{1D}^D (1 - \tilde{\beta}_1^D) & 0 & 0 & \tilde{\gamma}_{1N}^D (1 - \tilde{\beta}_1^N) & 0 & 0 \\
0 & \ddots & 0 & 0 & \ddots & 0 \\
0 & 0 & \tilde{\gamma}_{2D}^D (1 - \tilde{\beta}_2^D) & 0 & 0 & \tilde{\gamma}_{2N}^D (1 - \tilde{\beta}_2^N) \\
\tilde{\gamma}_{1N}^D (1 - \tilde{\beta}_1^N) & 0 & 0 & \tilde{\gamma}_{1N}^N (1 - \tilde{\beta}_1^N) & 0 & 0 \\
0 & \ddots & 0 & 0 & \ddots & 0 \\
0 & 0 & \tilde{\gamma}_{2N}^D (1 - \tilde{\beta}_2^N) & 0 & 0 & \tilde{\gamma}_{2N}^N (1 - \tilde{\beta}_2^N)
\end{bmatrix},
\]
and
\[
\Pi(\hat{\omega}) = \begin{bmatrix}
\Pi^D(\hat{\omega}) & 0 \\
0 & \Pi^N(\hat{\omega})
\end{bmatrix}.
\]
where \((\Pi^T)'(\bar{\omega})\) has \(\pi_{ni}(\bar{\omega})\) in its \(n^\prime\)th row and \(i^\prime\)th column. We can denote the solution by

\[ X(\bar{\omega}) = \left[ I - \bar{\Gamma}^T[\Pi(\bar{\omega})]^T \right]^{-1} \left[ \bar{\alpha}X' - \left( \delta_0 S \right)' \right], \]

where the elements of \(X(\bar{\omega})\) are \(X^i_j(\bar{\omega}) = \left( X^i_j \right)'\).

Finally, summing up (22) over \(j \in \Omega_M\) yields

\[ X^D_i(\bar{\omega}) + X^N_i(\bar{\omega}) - \left( D'_i - (D^L_i)' \right) = \sum_{n=1}^{I} \pi^D_{ni}(\bar{\omega})X^D_n(\bar{\omega}) + \sum_{n=1}^{I} \pi^N_{ni}(\bar{\omega})X^N_n(\bar{\omega}). \tag{31} \]

This non-linear system of equations can be solved for the \(I-1\) changes in wages.

### 8 Appendix D: Relationship Between Trade Frictions and Productivity

Changes in trade frictions and changes in productivity are intimately connected. We can bring out this connection, and get some insights into the logic of the model, by combining trade friction shocks and productivity shocks in the term:

\[ \tilde{\delta}_ni = \frac{\hat{\Phi}_n}{\hat{\Phi}_i} \tilde{\delta}^j_{ni}, \tag{32} \]

where the \(\hat{\Phi}_i\) represent productivity changes through:

\[ \hat{\Phi}_i = \left( \Phi_i \right)^{1-\tilde{\gamma}_i/(1-\tilde{\beta}_i^i)} \left( \Phi_i \right)^{-\tilde{\gamma}_i/(1-\tilde{\beta}_i^i)}. \tag{33} \]

In addition, we define a productivity-adjusted price change by

\[ \tilde{q}_i^j = \hat{p}_i \tilde{\Phi}_j. \tag{34} \]

Using this reparameterization, (18) and (19) remain unchanged while (20) becomes:

\[ \tilde{q}_n^i_j = \left( \sum_{i=1}^{I} \pi^j_{ni} \bar{\omega}_i \right)^{-\theta j} \left( \hat{q}_i^j \right)^{1-\tilde{\gamma}_i^j/(1-\tilde{\beta}_i^j)} \left( \hat{q}_i^j \right)^{-\theta j \tilde{\gamma}_i^j/(1-\tilde{\beta}_i^j)} \left( \tilde{\delta}_ni \right)^{-\theta j} \left( \tilde{\delta}_ni \right)^{-1/\theta j}, \tag{35} \]

and (21) becomes:

\[ \left( \pi^j_{ni} \right)' = \pi^j_{ni} \hat{w}_i \tilde{\delta}_ni \tilde{\delta}_ni \left( \hat{q}_i^j \right)^{-\theta j \tilde{\gamma}_i^j/(1-\tilde{\beta}_i^j)} \left( \hat{q}_i^j \right)^{-\theta j \tilde{\gamma}_i^j/(1-\tilde{\beta}_i^j)} \left( \tilde{\delta}_ni \right)^{-\theta j \tilde{\delta}_ni}. \tag{36} \]

Note that productivity changes do not enter directly into (35) or (36) as they are embedded in the \(\tilde{\delta}_ni\) and \(\tilde{q}_i^j\).

The solution to (18), (19), (35), and (36) is also the solution to (18), (19), (20), and (21). To see why, substitute (32) into (35) to get:

\[ \tilde{q}_n^j = \left( \sum_{i=1}^{I} \pi^j_{ni} \bar{\omega}_i \tilde{\delta}_ni \right)^{-\theta j} \left( \hat{q}_i^j \right)^{1-\tilde{\gamma}_i^j/(1-\tilde{\beta}_i^j)} \left( \hat{q}_i^j \right)^{-\theta j \tilde{\gamma}_i^j/(1-\tilde{\beta}_i^j)} \left( \tilde{\delta}_ni \right)^{-\theta j \tilde{\delta}_ni} \left( \tilde{\delta}_ni \right)^{-1/\theta j}. \]

Grouping terms, the left hand side becomes \(\tilde{q}_n^j / \hat{\Phi}_i^j\) and the price terms on the right hand side become
where\( \hat{q}_i^j/\hat{\Phi}_i^j \) and \( \hat{q}_i^j/\hat{\Phi}_i^j \), leaving a term on the right hand side equal to \( \left( \hat{\Phi}_i^j \right)^{\theta_j[1-\bar{\nu}_i^j(1-\bar{\nu}_i^j)]} \left( \hat{\Phi}_i^j \right)^{-\theta_j \bar{\nu}_i^j(1-\bar{\nu}_i^j)} \). This expression then replicates (20) after substituting in (34) and (33). Similarly, substituting (32) into (36), applying (34) and (33), yields (21).

One implication of this result is that productivity shocks of the form

\[
\hat{A}_i^j = \lambda \bar{\nu}_i^j,
\]

for any \( \lambda > 0 \), leave equilibrium wages, spending, and trade shares unaffected. The resulting price changes are \( \hat{p}_i^j = 1/\lambda \) for \( j \in \Omega_M \). Furthermore, changes in service-sector productivity do not change equilibrium outcomes given the \( \hat{A}_i^j \). Such changes would have welfare consequences, but are irrelevant to the equilibrium considered here.

Another implication of this result is that to solve the model for changes in wages and trade shares, all we need is \( ^j \delta_{ni} \) rather than \( ^j \delta_{ni}^j \) and \( \hat{A}_i^j \) separately. We can decompose the contribution of trade friction and productivity shocks using additional restrictions or data, as we do above with data on sectoral price changes.

If we do not wish to impose further restrictions, we can calibrate the \( ^j \delta_{ni} \) directly. Start by dividing both sides of equation (36) by \( \pi_{ni}^j \) to get an expression for \( \hat{\pi}_{ni}^j \). Dividing by the corresponding expression for \( \hat{\pi}_{ni}^j \) gives:

\[
(\hat{\delta}_{ni}^j)^{-\theta_j} = \frac{\hat{\pi}_{ni}^j}{\hat{\pi}_{ni}^j} \left( \frac{\hat{q}_i^j}{\hat{q}_i^j} \right)^{\theta_j}.
\]

We can then use (36) (for \( n = i \)) and (35) to get:

\[
\hat{\pi}_{ni}^j = \hat{\pi}_{ni}^j \theta_j \left( \frac{\hat{q}_i^j}{\hat{q}_i^j} \right)^{-\theta_j} \left( \frac{1-\bar{\gamma}_i^j(1-\bar{\gamma}_i^j)}{\bar{\gamma}_i^j(1-\bar{\gamma}_i^j)} \right) \left( \frac{\hat{q}_i^j}{\hat{q}_i^j} \right)^{-\theta_j \bar{\gamma}_i^j(1-\bar{\gamma}_i^j)},
\]

where \( l \neq j \) is the other manufacturing sector. Combining these equations for the two manufacturing sectors, and rearranging yields:

\[
\left( \frac{\hat{q}_i^j}{\hat{q}_i^j} \right)^{\theta_j} = \left( \frac{\hat{\pi}_{ni}^j \theta_j}{\hat{\pi}_{ni}^j} \right)^{\theta_j} \left( \frac{1-\bar{\gamma}_i^j(1-\bar{\gamma}_i^j)}{\bar{\gamma}_i^j(1-\bar{\gamma}_i^j)} \right) \left( \frac{\hat{q}_i^j}{\hat{q}_i^j} \right)^{-\theta_j \bar{\gamma}_i^j(1-\bar{\gamma}_i^j)} \left( \frac{\hat{q}_i^j}{\hat{q}_i^j} \right)^{-\theta_j \bar{\gamma}_i^j(1-\bar{\gamma}_i^j)}
\]

where

\[
\Delta_i = \prod_{l \in \Omega_M} \left( 1 - \bar{\gamma}_i^j(1-\bar{\gamma}_i^j) \right) - \prod_{l,j \in \Omega_M, l \neq j} \bar{\gamma}_i^j(1-\bar{\gamma}_i^j).
\]

These expressions for price changes can be plugged into (37) to get:

\[
(\hat{\delta}_{ni}^j)^{-\theta_j} = \frac{\hat{\pi}_{ni}^j}{\hat{\pi}_{ni}^j} \left( \frac{\hat{\pi}_{ni}^j \theta_j}{\hat{\pi}_{ni}^j} \right)^{\theta_j} \left( \frac{1-\bar{\gamma}_i^j(1-\bar{\gamma}_i^j)}{\bar{\gamma}_i^j(1-\bar{\gamma}_i^j)} \right) \left( \frac{\hat{q}_i^j}{\hat{q}_i^j} \right)^{-\theta_j \bar{\gamma}_i^j(1-\bar{\gamma}_i^j)} \left( \frac{\hat{q}_i^j}{\hat{q}_i^j} \right)^{-\theta_j \bar{\gamma}_i^j(1-\bar{\gamma}_i^j)}
\]

This way of calibrating the model is consistent with how we proceed in the paper, except that it does not allow for calculation of the contribution of productivity shocks separate from trade-friction shocks.

We now turn to a method of separating the contribution of productivity and trade-friction shocks by imposing symmetry on the two changes in trade-frictions between any given pair of countries. Since the Head-Ries index is \( \Theta_{ni}^j = \left[ \hat{d}_{ni}^j \hat{d}_{ni}^j \right]^{-\theta_j} \), imposing \( \hat{d}_{ni}^j = \hat{d}_{ni}^j \) implies, in changes, \( \Theta_{ni}^j = \left( \hat{d}_{ni}^j \right)^{-\theta_j} = \left( \hat{d}_{ni}^j \right)^{-\theta_j} \).

Combining with (32), and allowing for deviations \( \mu_{ni}^j \) around symmetry, we get:

\[
\frac{\hat{\Theta}_{ni}^j}{(\hat{\delta}_{ni}^j)^{-\theta_j}} = \left( \frac{\hat{\Phi}_n^j}{\hat{\Phi}_i^j} \right)^{\theta_j} e^{\mu_{ni}^j}.
\]
Taking logs gives an estimating equation:

\[ \ln \Theta_{ni}^j + \theta^i \ln \delta_{ni}^j = \theta^j \ln (\Phi_{ni}^j) - \theta^i \ln (\Phi_{ni}^i) + \mu_{ni}^j. \]  

(40)

The left-hand side can be calculated from our data (employing (15) and (39)), while for the right-hand side we estimate the coefficients on a set of \( N \) dummy variables, one for each country. For each \((n, i)\) observation, there are two non-zero dummy values. The first, corresponding to country \( n \), takes a value of \((+1)\), while the second, corresponding to country \( i \), takes a value of \((-1)\). We estimate \( \Phi_{ni}^j \) by dividing the corresponding coefficients (on the dummy variables for country \( i \)) by \( \theta^j \) (for each sector \( j \)) and exponentiating the result. We drop “Rest of World” since a common scalar won’t change anything. Finally, to recover changes in sectoral productivity, we substitute these estimates into (33).