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Trade and the Global Recession

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Abstract

Global trade fell 20 percent relative to world GDP during the global recession of 2008-2009. We develop a dynamic multi-country general equilibrium model of international trade to investigate the sources of this collapse. Our framework provides a complete accounting for what happened to individual countries' manufacturing trade and production, as well as their relative GDP's, over the period, in terms of different sets of shocks hitting the world economy. We find that declines in the perceived future value of stocks of manufactures account for almost all of the collapse in global trade and production. In contrast, changes in relative GDP's are largely the consequence of shocks to intertemporal preferences. For about half of the 22 countries in our analysis the shocks were primarily from abroad rather than domestic. Unlike the period preceding the global recession, in which declining trade barriers explain a significant component of the variation in trade, little of the trade collapse resulted from increased trade barriers.

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1 Introduction

Global trade plunged 29 percent during the global recession of 2008-2009. That trade would fall in line with other economic magnitudes such as GDP is perhaps not surprising, but global trade fell 20 percent relative to global GDP.[1] What happened during the crisis that led trade to collapse?

We investigate this question using a framework that embeds recent developments in general equilibrium modeling of bilateral trade into a multicountry real business cycle model. In line with the real business cycle literature, representative households populate individual countries. Households consume a nonmanufacturing good and enjoy the services of stocks of durable and semi-durable manufactures. Accumulating these stocks incurs adjustment costs. Competition is perfect and asset markets are complete.

We model trade in the two types of manufactures by treating each as an aggregate of differentiated varieties. Countries specialize in producing different varieties according to Ricardian comparative advantage. Bilateral trade flows reflect the offsetting forces of technological differences and geographic barriers. While trade links countries, the use of intermediates links production across the three sectors. Four types of shocks buffet countries in each period: (i) shocks to intertemporal preferences, (ii) to the value of each type of capital, (iii) to productivity in each sector, and (iv) to the cost of trade with each trading partner.[2]

We apply the framework both to the global recession and to the years leading up to it. We put together data on GDP, manufacturing production, trade, manufacturing prices, and nonmanufacturing deficits for 22 countries (including a "rest of world") that encompass the entire globe. We then apply our framework to these data to extract time series of the different shocks. Together, the shocks account fully for changes in production, trade, and prices, while in the absence of any shocks the world would have changed only because of investment decisions from the past. Of interest to us is how much different types of shocks contributed to what happened, which we can assess through counterfactuals in which we allow only subsets of the shocks to

[1] We measure the drop from the third quarter of 2008 to the second quarter of 2009 using trade and GDP in nominal U.S. dollars for all available countries. Figure 1 plots the average of merchandise imports and merchandise exports relative to GDP for the four largest economies in the world: the United States, Japan, China, and Germany. The ratio of trade to GDP fell sharply in each of these countries, starting in the third quarter of 2008 before beginning a recovery late in the second quarter of 2009, the shaded region in the figure. This large drop in international trade generated attention and concern. 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."

[2] Since we do not model trade in nonmanufactures, to respect accounting identities we introduce nonmanufacturing deficits, which we treat as transfers. This fifth type of shock turns out to play only a very small role.

operate.[3]

We ask two questions: What type of shocks drove what happened? Where did these shocks originate? We look not only at trade, but also at manufacturing production and GDP around the world. Several results stand out.

With respect to the types of shocks that mattered, shocks to the value of capital were the major driver of the overall collapse in trade and in manufacturing production during the global recession. Moreover, cross-country differences in shocks to the value of capital were the primary determinants of cross-country variation in the decline. In contrast, differences in shocks to intertemporal preferences were the primary reason for individual countries' relative GDP fluctuations. Although trade cost shocks were the primary driver of fluctuations in overall trade prior to the recession, they played no role in the collapse of trade during the recession.

With respect to where the relevant shocks originated, the picture is mixed. For about half our countries, trade and manufacturing production collapsed primarily because of shocks emanating from abroad, while for the rest domestic shocks mattered more.

Our work relates to two different literatures: First, our results complement various papers investigating the forces driving the trade collapse during the global recession. Second, our methodology builds on efforts to understand the links between macroeconomic fluctuations and international trade.

1.1 Related Literature: The Trade Collapse

In Baldwin (2009), dozens of researchers pose various hypotheses for why trade plummeted. Explanations fall into several categories.

One attributes the collapse to forces increasing barriers to trade. The literature points to two specific trade barriers. Since a banking crisis was a major component of the global recession, several authors have blamed the trade collapse on tightening trade credit.[4] Others have cited increased protectionism.[5]

[3]Just as growth accounting uses a theoretical framework to decompose output growth into the growth of labor and capital inputs and the Solow residual, we use our model to decompose changes in output, trade, and prices into our sets of shocks. Unlike growth accounting, however, evaluating the contribution of individual shocks requires solving a counterfactual equilibrium, as in the Chari, Kehoe, and McGrattan (2007) "wedges" approach to business cycle accounting.

[4]Amiti and Weinstein (2011) show that the health of Japanese firms' banks significantly affected the firms' export activity, presumably through their role in issuing trade credit. Using U.S. trade data during the recent episode, Chor and Manova (2011) 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 access to trade credit in explaining the recent trade collapse.

[5]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." The

Another literature has attributed the collapse in trade to the differential impact of the recession on different sectors of the economy.[6] A third hypothesis is that international vertical supply chains disintegrated.[7]

In line with our analysis here, Engel and Wang (2011) and Alessandria, Kaboski, and Midrigan (2010a,b) develop dynamic two-country models capable of explaining the trade collapse. In these models durable goods or inventories play a central role, much as capital stock dynamics do in our analysis.

1.2 Related Literature: Macroeconomics and Trade

Our methodology differs from others applied to the trade collapse, instead building on a literature that studies the role of trade barriers in segmenting financial markets as well as goods markets. A pioneering paper by Obstfeld and Rogoff (2001) provides a series of stylized models of the world economy in which trade barriers separate individual countries subject to individual shocks. They show how barriers to goods trade lead to incomplete international risk sharing, deviations from interest parity, and correlations at the national level between savings and investment, thus explaining the Feldstein-Horioka (1980) puzzle. Their analysis is limited to two countries, so is not amenable to realistic quantification.

Other papers have examined macroeconomic phenomena in terms of a model that can exploit the rich data on bilateral trade. Dekle, Eaton, and Kortum (2007, 2008) use such a model to ask what eliminating trade deficits would imply for relative wages in different countries of the world. Their model is static, however. In particular, they treat deficits and shocks to the demand for manufactures as exogenous.[8]

Closest to the framework here is Fitzgerald (2012), who embeds a multi-country model with trade barriers into an explicitly dynamic framework. She uses the model to test for asset-market completeness, and, among rich counties, is unable to reject it.

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fiscal stimulus measures implemented in various countries might have included home bias in government purchases, constituting a particular form of protectionism.

[6]Using U.S. data, Levchenko, Lewis, and Tesar (2010) show that the decline in trade was accompanied by a relative decline in demand for tradables, particularly durable goods. Using multicountry trade and production data, Bems, Johnson, and Yi (2010) link changes in final demand during the recent recession to changes in trade flows throughout the global system, showing that the changing composition of GDP can largely account for the decline in trade. Using firm-level data, Behrens, Corcos, and Mion (2010) (for Belgium) and Bricongne, Fontagne, Gaulier, Taglioni, and Vicard (2011) (for France) also find support for the view that a shift in the composition of demand was behind the decline in trade.

[7]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." Yi (2009) puts forth a similar hypothesis.

[8]An earlier version of this paper (Eaton, Kortum, Neiman, and Romalis, 2011) followed Dekle, Eaton, and Kortum (2007, 2008) in treating shocks to deficits and shocks to the demand for durable and semi-durable manufactures as primitives. In the current version they arise endogenously.

To build on this literature, in light of Fitzgerald's result, we assume asset-market completeness. We push the framework much further, however, adapting it to measure the shocks hitting the world economy, to assess their contributions to the global recession, and to track their transmission across countries. In contrast to Dekle, Eaton, and Kortum (2007, 2008), our dynamic setting ties trade deficits and spending on manufactures to the equilibrium savings and investment decisions of households and firms in different countries. We can thus relate what happened to deeper underlying shocks to preferences and technology.

We proceed as follows. Section 2 provides an overview of the data. Section 3 presents our model. We reformulate the model's equilibrium conditions in Section 4 to connect them with the data. Section 5 shows how we use the model to extract the model's underlying shocks from production, trade, and price data. Section 6 then uses the model to conduct a set of decompositions that identify the role of different types of shocks in the global recession. Here we conduct the analysis period-by-period while in Section 7 we perform decompositions examining what happens if we shut down shocks over longer horizons. Section 8 concludes.

2 A First Look at the Data

Is the decline in trade relative to GDP during the global recession anomalous or just the manifestation of a business cycle regularity?[9] To get a handle on the answer, Figure 2 plots four-quarter changes in non-oil imports relative to GDP against the change in real GDP for the United States, Japan, China, and Germany through 2009:Q4. The observations since 2008:Q3, the onset of the global recession, appear as solid squares while previous quarters are hollow circles. We include regression lines based on pre-recession observations. Note that, for the United States and Germany, the slope of the line is distinctly positive and that the observations for the global recession lie close to the regression line based on the prior period. They are, of course, at the lower left-hand tail, reflecting the fact that the global recession was the worst recession in the period. For Japan and China, however, there is little or no relationship between imports and GDP in the earlier years. So the decline in their trade-GDP ratios during the global recession constitutes a more marked departure from previous patterns.

Figure 3 reports the corresponding four-quarter changes in the share of spending on manufactures relative to GDP against changes in real GDP for the same four countries and the same periods. Slopes for the United States and Germany indicate that manufacturing spending, like

[9] Appendix A, found in the online appendix available at the authors' web pages, describes the data used here and throughout the paper.

trade, has been more procyclical than in Japan and China, although even for these countries the slope, again based on the earlier period, is positive. The global recession does not appear particularly anomalous.

We explore these issues in greater detail expanding our sample to 21 economies which comprise nearly three-fourths of world GDP, combining all others into a single Rest of World. Table 1 lists the countries, reporting their shares of global GDP and trade and the ratios of their own trade (exports plus imports divided by two) and manufacturing production to their own GDP. All data are for 2008:Q3, the base period before the global trade collapse.

We focus now on the global recession, looking at the change from 2008:Q3 to 2009:Q2. To delve further into the role of manufactures we decompose them into durables and semi-durables.[10] Figure 4 plots each country's change in trade in manufactures against the change in its manufacturing production, separating durables trade and production (in solid squares) and semi-durables trade and production (in hollow circles). Here and below we report changes as the ratio of the end-period value to the beginning-period value. Note the sharp declines, particularly for durables. Note also the correlation across countries between the change in production and in trade, which is also more pronounced for durables.

We now turn to our dynamic, multi-country model in which durable and semi-durable manufactures have distinct, central roles. We then return to these data to quantify our model in order to isolate the factors driving the global collapse of trade and production.

3 The Model

We consider a multi-country infinite-horizon model. Time is discrete. Let s_t denote a state of nature in period t (with s_0 given), $s^t = (s_0, s_1, ..., s_t)$ the history of states through period t, and $\Pi_t(s^t)$ the probability as of date 0 of the history of states s^t. (The t subscript on the function Π_t indicates the dimension of its argument.) We use the term "state" to refer to s^t at date t.

As is standard in a Ricardian model, each country $i = 1, ..., I$ has an endowment L_i of homogeneous workers, which we treat as constant across time and states. Workers can move across different activities within a country but can't change countries.

[10] Appendix Table A.2 lists the industries we classify as durable manufactures and as semi-durable manufactures (as well as nonmanufactures). We distinguish between them because these two components of manufacturing have experienced shocks of different sizes, as documented in Engel and Wang (2011) and Levchenko, Lewis, and Tesar (2010).

3.1 Technology

We begin by describing the static technology for production within any state s^t. We then turn to how investment connects endowments across periods.

3.1.1 The Static Framework

Our static general equilibrium framework builds on Eaton and Kortum (2002), Alvarez and Lucas (2007), and Dekle, Eaton, and Kortum (2008).[11] The economy consists of three sectors, indexed by j: nonmanufactures ($j = N$), semi-durable manufactures ($j = S$), and durable manufactures ($j = D$).[12] We let $\Omega = \{N, S, D\}$ denote the set of three sectors and $\Omega_M = \{S, D\}$ denote the set of manufacturing sectors.

Output from each of the three sectors can serve as intermediate inputs in each sector. Output from the nonmanufacturing sector ($j = N$) is also used for consumption. Output of the durable and semi-durable manufactures sectors is also used to invest in stocks of installed capital whose services are consumed. These installed stocks themselves do not trade across countries.

Production in each sector combines the services of labor with intermediates from each of the three sectors. Technology is Cobb-Douglas with constant returns to scale. Labor has a share β_i^j of gross production in sector j of country i, while γ_i^{jl} denotes the share of sector l in intermediates used by sector j with $\sum_{l\in\Omega} \gamma_i^{jl} = 1$ for each $j \in \Omega$.[13]

In each manufacturing sector ($j \in \Omega_M$) output is a CES aggregate (with elasticity of substitution σ^j) of the outputs of a unit continuum of goods (one for S and one for D) indexed by $z^j \in [0, 1]$. Country i's efficiency $a_{i,t}^j(z^j, s^t)$ at making good z^j in state s^t is the realization of a random variable $a_{i,t}^j$ with distribution

$$F_{i,t}^j(a|s^t) = \Pr\left[a_{i,t}^j \le a\right] = e^{-T_{i,t}^j(s^t)a^{-\theta^j}}, \tag{1}$$

drawn independently for each z^j across countries i. Here, $T_{i,t}^j(s^t) > 0$ is a parameter that reflects

[11] Papers that have introduced interindustry interaction into this framework include Shikher (2011) and Caliendo and Parro (2009).

[12] When we connect the model to data, services will represent the largest share of non-manufactures, though this category also includes agriculture and commodities such as petroleum and other raw materials.

[13] Hence the Cobb-Douglas aggregate input bundle $B_{i,t}^j(s^t)$ used to produce output for sector j in state s^t is:

$$B_{i,t}^j(s^t) = \left(\frac{l_{i,t}^j(s^t)}{\beta_i^j}\right)^{\beta_i^j} \prod_{l\in\Omega} \left(\frac{y_{i,t}^{jl}(s^t)}{\gamma_i^{jl}(1-\beta_i^j)}\right)^{\gamma_i^{jl}(1-\beta_i^j)},$$

where $l_{i,t}^j$ is labor input in sector j and $y_{i,t}^{jl}$ is sector-l intermediate input used in sector-j production. Input-output tables offer support for our Cobb-Douglas assumption for short periods of time. Appendix Figure A.2 shows that the β and γ values in several large economies remained quite stable from 2000 to 2005.

country i's overall efficiency in producing any good z^j in state s^t. The parameter θ^j, constant over time and states, is an inverse measure of the dispersion of efficiencies.[14] In the nonmanufacturing sector, country i's efficiency in state s^t is $A^N_{i,t}(s^t)$.

We make the standard iceberg assumption about trade costs for manufactures, that delivering one unit of a good from country i to country n in state s^t requires shipping $d^j_{ni,t}(s^t) \geq 1$ units, with $d^j_{ii,t}(s^t) = 1$. Our analysis treats the value of each country's trade deficit in nonmanufactures $D^N_{i,t}(s^t)$ as exogenous, so we require no further assumption about trade in this sector. Unlike Dekle, Eaton, and Kortum (2008) and Caliendo and Parro (2009), however, a country's overall trade deficit emerges as an endogenous outcome.

3.1.2 Capital Stock Dynamics

Capital of type $j \in \Omega_M$ accumulates in country i according to:

$$K^j_{i,t+1}(s^t) = K^j_{i,t}(s^{t-1}) \left[\left(1 - \delta^j\right) + \chi^j \iota^j_{i,t}(s^t)^{\alpha^j} \right], \tag{2}$$

where $\iota^j_{i,t}(s^t)$ is investment per unit of capital, χ^j governs the efficiency of investment, $0 < \alpha^j < 1$ governs adjustment costs, and δ^j is the depreciation rate. Due to the one-period delay built into the accumulation equation, capital at date t is determined by the state in the previous period s^{t-1}. We take initial capital stocks $K^j_{i,1}(s^0)$ as given.

3.2 Preferences

Each period t (and state s^t) the household receives utility from the consumption of the non-manufacturing bundle in amount $C^N_{i,t}\left(s^t\right)$ as well as from the stock of durables or semi-durables, $K^j_{i,t}(s^{t-1})$. Consumption from each sector j combines to form aggregate consumption:

$$C_{i,t}\left(s^t\right) = C^N_{i,t}\left(s^t\right)^{\psi^N} K^S_{i,t}\left(s^{t-1}\right)^{\psi^S} K^D_{i,t}\left(s^{t-1}\right)^{\psi^D},$$

where $\psi^j \geq 0$ and $\psi^N + \psi^S + \psi^D = 1$. From the perspective of period 0, the lifetime utility of the representative agent in country i is:

$$U_i = \sum_{t=1}^{\infty} \sum_{s^t} \rho^t \Pi_t\left(s^t\right) \phi_{i,t}\left(s^t\right) \ln C_{i,t}\left(s^t\right), \tag{3}$$

[14]In order to obtain a solution for the price index below, we require that $\theta^j > \sigma^j - 1$. As long as this condition is satisfied, the value of the parameter σ^j doesn't matter for our analysis.

where ρ is a constant discount factor and $\phi_{i,t}(s^t)$ is the intertemporal preference (or intertemporal demand) shock for country i in state s^t.

3.3 Market Structure and Equilibrium

Markets are perfectly competitive and complete. Households make consumption decisions, buying the nonmanufacturing good and renting manufactures from firms, while firms, which own the stocks of capital rented by households, make production and investment decisions. Households supply labor to firms, in which they own shares. An equilibrium of the model has the following components:

1. Within each state s^t for each country i, competitive labor, capital, and goods-market equilibrium establishes: (i) the wage of labor $w_{i,t}(s^t)$; (ii) the value of a unit of the capital stock $v^j_{i,t}(s^t)$ and its rental price $r^j_{i,t}(s^t)$, $j \in \Omega_M$, (iii) the price of each manufactured good $p^j_{i,t}(z^j, s^t)$, $z^j \in [0,1]$, (iv) the associated sectoral price indices $p^j_{i,t}(s^t)$, $j \in \Omega_M$, and (v) the price of the nonmanufactured good $p^N_{i,t}(s^t)$. Markets for labor, capital, and nonmanufactures are national but international trade links the prices of manufactures $p^j_{i,t}(z^j, s^t)$ across countries. In any state s^t, prices are normalized so that world labor income is equal to a constant Y.

2. As in Arrow (1964), asset market equilibrium establishes the price $q_t(s^t)$ at date 0 of an asset delivering one monetary unit in state s^t. Such a security exists for each possible state s^t, with the price common to all countries. Arbitrage implies that the price $q(s^{t+1}|s^t)$ in state s^t of an asset delivering one monetary unit in state s^{t+1} is:

$$q\left(s^{t+1}|s^t\right) = \begin{cases} q_{t+1}\left(s^{t+1}\right)/q_t\left(s^t\right) & s^{t+1} = \left(s^t, s_{t+1}\right) \\ 0 & \text{otherwise} \end{cases}. \tag{4}$$

3. Firms choose an investment rate $\iota^j_{i,t}(s^t)$ in each country i in each state s^t to maximize the value $v^j_{i,t}(s^t)$ of each unit of installed capital:[15]

$$v^j_{i,t}(s^t) = \max_{\iota}\left(r^j_{i,t}(s^t) - p^j_{i,t}(s^t)\iota + \left[\left(1-\delta^j\right) + \chi^j \iota^{\alpha_j}\right]\sum_{s'} q\left(s'|s^t\right) v^j_{i,t+1}(s')\right). \tag{5}$$

4. Consumers make a set of consumption choices $\{C^N_{i,t}(s^t), K^S_{i,t}(s^{t-1}), K^D_{i,t}(s^{t-1})\}$ in each coun-

[15]In this expression and below the summation is over states in the subsequent period.

try i in each state s^t to maximize (3) subject to the lifetime intertemporal budget constraint:

$$\begin{aligned}&\sum_{t=1}^{\infty}\sum_{s^t} q_t\left(s^t\right)\left[p_{i,t}^N\left(s^t\right)C_{i,t}^N\left(s^t\right)-D_{i,t}^N(s^t)+r_{i,t}^S\left(s^t\right)K_{i,t}^S\left(s^{t-1}\right)+r_{i,t}^D\left(s^t\right)K_{i,t}^D\left(s^{t-1}\right)\right]\\ = \;& V_i^S+V_i^D+H_i+B_i, \qquad (6)\end{aligned}$$

where the initial value of the type-j capital stock is:

$$V_i^j=\sum_{s^1} q_1(s^1)v_{i,1}^j(s^1)K_{i,1}^j(s^0),$$

the initial value of future labor earnings is:

$$H_i=\sum_{t=1}^{\infty}\sum_{s^t} q_t\left(s^t\right)w_{i,t}\left(s^t\right)L_i,$$

and B_i is the initial net foreign position of country i (which sums to zero across countries).

4 Solution

Our goal is to use this model to provide a mapping between observables and an underlying set of shocks in order to infer the shocks from observables and to derive counterfactual observables from counterfactual shocks. To do so we now (1) report the equilibrium conditions that we use in quantifying the model, (2) show how we reduce the dimensionality of the equilibrium conditions by collapsing nonmanufactures into manufactures, and (3) express these equilibrium conditions in changes.

4.1 Key Expressions

We now consider the expressions for prices and trade shares and for consumption and investment which we then combine into conditions for equilibrium.

4.1.1 Prices and Trade Shares

The cost of a bundle of inputs for each sector $j \in \Omega$, which we denote $c_{i,t}^j\left(s^t\right)$, is given by:

$$c_{i,t}^j\left(s^t\right)=w_{i,t}\left(s^t\right)^{\beta_i^j}\prod_{l\in\Omega} p_{i,t}^l\left(s^t\right)^{\gamma_i^{jl}\left(1-\beta_i^j\right)}. \qquad (7)$$

Perfect competition equates prices to marginal cost.

International competition establishes a price for each good $z^j,\ j \in \Omega_M$ in country n of:

$$p^j_{n,t}(z^j, s^t) = \min_i \left\{ \frac{c^j_{i,t}(s^t) d^j_{ni,t}(s^t)}{a^j_{i,t}(z^j, s^t)} \right\}.$$

The probability that source i attains this minimum cost, and is thus the source of a good in sector $j \in \Omega_M$ in market n, is:

$$\pi^j_{ni,t}(s^t) = T^j_{i,t}(s^t) \left[\frac{c^j_{i,t}\left(s^t\right) d^j_{ni,t}(s^t)}{p^j_{n,t}(s^t)/\varphi^j} \right]^{-\theta^j}, \tag{8}$$

which, since there are a continuum of each type of manufactures, is also the share of country n's spending (in sector j) devoted to goods from i. Finally,

$$p^j_{n,t}(s^t) = \varphi^j \left[\sum_{i=1}^{I} T^j_{i,t}(s^t) \left(c^j_{i,t}(s^t) d^j_{ni,t}(s^t) \right)^{-\theta^j} \right]^{-1/\theta^j}, \tag{9}$$

is the price index for manufactures $j \in \Omega_M$ in country n.[16]

We treat nonmanufactures as undifferentiated and nontraded. We account for nonmanufacturing trade deficits by treating them as transfers of nonmanufactures, but assume that in equilibrium every country makes at least some of its own nonmanufactures. Hence the price of nonmanufactures in country i is simply $p^N_{i,t}\left(s^t\right) = c^N_{i,t}\left(s^t\right)/A^N_{i,t}\left(s^t\right)$.

4.1.2 Intertemporal Choices

Choosing an investment rate to maximize (5) implies a level of investment spending:

$$p^j_{i,t}(s^t)\iota^j_{i,t}(s^t)K^j_{i,t}(s^{t-1}) = \left(p^j_{i,t}(s^t)\right)^{\frac{-\alpha^j}{1-\alpha^j}} \left(\alpha^j \chi^j Q^j_{i,t}(s^t)\right)^{\frac{1}{1-\alpha^j}} K^j_{i,t}(s^{t-1}), \tag{10}$$

where

$$Q^j_{i,t}\left(s^t\right) = \sum_{s'} q\left(s'|s^t\right) v^j_{i,t+1}(s') \tag{11}$$

is the value in state s^t of a unit of capital available in the subsequent period.

Choosing consumption of nonmanufactures to maximize (3), subject to the budget constraint

[16] See Eaton and Kortum (2002) for derivations of (8) and (9). The parameter φ^j in those equations is a constant determined by θ^j and σ^j:

$$\varphi^j = \left[\Gamma\left(\frac{\theta^j - \sigma^j + 1}{\theta^j} \right) \right]^{1/(1-\sigma^j)},$$

with

$$\Gamma(a) = \int_0^\infty e^{-t} t^{a-1} dt,$$

the complete gamma function. Its value drops out of the expressions used in our quantitative analysis.

(6), implies a level of spending on nonmanufactures:

$$p_{i,t}^{N}\left(s^{t}\right)C_{i,t}^{N}\left(s^{t}\right)=\frac{\rho^{t}\psi^{N}\Pi_{t}\left(s^{t}\right)}{\lambda_{i}q_{t}\left(s^{t}\right)}\phi_{i,t}\left(s^{t}\right), \tag{12}$$

where λ_i is the Lagrange multiplier associated with the intertemporal wealth constraint (6). A key implication of complete markets is that λ_i is time invariant while $\Pi_t\left(s^t\right)/q_t\left(s^t\right)$ is country invariant. The intertemporal preference shock $\phi_{i,t}\left(s^t\right)$ accounts for variation in spending on nonmanufactures across countries over time.

4.1.3 Equilibrium Conditions

Define $Y_{i,t}^{j}(s^t)$ as the value of sector j gross production in country i and $X_{i,t}^{j}(s^t)$ as country i's total spending on the output of sector j. The deficit of country i for sector j is thus $D_{i,t}^{j}(s^t)=X_{i,t}^{j}(s^t)-Y_{i,t}^{j}(s^t)$.

Total spending $X_{i,t}^{j}(s^t)$ is in turn the sum of country i's spending on final goods and its demand for intermediates from each sector $l\in\Omega$:

$$X_{i,t}^{j}(s^t)=X_{i,t}^{F,j}(s^t)+\sum_{l\in\Omega}\gamma_i^{lj}(1-\beta_i^{l})Y_{i,t}^{j}(s^t), \tag{13}$$

where final spending in sector j is:

$$X_{i,t}^{F,j}(s^t)=\begin{cases} p_{i,t}^{j}(s^t)\iota_{i,t}^{j}(s^t)K_{i,t}^{j}(s^{t-1}) & j\in\Omega_M \\ p_{i,t}^{N}\left(s^t\right)C_{i,t}^{N}\left(s^t\right) & j=N \end{cases}.$$

Final spending across all sectors equals GDP plus deficits:

$$\sum_{j\in\Omega}X_{i,t}^{F,j}(s^t)=Y_{i,t}^{F}(s^t)+\sum_{j\in\Omega}D_{i,t}^{j}(s^t), \tag{14}$$

where GDP equals labor income, $Y_{i,t}^{F}(s^t)=w_{i,t}\left(s^t\right)L_i$.[17] The market for each manufacturing sector $j\in\Omega_M$ clears, requiring that the value of production in each country i equals global demand for it:

$$Y_{i,t}^{j}(s^t)=\sum_{n=1}^{I}\pi_{ni,t}^{j}(s^t)X_{n,t}^{j}(s^t). \tag{15}$$

[17]In taking the model to data we treat stocks of manufactures as if they were all owned by households, so the rental income they generate does not appear in GDP.

4.2 Hiding Nonmanufactures

To simplify the solution we fold the conditions for equilibrium in nonmanufactures into the conditions for equilibrium in the two manufacturing sectors $j \in \Omega_M$. To perform this step we introduce the following compound input shares:

1. We add to β_i^j a term to capture sector j's use of labor through nonmanufactured intermediates:
$$\tilde{\beta}_i^j = \beta_i^j + \frac{\gamma_i^{jN}(1-\beta_i^j)\beta_i^N}{1-\gamma_i^{NN}(1-\beta_i^N)}. \tag{16}$$

2. We add to γ_i^{jl} a term to capture j's use of output from l through nonmanufactured intermediates:
$$\tilde{\gamma}_i^{jl} = \gamma_i^{jl} + \gamma_i^{jN}\frac{\gamma_i^{Nl}(1-\beta_i^N)+\gamma_i^{jl}\beta_i^N}{1-\gamma_i^{NN}(1-\beta_i^N)-\gamma_i^{jN}\beta_i^N}. \tag{17}$$

3. We introduce a term that reflects the share of intermediates from manufacturing sector j in the final output of nonmanufactures:
$$\xi_i^j = \frac{\gamma_i^{Nj}(1-\beta_i^N)}{1-\gamma_i^{NN}(1-\beta_i^N)}. \tag{18}$$

We fold nonmanufacturing productivity into sector j's productivity with the term:

$$A_{i,t}^j(s^t) = A_{i,t}^N(s^t)^{\frac{\tilde{\beta}_i^j-\beta_i^j}{\beta_i^N}} T_{i,t}^j(s^t)^{1/\theta^j}, \tag{19}$$

allowing us to express the price index (9) as:

$$p_{n,t}^j(s^t) = \varphi^j\left[\sum_{i=1}^{I}\left(w_{i,t}\left(s^t\right)^{\tilde{\beta}_i^j}\left[\prod_{l\in\Omega_M} p_{i,t}^l\left(s^t\right)^{\tilde{\gamma}_i^{jl}(1-\tilde{\beta}_i^j)}\right]\frac{d_{ni,t}^j(s^t)}{A_{i,t}^j(s^t)}\right)^{-\theta^j}\right]^{-1/\theta^j}. \tag{20}$$

The share (8) of country n's sector-j spending devoted to goods from i becomes:

$$\pi_{ni,t}^j(s^t) = \left[w_{i,t}\left(s^t\right)^{\tilde{\beta}_i^j}\left(\prod_{l\in\Omega_M} p_{i,t}^l\left(s^t\right)^{\tilde{\gamma}_i^{jl}(1-\tilde{\beta}_i^j)}\right)\frac{\varphi^j d_{ni,t}^j(s^t)}{A_{i,t}^j(s^t)p_{n,t}^j(s^t)}\right]^{-\theta^j}. \tag{21}$$

4.3 The Equilibrium in Changes

The next step toward quantification is to reformulate the model in terms of values at date $t+1$ relative to values at date t. For any variable $x_t(s^t)$, then, we define:

$$\hat{x}_{t+1} = \frac{x_{t+1}(s^{t+1})}{x_t(s^t)}.$$

Expressing the model in changes we relate five sets of equilibrium outcomes to five sets of underlying shocks through five sets of equations.

4.3.1 Three Background Results

Before turning to the five sets of equilibrium equations, we introduce three other relationships that operate behind the scenes.

The first relates period $t+1$ total expenditure on manufactures around the world to changes in final demand for manufactures $\hat{X}^{F,j}_{i,t+1}$ and nonmanufactures $\hat{X}^{F,N}_{i,t+1}$, conditioning on period t values. Substituting the goods-market clearing condition (15) into the input-output relations (13), we obtain a global input-output system for sectors $j \in \Omega_M$:

$$X^j_{i,t+1} = \hat{X}^{F,j}_{i,t+1} X^{F,j}_{i,t} + \sum_{l \in \Omega_M} \tilde{\gamma}^{lj}_i (1 - \tilde{\beta}^l_i) \sum_{n=1}^{I} \hat{\pi}^l_{ni,t+1} \pi^l_{ni,t} X^l_{n,t+1} + \xi^j_i Y^{F,N}_{i,t+1}, \tag{22}$$

where ξ^j_i is given in (18) and

$$Y^{F,N}_{i,t+1} = \hat{X}^{F,N}_{i,t+1} X^{F,N}_{i,t} - D^N_{i,t+1}$$

is the value of production to meet final demand for nonmanufactures in country i. Given period t magnitudes, changes from t to $t+1$, and parameters, we can solve the system of equations (22) for period $t+1$ total spending on each sector $j \in \Omega_M$ in each country i, $X^j_{i,t+1}$.

The second relationship relates changes in spending on nonmanufactures to shocks to intertemporal prices and to intertemporal demand. Within any period we can relate our model to data on relative prices and expenditures. But intertemporal choices (10) and (12) depend on how a unit of expenditure in the subsequent state s^{t+1} is evaluated relative to expenditure in state s^t through $q\left(s^{t+1}|s^t\right)$. To relate this intertemporal price, which is the same everywhere, to observables we proceed as follows.

From (12), the growth in nonmanufacturing consumption spending in country i is:

$$\hat{X}^{F,N}_{i,t+1} = \rho \frac{\Pi\left(s^{t+1}|s^t\right)}{q\left(s^{t+1}|s^t\right)} \hat{\phi}_{i,t+1}, \tag{23}$$

where $\Pi(s^{t+1}|s^t)$ is the conditional probability of a state s^{t+1} given s^t:

$$\Pi(s^{t+1}|s^t) = \begin{cases} \Pi_{t+1}\left(s^{t+1}\right)/\Pi_t\left(s^t\right) & s^{t+1} = \left(s^t, s_{t+1}\right) \\ 0 & \text{otherwise} \end{cases}.$$

Summing across countries gives an expression for the change in world spending on nonmanufactures:

$$\hat{X}^{F,N}_{t+1} = \rho \frac{\Pi\left(s^{t+1}|s^t\right)}{q\left(s^{t+1}|s^t\right)} \hat{\phi}^W_{t+1}, \tag{24}$$

where:

$$\hat{\phi}^W_{t+1} = \sum_{i=1}^{I} \left(\frac{X^{F,N}_{i,t}}{X^{F,N}_{t}} \right) \hat{\phi}_{i,t+1} \tag{25}$$

can be interpreted as the world intertemporal preference shock. Expression (24) shows how changes in world spending on nonmanufactures, which we can observe, reflect both the intertemporal price $q\left(s^{t+1}|s^t\right)$ (relative to $\Pi\left(s^{t+1}|s^t\right)$) and the world intertemporal preference shock $\hat{\phi}^W_{t+1}$.[18]

The third relationship pertains to our use of world income in any state s^t as numéraire. We express growth in global consumption of nonmanufactures $\hat{X}^{F,N}_{t+1}$ in terms of the growth of final spending on manufactures in each country as follows. Since world GDP is the sum of all final spending, and is normalized to $Y = 1$ each period, we can write:

$$X^{F,N}_{t+1} = 1 - \sum_{i=1}^{I} \sum_{j \in \Omega_M} X^{F,j}_{i,t+1}.$$

Dividing both sides by $X^{F,N}_t$, we have:

$$\hat{X}^{F,N}_{t+1} = \frac{1}{X^{F,N}_t} \left[1 - \sum_{j \in \Omega_M} \sum_{i=1}^{I} X^{F,j}_{i,t} \hat{X}^{F,j}_{i,t+1} \right]. \tag{26}$$

Together, expressions (24) and (26) allow us to relate data on changes in final spending on manufactures around the world and data on world spending on nonmanufactures to global intertemporal shocks. Our choice of numéraire implies that all level variables such as $X^{F,j}_{i,t}$, $Y^F_{i,t}$, and $D^N_{i,t}$ are measured in terms of world GDP.

4.3.2 Shocks and Conditions for Equilibrium

Our five sets of equations determine five sets of equilibrium outcomes: (i) changes in the trade shares for manufactures $\hat{\pi}^j_{ni,t+1}$, (ii) changes in the prices of manufactures $\hat{p}^j_{n,t+1}$, (iii) changes

[18] Our data do not allow us to disentangle the effects of $q\left(s^{t+1}|s^t\right)$ and $\hat{\phi}^W_{t+1}$ on intertemporal decisions. Hence we design our approach to avoid any need to separate them.

in final demand for manufactures $\hat{X}^{F,j}_{i,t+1}$, all for $j \in \Omega_M$, (iv) changes in the final demand for nonmanufactures $\hat{X}^{F,N}_{i,t+1}$, and (v) changes in wages $\hat{w}_{i,t+1}$. The five sets of equations also relate these five sets of outcomes to five sets of underlying shocks.

Five Sets of Shocks Trade cost shocks $\hat{d}^{j}_{ni,t+1}$ and productivity shocks $\hat{A}^{j}_{i,t+1}$ are simply the changes in the corresponding level variables introduced above. The third set are the nonmanufacturing deficits $D^{N}_{i,t+1}$, which we simply connect to the observed levels (these shocks appear in levels since they can be zero).

The fourth set of shocks are to country-level demand. We cannot identify $\hat{\phi}_{i,t+1}$ but instead define:

$$\hat{\phi}^{*}_{i,t+1} = \frac{\hat{\phi}_{i,t+1}}{\hat{\phi}^{W}_{t+1}}$$

where $\hat{\phi}^{W}_{t+1}$ is given by (25). Hence a country's intertemporal preference shock is relative to the world's intertemporal preference shock.

The fifth set, shocks to the value of capital, are more involved and warrant a separate paragraph. Expression (10) relates investment spending to the value of capital $Q^{j}_{i,t+1}$ given by (11). In terms of changes:

$$\hat{Q}^{j}_{i,t+1} = \frac{Q^{j}_{i,t+1}(s^{t+1})}{Q^{j}_{i,t}(s^{t})} = \frac{\sum_{s''} q\left(s''|s^{t+1}\right) v^{j}_{i,t+2}(s'')}{\sum_{s'} q\left(s'|s^{t}\right) v^{j}_{i,t+1}(s')},$$

which depends not only on the future value of the capital stock $v^{j}_{i,t+2}(s^{t+2})$ but also on the intertemporal price $q\left(s^{t+2}|s^{t+1}\right)$, which responds to other contemporaneous shocks through $q_{t+1}(s^{t+1})$. (Note that s^{t+1} in the numerator is the realized state while s' in the denominator indexes all possible states at date $t+1$.) To purge $\hat{Q}^{j}_{i,t+1}$ of $q_{t+1}(s^{t+1})$ and to relate it to observables we replace it with the shock:

$$\hat{Q}^{*j}_{i,t+1} = \frac{q(s^{t+1}|s^{t})}{\Pi(s^{t+1}|s^{t})\rho\hat{\phi}^{W}_{t+1}} \hat{Q}^{j}_{i,t+1}. \tag{27}$$

The term $q(s^{t+1}|s^{t})$ cancels $q_{t+1}(s^{t+1})$.[19] Combining $\hat{\phi}^{W}_{t+1}$, introduced in (25), with $\hat{Q}^{j}_{i,t+1}$ creates a single shock that splits final spending between investment in capital and consumption of

[19] To see this cancellation write (27) as:

$$\begin{aligned}
\hat{Q}^{*j}_{i,t+1} &= \frac{q_{t+1}(s^{t+1})/q_{t}(s^{t})}{\Pi(s^{t+1}|s^{t})\rho\hat{\phi}^{W}_{t+1}} \frac{\sum_{s''}\left[q_{t+2}\left(s''\right)/q_{t+1}(s'')\right] v^{j}_{i,t+2}(s'')}{\sum_{s'}\left[q_{t+1}\left(s'\right)/q_{t}(s^{t})\right] v^{j}_{i,t+1}(s')} \\
&= \frac{1}{\Pi(s^{t+1}|s^{t})\rho\hat{\phi}^{W}_{t+1}} \frac{\sum_{s''} q_{t+2}(s'') v^{j}_{i,t+2}(s'')}{\sum_{s'} q_{t+1}(s') v^{j}_{i,t+1}(s')},
\end{aligned}$$

so that $q_{t+1}(s^{t+1})$ no longer appears.

nonmanufactures. Finally, introducing $\Pi(s^{t+1}|s^t)\rho$ allows us to use (24) to write:

$$\hat{Q}^{*j}_{i,t+1} = \frac{\hat{Q}^j_{i,t+1}}{\hat{X}^{F,N}_{t+1}},$$

which is convenient in connecting the model to observables.[20]

In summary, our model relates the five sets of equilibrium outcomes enumerated above to shocks (i) to bilateral trade frictions $\hat{d}^j_{ni,t+1}$, (ii) to productivity $\hat{A}^j_{i,t+1}$, (iii) to the value of capital $\hat{Q}^{*j}_{i,t+1}$, (iv) to intertemporal preferences $\hat{\phi}^*_{i,t+1}$, and (v) to the nonmanufacturing deficit $D^N_{i,t+1}$.

Five Equilibrium Conditions We now turn to the five sets of equations that relate these five sets of outcomes to the five sets of shocks:

1. We express the trade share equation (21) in changes, for sectors $j \in \Omega_M$:

$$\hat{\pi}^j_{ni,t+1} = \left[(\hat{w}_{i,t+1})^{\tilde{\beta}^j_i} \left(\prod_{l \in \Omega_M} (\hat{p}^l_{i,t+1})^{\tilde{\gamma}^{jl}_i (1-\tilde{\beta}^j_i)} \right) \left(\frac{\hat{d}^j_{ni,t+1}}{\hat{A}^j_{i,t+1} \hat{p}^j_{n,t+1}} \right) \right]^{-\theta^j}. \tag{28}$$

2. Similarly, we express the price equation (20) in changes, for sectors $j \in \Omega_M$:

$$\hat{p}^j_{n,t+1} = \left(\sum_{i=1}^{I} \pi^j_{ni,t} \left[(\hat{w}_{i,t+1})^{\tilde{\beta}^j_i} \left(\prod_{l \in \Omega_M} (\hat{p}^l_{i,t+1})^{\tilde{\gamma}^{jl}_i (1-\tilde{\beta}^j_i)} \right) \left(\frac{\hat{d}^j_{ni,t+1}}{\hat{A}^j_{i,t+1}} \right) \right]^{-\theta^j} \right)^{-1/\theta^j}. \tag{29}$$

3. Taking the change in investment (10) for sector $j \in \Omega_M$, accounting for the change in the sectoral price, we get:

$$\hat{X}^{F,j}_{i,t+1} = \left[\hat{X}^{F,N}_{t+1} \left(\hat{p}^j_{i,t+1}\right)^{-\alpha^j} \hat{Q}^{*j}_{i,t+1} \right]^{1/(1-\alpha^j)} \hat{K}^j_{i,t+1}, \tag{30}$$

   which, together with (26), yields a system of equations determining $\hat{X}^{F,j}_{i,t+1}$ and $\hat{X}^{F,N}_{t+1}$.

4. Combining (23) and (24), we get:

$$\hat{X}^{F,N}_{i,t+1} = \hat{\phi}^*_{i,t+1} \hat{X}^{F,N}_{t+1}, \tag{31}$$

[20] In treating $\hat{Q}^{*j}_{i,t+1}$ as a self-standing shock we are limiting the effects of other shocks to their effect on the current period equilibrium. Any effect on expectations about the future is captured in $\hat{Q}^{*j}_{i,t+1}$. Unlike Chari, Kehoe, and McGrattan (2007), we leave open the connection between expectations about the future and what ultimately happened. Given the high-dimensionality of our shocks, our short time horizon, and the turbulence of the period, we simply back out what expectations must have been to drive what happened. Closing this connection is an important question for future research.

showing how a country's relative intertemporal demand shock drives the change in its share of world nonmanufacturing consumption spending.

5. Using (15) to replace manufacturing deficits in (14), we see that the exogenous nonmanufacturing trade deficit places an additional restriction on spending and changes in wages:

$$D^N_{i,t+1} = \sum_{l\in\Omega} \hat{X}^{F,l}_{i,t+1} X^{F,l}_{i,t} - \hat{w}_{i,t+1} Y^F_{i,t} - \sum_{j\in\Omega_M} \left(X^j_{i,t+1} - \sum_{n=1}^{I} \hat{\pi}^j_{ni,t+1} \pi^j_{ni,t} X^j_{n,t+1} \right) \tag{32}$$

where $X^j_{i,t+1}$ is determined by (22).

In attributing the changes in these five sets of outcomes from period t to $t+1$ to our five sets of shocks we condition on the following period t magnitudes: (i) trade shares $\pi^j_{ni,t}$ for $j \in \Omega_M$, (ii) final spending $X^{F,j}_{i,t}$, (iii) GDP $Y^F_{i,t}$, and (iv) changes in capital stocks $\hat{K}^j_{i,t+1}$ (which are determined in period t). The only parameters required are

$$\Theta = \{\theta^j, \delta^j, \alpha^j, \tilde{\beta}^j_i, \tilde{\gamma}^{jl}_i, \xi^j_i\},$$

for $j, l \in \Omega_M$ and $i = 1, ..., I$. (Since we hold them fixed over time the investment efficiency parameters χ^j's drop out of the model in changes.)

To summarize, equations (28), (29), (30), (31), and (32) determine $\hat{\pi}^j_{ni,t+1}$, $\hat{p}^j_{n,t+1}$, $\hat{X}^{F,j}_{i,t+1}$ ($j \in \Omega_M$), $\hat{X}^{F,N}_{i,t+1}$, and $\hat{w}_{i,t+1}$ implied by the shocks $\hat{d}^j_{ni,t+1}$, $\hat{A}^j_{i,t+1}$, $\hat{Q}^{*j}_{i,t+1}$ ($j \in \Omega_M$), $\hat{\phi}^*_{i,t+1}$, and $D^N_{i,t+1}$, given the initial conditions $\pi^j_{ni,t}$, $X^{F,j}_{i,t}$, $Y^F_{i,t}$, $\hat{K}^j_{i,t+1}$, and the parameters Θ.[21]

We use these equations in two ways. In the next section we use them to extract the underlying shocks from data, so we can track their history. In the section after that we ask which shocks were the driving forces of the trade collapse.

5 Quantification

We now use our model to extract the five shocks from measures of $\hat{\pi}^j_{ni,t+1}$, $\hat{p}^j_{i,t+1}$, $\hat{X}^{F,j}_{i,t+1}$ (for $j \in \Omega_M$), $\hat{w}_{i,t+1}$, and $D^N_{i,t+1}$. We build up $\hat{K}^j_{i,t+1}$ using data on investment, as suggested by our model.

[21] Note that $\hat{d}^j_{ni,t+1}$ and $\hat{A}^j_{i,t+1}$ enter only through equations (28) and (29), and only as the ratio $\hat{d}^j_{ni,t+1}/\hat{A}^j_{i,t+1}$. An alternative to the strategy pursued here would have been to consider only their combined effect through this ratio. The implications for their joint contribution and the contribution of the other three types of shocks would be identical. Since a key issue for us is the role of increased cross-country barriers to the trade collapse, we adopt the normalization that $\hat{d}^j_{ii,t+1} = 1$, interpreting any increase in domestic barriers as a decline in productivity.

5.1 Shock Equations

We first show how our model delivers values of the shocks from these magnitudes:

1. We use expression (28) as it applies to $n \neq i$ (relative to how it applies to $n = i$) to obtain trade cost shocks:

$$\hat{d}^j_{ni,t+1} = \left(\frac{\hat{\pi}^j_{ni,t+1}}{\hat{\pi}^j_{ii,t+1}} \right)^{-1/\theta^j} \frac{\hat{p}^j_{n,t+1}}{\hat{p}^j_{i,t+1}}. \tag{33}$$

2. We use expression (28) as it applies to $n = i$ to solve for productivity shocks:

$$\hat{A}^j_{i,t+1} = \left(\hat{\pi}^j_{ii,t+1}\right)^{1/\theta^j} \hat{w}^{\tilde{\beta}^j_i}_{i,t+1} \left(\hat{p}^j_{i,t+1}\right)^{\tilde{\gamma}^{jj}_i (1-\tilde{\beta}^j_i)-1} \left(\hat{p}^l_{i,t+1}\right)^{\tilde{\gamma}^{jl}_i (1-\tilde{\beta}^j_i)} \quad l, j \in \Omega_M; \; l \neq j. \tag{34}$$

3. We use (30) to back out value of capital shocks:

$$\hat{Q}^{*j}_{i,t+1} = \left(\hat{X}^{F,j}_{i,t+1}\right)^{1-\alpha^j} \left(\hat{X}^{F,N}_{t+1}\right)^{-1} \left(\hat{p}^j_{i,t+1}\right)^{\alpha^j} \left(\hat{K}^j_{i,t+1}\right)^{\alpha^j - 1}. \tag{35}$$

4. We use (31) to back out the relative intertemporal preference shocks:

$$\hat{\phi}^*_{i,t+1} = \frac{\hat{X}^{F,N}_{i,t+1}}{\hat{X}^{F,N}_{t+1}}. \tag{36}$$

5. We take nonmanufacturing trade deficits $D^N_{i,t+1}\left(s^{t+1}\right)$ directly from the data.

For measures of $\hat{\pi}^j_{ni,t+1}$, $\hat{p}^j_{i,t+1}$, $\hat{X}^{F,j}_{i,t+1}$, and $D^N_{i,t+1}$ we go directly to data. For $\hat{w}_{i,t+1}$ our assumptions of full employment and constant labor forces let us equate wage growth to growth in GDP. To extract $\hat{K}^j_{i,t+1}$ we divide (2) by $K^j_{i,t}(s^{t-1})$ to obtain:

$$\begin{aligned} \hat{K}^j_{i,t+1} &= \left(1 - \delta^j\right) + \chi^j \iota^j_{i,t}(s^t)^{\alpha^j} \\ &= \left(1 - \delta^j\right) + \left(\hat{\iota}^j_{i,t}\right)^{\alpha^j} \left[\chi^j \iota^j_{i,t-1}(s^{t-1})^{\alpha^j}\right]. \end{aligned}$$

Replacing $\hat{\iota}^j_{i,t}$ with the observed change in real investment spending per unit of capital and the term in square brackets with the lagged version of (2) yields:

$$\hat{K}^j_{i,t+1} = 1 - \delta^j + \left(\frac{\hat{X}^{F,j}_{i,t}}{\hat{p}^j_{i,t} \hat{K}^j_{i,t}} \right)^{\alpha^j} \left[\hat{K}^j_{i,t} - (1 - \delta^j)\right]. \tag{37}$$

This recursive equation allows us to piece together measures of $\hat{K}^j_{i,t+1}$ from an initial condition for $\hat{K}^j_{i,t_0} = \kappa^j_i > 1 - \delta^j$ and time series of $\hat{X}^{F,j}_{i,\tau}$ and $\hat{p}^j_{i,\tau}$ from $\tau = t_0$ to t.

5.2 Parameter Values and Initial Conditions

For the parameters Θ we set $\theta^D = \theta^S = 2$, a value between the smaller values typically used in the open-economy macro literature and the larger values used in Eaton and Kortum (2002). A larger α^j means lower capital adjustment costs. We choose $\alpha^D = 0.6$ and $\alpha^S = 0.8$. To allow durables to depreciate more slowly we choose $\delta^D = 0.018$ to correspond to an annual durables depreciation rate of 7 percent and $\delta^S = 0.438$ to correspond to an annual semi-durables depreciation rate of 90 percent.[22]

We calculate the input-output coefficients β_i^j and γ_i^{jl} from the 2009 edition of the OECD's country tables.[23] To determine β_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 γ_i^{jl}, 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). We then use (16), (17), and (18) to get $\tilde{\beta}_i^l$, $\tilde{\gamma}_i^{jl}$, and ξ_i^j. Finally, we choose $\kappa_i^D = \kappa_i^S = 1$, implying that investment in the earliest quarter of our data was such that the capital stock did not change in that period.

5.3 Shock Values

We back out the five sets of shocks for each of our 22 countries using quarterly data from 2000:Q1 to 2009:Q4. Tables 2 and 3 report the average change in the shocks during the period we identify as the global recession, 2008:Q3 to 2009:Q2, across all 22 countries. They also report the change during the previous period (typically 2000:Q1 to 2008:Q3). Both are annualized.

Since there are 462 trade shocks $\hat{d}_{ni}^j$, one for each ordered pair of separate countries, we report only a trade-weighted average for each country (as exporter and importer).[24] Note that several countries show an increase in trade barriers in the recession period, particularly for durables, while increases in the prerecession period are rare. But only for Canada, China, and Finland do

[22]Our qualitative conclusions are robust to changing any of these parameters by a factor of two (our robustness checks considered halving, but not doubling, α^S and α^D).

[23]The only exception is the Chinese input-output table, which was provided by Robert Feenstra. We use the most recent input-output table available for each country. We concord the 48 sectors used in these tables to form input-output tables for the three sectors $j \in \Omega$. Appendix Table A.2 shows how we classified these 48 sectors into durables, semi-durables, and nonmanufactures.

[24]In line with our theory, we calculate the average change in the trade barrier for country i in sector j as:

$$\hat{d}_i^j = \left[\sum_{n \neq i} \frac{X_{ni}^j}{E_i^j + M_i^j} \left(\hat{d}_{ni}^j\right)^{-\theta^j} + \sum_{k \neq i} \frac{X_{ik}^j}{E_i^j + M_i^j} \left(\hat{d}_{ik}^j\right)^{-\theta^j} \right]^{-1/\theta^j},$$

where $E_i^j = \sum_{n \neq i} X_{ni}^j$ and $M_i^j = \sum_{k \neq i} X_{ik}^j$ are the total exports and imports of country i in sector j. We aggregate across countries, in a similar manner, to create the global average.

frictions increase by more than five percent. At the same time, some countries appear to have experienced large declines in trade barriers in the recession period.[25] (The higher variation in changes in trade barriers, and hence the greater frequency of increases as well as large declines partly simply reflects the fact that the recession period is shorter.) There was a slight global in semi-durable trade barriers, but, overall, the weighted average of trade friction shocks during the crisis looks similar to the prerecession period.

More than three-fourths of our countries experienced productivity declines in one or both manufacturing sectors during the global recession, while in the previous period most countries experienced modest productivity growth. But overall, productivity growth during the recession hardly differed from previous quarters.

The most striking departure from the prerecession period is the decline in the value of capital $\hat{Q}^{*j}$ during the global recession.[26] The decline is particularly sharp for durables.[27] The only increases are in China and Japan, and in those countries only for semi-durables. In the prerecession period, in contrast, shocks to the value of capital are tightly centered around 1. Some of the other shocks show considerable action, but not in any consistent direction.[28]

We now consider the extent to which these various types of shocks contributed to the global collapse in trade and manufacturing production during the global recession. We then ask how the different experiences of individual countries are explained by different sets of shocks, according to the type of shock or to its provenance.

[25]We report an enormous *decline* in Hungary's durables trade frictions. Note that we also report a large decline in its productivity in that sector. The explanation is that our data for Hungary indicate that its home share in durables, π_{ii}^D, plummeted from 0.19 to 0.06 over the period, implying $\hat{\pi}_{ii}^D = 0.33$. Equations (33) and (34) show how such a tiny $\hat{\pi}_{ii}^D$ implies a tiny $\hat{d}_i^D$ and $\hat{A}_i^D$.

[26]Similarly to our calculation of the average change in trade frictions, we calculate the global average change in the value of capital in sector j as:

$$\hat{Q}^{*j} = \left[\sum_i \frac{X_i^{F,j}}{X^{F,j}} \left(\hat{Q}_i^{*j} \right)^{\frac{1}{1-\alpha^j}} \right]^{1-\alpha^j},$$

where $X^{F,j} = \sum_i X_i^{F,j}$ is total world investment spending in sector j.

[27]Spain is an extreme case, with a tiny value of $\hat{Q}^{D*}$. Mechanically, this result reflects a dramatic fall in *final* absoption of durable manufactures. We construct this measure as the difference between *total* absorption of durable manufactures and demand for them as intermediates (typically about 75 percent of total absorption). Total absorption in Spain declined substantially (but not alarmingly) over the recession, $\hat{X}^D = 0.57$ (at an annual rate) while demand for intermediates declined by only about half as much. As a consequence, the difference plummeted, with $\hat{X}^{F,D}$ close to zero.

[28]Since each country's intertemporal preference shock is relative to the world's, we shouldn't expect a systematic movement in any one direction. Similarly, nonmanufacturing trade deficits sum to zero across the world and show very little action in the prerecession period. They decline for 17 of our 21 real countries in the recession itself, however, reflecting in part the fact that most of them are oil importers, and oil prices fell in this period. (Table 3 reports the change in each country's nonmanufacturing trade deficit relative to its GDP in order to keep absolute magnitudes similar.)

6 Structural Decompositions

Having backed out the shocks that fully account for the changes that occur over a particular quarter, we can ask how any subset of them contributed to what happened. We can shut down the contribution of a particular type of shock by replacing its value with a 1 (for shocks to trade costs, productivity, intertemporal prices, or intertemporal demand) or with its previous level (for nonmanufacturing deficits). At one extreme, including all the shocks delivers what actually happened. At the other extreme, shutting down all shocks delivers no change other than what results from capital accumulation. Of interest to us, of course, are the cases in between, in which we can isolate the implications of particular sets of shocks. Such counterfactual exercises require solving for the wage and price changes, and consequent production and trade, consistent with global equilibrium.[29] Since the counterfactuals use a structural model to decompose the realized global outcomes into the contributions of particular combinations of shocks, we call them structural decompositions.

Some of our decompositions span multiple quarters. Our model implies that shocks affect subsequent periods through their impact on the capital stocks as well as on variables such as GDP and trade shares, all of which constitute the initial conditions for any 1-quarter counterfactual. In our analysis in this section, we start each quarter anew using actual data for the initial conditions instead of the hypothetical results implied by the previous quarter's counterfactual outcome. Hence, in this section, we do not cumulate shocks over multiple periods. In Section 7, we do allow for these dynamics and consider rolling decompositions in which shocks have cumulative effects.

In reporting changes over multiple quarters, we multiply the relevant quarterly changes together. For instance, we look at changes over the recession by multiplying together the three quarterly changes from 2008:Q3 to 2009:Q2.

6.1 Global Trade and Production

We first ask what our analysis has to say about the overall collapse of trade and production in the global recession. We isolate the effects of individual shocks to the value of capital (separating durables and semi-durables), trade frictions, productivity, intertemporal preferences, and nonmanufacturing deficits. Together their effects account for the total collapse.

Figure 5 reports the contributions of each to changes in global trade from 2008:Q3 to 2009:Q4. As is evident, the collapse is totally the consequence of the decline in the value of capital, mostly for durable capital. Other shocks, including those to trade frictions, contribute nothing. The

[29] Appendix B explains the algorithm used to compute a counterfactual equilibrium.

story for manufacturing production (illustrated in Figure A.5 in the Appendix) is the same.

Is the recession period anomalous in terms of the factors driving fluctuations in trade and in manufacturing production? Figures 6 and 7 illustrate the contributions of different types of shocks to quarterly changes, both within the recession (in solid squares) and before, going back to 2000:Q1 (in hollow circles). Actual quarterly changes are on the horizontal axis and the changes we attribute to the indicated shocks (trade frictions, the value of capital, intertemporal demand, and all others) are on the vertical. The combination of all shocks would put us on the 45-degree line.

Figure 6 shows that, in normal times, shocks to trade frictions and, to a lesser extent, to the value of capital, contribute to fluctuations in global trade, with essentially no contribution from the other shocks. The first two quarters of the recession (appearing at the far left of these panels) thus represent a departure in that the shock to the value of capital was the sole contributor.

Figure 7 shows that, for manufacturing production, the global recession was anomalous only for the extent of the changes, not the sources. In both prerecession and recession periods, production appears driven almost solely by shocks to the value of capital.

6.2 Country-Level Decompositions by Type of Shock

Table 4 reports the change in trade from 2008:Q3 to 2009:Q2 implied by different types of shocks for each of our 22 countries. The first column reports trade in 2008:Q3 and the second column reports the actual change over the period, which is what our analysis delivers incorporating all shocks. Globally, trade fell 21 percent, as implied by the bold value of 0.79 at the top of the column. The decline was experienced by every individual country as well, although to quite different degrees. India's trade hardly fell while Finland's declined by about a third.

The remaining six columns report what would have happened to each country's trade if only the shock indicated in the column heading is allowed to operate. The first shows the change in trade implied by investment in 2008:Q2, the last prerecession quarter, which, not surprisingly, is small. Of more interest to us are the remaining five columns, which report the effects of individual shocks from the global recession itself. In line with Figure 5, shocks to the value of capital, the effects of which are reported in the sixth column, are responsible for almost all the decline in world trade as is indicated by the 0.83 value listed in the first row. Shocks to the value of capital were also the largest single contributor to the decline in every individual country except Hungary. The only countries where trade friction shocks contributed to more than a 10 percent decline in trade are Canada, China, and Finland.[30]

[30]The numbers in Table 4 imply that productivity shocks contributed substantially to the decline in the trade of

Figure 8 illustrates the contribution of various sets of shocks to the decline in trade of these countries. A country's actual change in trade (from the second column of Table 4) is on the horizontal axis and the change resulting from the indicated shocks is on the vertical. Analogous with Figures 6 and 7, the horizontal line corresponds to no change and the 45-degree line to the actual change from 2008:Q3 to 2009:Q2. Note that only shocks to the value of capital have a consistently negative effect.

Figure 9 shows the analogous results for manufacturing production over the same period. Shocks to the value of capital drove the decline in production everywhere except Japan. Intertemporal demand shocks were behind the decline in Japan and the slight rise in India. Productivity, incorporated in "other," drove China's substantial rise. The main message, though, is that shocks to the value of capital were largely responsible for the decline in both trade and in manufacturing production across the world during the global recession.

Changes in overall GDP are a different story. Figure 10 presents the analogous results for relative GDP. Intertemporal demand shocks are the primary mover here, except for China, where, again, productivity, incorporated in "other," is the primary driver of its large GDP growth.

We can combine these results to look at what happened to the ratio of trade to GDP by country. Looking first at the denominator, since we normalize each period's world GDP to one, it's not surprising that changes to individual countries' GDP are centered around one. But they range widely from about 0.8 to 1.2. By contrast, shocks to the value of capital reduced trade in all countries, generating shocks to the numerator equaling about 0.8 for most countries. Hence, while shocks to the value of capital were clearly the most important factor explaining the collapse in global trade, intertemporal demand shocks are more important for explaining cross-country variation in the declines in the ratio of trade to country-level GDP. Figure 11 shows the outcome of a decomposition run with both value of capital and intertemporal demand shocks. While most countries are slightly above the 45 degree line, implying that the remaining three sets of shocks do contribute positively to the trade decline, this counterfactual does a good job of reproducing both the overall level and cross-country pattern of declines in the ratio of trade to GDP.

To summarize, not only was the drop in the value of capital the major factor behind the collapse in global trade and manufacturing production, it was the major factor for individual

Denmark, Mexico, and, particularly, Hungary. Note that, for Denmark and Hungary, we report that trade friction shocks had a particularly large *positive* effect on trade. The explanation for these anomalies is the massive decline in these countries' home shares in manufacturing. At the extreme, our $\hat{\pi}_{ii}^{D}$ for Hungary is 0.33. Note how $\hat{\pi}_{ii}^{j}$ enters equations (33) and (34) to create these effects. We calculated the combined effect on global trade of the trade friction and productivity shocks (which are usually very close to the product of the individual effects reported in Table 4). We find that, together, the two types of shocks have a negative effect of more than 10 percent only for Canada (0.87) and Finland (0.82). The combined effect is positive for China (1.03), France (1.05), India (1.13), Japan (1.02), Poland (1.02), and South Korea (1.10). The rest all lie between 0.90 and 0.99.

countries as well. Relative GDP's on the other hand, were driven primarily by intertemporal demand shocks. Together, both shocks do a very good job of explaining realized changes in trade-GDP ratios during the recession, in the absence of shocks to trade frictions, productivities, or nonmanufacturing deficits.

6.3 Country-Level Decompositions by Origin of Shocks

Our analysis allows us to examine the effect of shocks not only according to their type but also according to their provenance. Table 5 reports, for each of our countries, the contribution of local shocks and of foreign shocks to the total changes in its trade, manufacturing production, and GDP over the recession.[31]

For trade and production the results are mixed. For 13 countries local shocks bore more responsibility for the decline in trade while, for the remaining 9, foreign shocks did more. For manufacturing production the story is virtually the same: In 12 of the 13 countries where the domestic shocks played a greater role in the decline in trade, domestic shocks also contributed more to the decline in manufacturing production. (For the United Kingdom the two appear to play equal roles.) Of the 9 countries where foreign shocks were paramount for the decline in trade, they were the dominant factor for the decline in manufacturing production in 5. The exceptions are China, France, India, and South Korea, where foreign shocks were largely responsible for the trade decline but domestic shocks drove the changes in production.

Table 6 separates the decline in trade into imports and exports, showing that domestic and foreign shocks typically had opposite effects on each. When we allow only foreign shocks, local exports decline in each case and local imports increase in each case except the Czech Republic and Hungary. Equation (30) is useful in understanding these results. When only foreign shocks operate, the lower $\hat{Q}^{*j}_{i,t+1}$'s abroad lower investment demand there and hence demand for the home country's manufactured exports. More subtle is why home manufactured imports rise. The drop in demand for manufactures abroad causes labor in foreign countries to relocate to nonmanufactures, causing $\hat{X}^{F,N}_{t+1}$ to rise. The effect at home, where $\hat{Q}^{*j}_{i,t+1}$ did not fall, is to raise demand for manufactures.

For most countries, the reduction in exports outweighs the increase in imports, generating the

[31] Specifically, a shock for country i is local if the subscript i appears in the shock and is foreign otherwise. Hence we extract the effect of local shocks by setting all shocks with an i subscript to their actual values with other shocks set to 1 (except for nonmanufacturing deficits). We extract the effect of foreign shocks by performing the opposite exercise. These counterfactuals use the actual shock values for only a subset of countries in the world, over which nonmanufacturing deficits will not typically sum to zero. We distribute any residual to each country in proportion to its GDP. The corresponding adjustment is made to ensure that the consumption-weighted $\hat{\phi}^*_i$'s sum to one.

result that foreign shocks are generally associated with reduced trade. This need not always be the case, though. Greece, for example, entered the recession running a large trade deficit. The increase in its relatively large value of imports dominated the decline in its smaller value of exports, causing its total trade to increase in response to foreign shocks. The logic and implications of counterfactuals with only domestic shocks are the reverse of the foreign shocks case.

As we saw in the previous section, shocks to the value of capital were the primary drivers of the declines in trade and production over the recession. Figure 12 illustrates the relative contributions of domestic and foreign shocks to the value of capital to changes in trade and production over the period, showing how each played a substantial role. In contrast, changes in relative GDP, which were largely driven by intertemporal demand shocks, appear to be driven primarily by those shocks at home, as reported in the last three columns of Table 5.[32] Our results thus imply that domestic factors were largely behind movements in relative GDP's while a mix of local and foreign factors drove what happened to trade and production.[33]

7 A Longer Horizon

The major finding about the collapse of trade during the global recession is that it was overwhelmingly the consequence of a decline in the value of capital, both at home and abroad. We now ask about the major factors behind fluctuations in trade in earlier periods.

Figure 13 plots the evolution of global manufacturing trade (the solid line) over two-year intervals up to 2009. (Again, world GDP each year is the numéraire.) The first panel illustrates the decline in trade that accompanied the much more moderate 2001 recession. In the intervening periods trade mostly grew, up until the global recession hit in late 2008.

Figure 13 also plots the results of decompositions that we initialize in the fourth quarters of 2001, 2003, 2005, and 2007. In contrast to our decompositions in Section 6, we now allow these decompositions to evolve endogenously for the subsequent 5 quarters without re-initializing the capital stocks, GDP's, trade shares, or levels of spending. Instead, after the first quarter we initialize a quarter's decomposition with the outcome of the previous quarter's counterfactual rather than data. We can ask about the cumulative contribution, say, of declining trade barriers

[32]Figure A.6, analogous to Figures 8-12, looks at the effect on the relative GDP's of our 22 countries of domestic and foreign intertemporal and value of capital shocks. Domestic intertemporal demand shocks are doing most of the work.

[33]We can also ask about the importance of shocks from individual countries to trade and production around the world. Figure A.7 examines the effects on manufacturing production in our 22 countries of shocks emanating from China, Germany, Japan, and the United States. The shocks were largely contained at home, except for Canada where U.S. shocks played a major role in the decline in its manufacturing production.

to trade growth over a longer horizon, shutting down the contributions of other factors in the intervening period. Results turn out similar to those in Section 6, where we re-initialize each quarter to the actual data.[34]

The figure shows decompositions in which (i) only intertemporal preference shocks, (ii) only shocks to the value of capital, (iii) only trade friction shocks, (iv) only productivity shocks, and (v) only nonmanufacturing deficit shocks are at work. The main message is that declining trade frictions were the major drivers of growth in trade in earlier periods. Only as the recession started did shocks to the value of capital become the dominant factor.

8 Conclusion

We find that shocks to the value of capital rather than to trade barriers were the primary contributor to the collapse in trade and in manufacturing production during the global recession. Our analysis thus supports the view that changes in the composition of demand, rather than higher trade barriers (for example, a drying up of trade credit or increased protectionism), led to the collapse in trade. In our analysis the change in the composition of demand is an endogenous response to changes in the value of capital. We go on to find that trade was a major conduit for transmitting the collapse in manufacturing around the world.

We think our analysis opens up exciting possibilities in jointly modeling macroeconomic fluctuations and international trade patterns to understand better how shocks spread from country to country. We conclude by summarizing what we think are some promising avenues for future research, both in terms of expanding the scope of this analysis and in terms of furthering the methodology.

We omitted some important aspects of the world. We have not modeled trade in nonmanufactures, thereby ignoring services, agriculture, and, particularly critical for macroeconomic fluctuations, oil. Our model of factor markets embodies only a single type of labor and assumes full employment.[35] In assuming global asset market completeness, we eliminate any role for financial market frictions in creating or propagating macroeconomic fluctuations. Incorporating such features would allow the analysis to address a much wider range of issues.

[34] In conducting these decompositions we extract a path of shocks $\hat{Q}^{*j}_{i,t+1}$ as described above. A limitation is that there is no feedback from endogenous investment responses in previous counterfactual quarters on the assumed value of capital in the current and future quarters. Thus, for the decompositions in Figure 13, we either specify a path in which $\hat{Q}^{*j}_{i,t+1}$ equals either the shock we extract or we set $\hat{Q}^{*j}_{i,t+1} = 1$. We limit the decompositions to 5 quarters to keep them from wandering too far from what's in the data.

[35] Tombe (2013) and Lagakos and Waugh (2013) have integrated world food trade into a static general equilibrium framework. Eaton, Kortum, and Neiman (2013) introduce unemployment in a simple way.

Our methodology does not provide a window into the future. We have used the framework only to back out shocks from actual data, and then used the model to examine the contributions of individual sets of shocks to what happened. To look forward would require understanding the time-series properties of these individual shocks. Discerning these properties for our many shocks from our narrow window over a turbulent period is problematic. We await more data. A related limitation is that we have included as one of our shocks the value of capital, which has not been tied either to the future returns on capital or to the stock of capital itself, even though the model itself makes this connection. These items point to a long road ahead, but we think that our structure takes some useful first steps.

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	Country	Share of Global GDP (percent)	Share of Global Trade (percent)	Trade / GDP (percent)	Production / GDP (percent)
(1)	Austria	0.7	1.5	39.6	59.4
(2)	Canada	2.6	3.0	20.5	40.1
(3)	China	7.6	10.3	24.0	124.8
(4)	Czech Republic	0.4	1.3	59.8	108.7
(5)	Denmark	0.6	0.9	28.5	39.4
(6)	Finland	0.5	0.8	29.4	73.9
(7)	France	4.8	5.2	19.3	47.8
(8)	Germany	6.1	11.1	32.4	69.5
(9)	Greece	0.6	0.4	12.8	30.9
(10)	Hungary	0.3	0.9	60.1	83.3
(11)	India	2.1	1.3	11.3	54.4
(12)	Italy	3.8	4.4	20.4	65.2
(13)	Japan	7.6	5.3	12.5	71.0
(14)	Mexico	2.0	2.4	21.5	55.0
(15)	Poland	1.0	1.6	29.6	65.5
(16)	Romania	0.4	0.5	26.2	49.2
(17)	South Korea	1.6	3.2	36.1	136.7
(18)	Spain	2.7	2.7	17.7	50.7
(19)	Sweden	0.8	1.4	30.5	58.5
(20)	United Kingdom	4.5	4.2	16.7	33.9
(21)	United States	23.6	12.3	9.2	40.5
(22)	Rest of World	26.0	25.2	17.3	63.0

Table 1: Summary Statistics for 21 Countries and Rest of World, 2008:Q3

Notes: Trade and production data are just for manufacturers. Trade data do not include flows between countries within Rest of World. See Appendix Section A for details.

	$\hat{d}_i^D$		$\hat{d}_i^S$		$\hat{A}_i^D$		$\hat{A}_i^S$	
	Prior Period	Global Recession	Prior Period	Global Recession	Prior Period	Global Recession	Prior Period	Global Recession
World	**0.99**	**0.99**	**0.98**	**0.99**	**1.02**	**1.03**	**1.01**	**1.03**
Austria	1.00	1.01	0.98	0.96	1.03	1.00	1.00	0.96
Canada	1.00	1.11	0.99	1.04	1.03	1.00	1.02	0.93
China	0.96	1.06	0.98	1.03	1.06	1.20	1.07	1.07
Czech Republic	0.95	0.98	0.97	0.94	1.01	0.98	1.01	0.95
Denmark	0.99	1.04	0.97	0.88	0.99	1.03	0.98	0.84
Finland	1.00	1.12	0.99	1.06	1.02	0.99	1.01	1.00
France	1.02	0.91	0.99	0.95	1.02	0.93	1.01	1.01
Germany	0.99	0.96	0.97	0.98	1.00	0.96	0.99	0.98
Greece	1.03	0.97	1.00	1.01	1.03	0.96	1.02	0.99
Hungary	0.96	0.62	0.96	0.95	0.99	0.47	1.00	0.95
India	0.98	0.91	0.96	1.05	1.02	1.09	1.04	1.04
Italy	1.00	1.01	0.99	1.00	1.00	1.01	1.00	0.99
Japan	1.02	0.92	0.97	1.00	0.99	1.01	0.99	0.99
Mexico	0.98	0.98	0.99	0.99	1.02	0.85	1.02	0.90
Poland	0.96	0.89	0.96	0.90	1.02	1.01	1.02	1.01
Romania	0.95	0.96	0.97	1.03	1.03	0.97	1.04	0.89
South Korea	1.00	0.91	1.00	0.94	1.01	1.03	1.05	1.04
Spain	1.00	1.03	0.98	1.03	1.02	1.02	1.02	0.99
Sweden	0.99	1.01	0.98	0.96	1.01	0.94	1.00	0.94
United Kingdom	1.00	0.98	0.98	0.95	1.01	0.96	1.01	0.93
United States	0.99	1.04	0.99	1.00	1.01	1.02	0.99	1.15
Rest of World	1.00	0.99	0.98	1.01	1.03	0.99	1.03	0.98

Table 2: Trade Friction and Productivity Shocks

Notes: Global Recession is 2008:Q3 to 2009:Q2. Prior Period begins in 2000:Q1 with exceptions documented in Appendix Section A. Shocks are annualized. Trade friction shocks are calculated as a trade-weighted average of the bilateral shocks including the Frechet parameter for each import and export partner $\left(\hat{d}_{ni}^j\right)^{-\theta^j}$, raised to the power $-1/\theta^j$. Trade friction and productivity shocks for World are also aggregated across countries analogously, taking into account trade weights and production weights respectively as well as the parameter θ.

	$\hat{Q}_i^{D*}$		$\hat{Q}_i^{S*}$		$\hat{\phi}_i^*$		$\Delta \frac{D_i^N}{Y_i}$	
	Prior Period	Global Recession	Prior Period	Global Recession	Prior Period	Global Recession	Prior Period	Global Recession
World	**1.00**	**0.73**	**0.99**	**0.90**	**1.00**	**1.00**	**0.00**	**0.00**
Austria	1.01	0.78	0.99	0.86	1.00	0.96	0.00	-0.02
Canada	0.97	0.76	0.98	0.88	1.03	0.90	0.00	0.05
China	1.25	0.83	0.97	1.24	1.05	1.06	0.01	-0.03
Czech Republic	1.05	0.58	1.04	0.72	1.09	0.94	0.00	0.00
Denmark	1.03	0.59	1.01	0.77	1.01	0.91	0.00	0.03
Finland	1.01	0.65	1.00	0.86	1.02	0.93	0.00	-0.01
France	1.01	0.69	0.99	0.79	1.02	0.97	0.00	-0.02
Germany	1.00	0.72	0.99	0.88	0.99	0.99	0.00	-0.03
Greece	1.03	0.69	1.01	0.90	1.05	0.96	0.00	-0.02
Hungary	1.01	0.35	1.04	0.69	1.10	0.75	0.01	-0.03
India	1.06	0.82	0.97	0.97	1.03	0.97	0.00	-0.03
Italy	1.01	0.59	1.00	0.87	1.01	1.00	0.00	-0.01
Japan	0.95	0.85	0.94	1.10	0.92	1.28	0.00	-0.04
Mexico	0.96	0.64	0.96	0.79	1.00	0.71	0.00	0.01
Poland	1.04	0.48	1.01	0.65	1.07	0.66	0.00	-0.02
Romania	1.10	0.57	1.06	0.81	1.16	0.68	0.00	-0.01
South Korea	0.99	0.61	0.91	0.74	0.99	0.92	0.01	-0.06
Spain	1.00	0.01	1.00	0.87	1.05	0.94	0.00	-0.02
Sweden	0.99	0.53	0.99	0.74	1.00	0.80	0.00	-0.01
United Kingdom	0.96	0.71	0.97	0.81	1.00	0.75	0.00	-0.01
United States	0.95	0.80	0.98	0.83	0.98	1.06	0.00	-0.03
Rest of World	1.02	0.70	0.99	0.85	1.03	0.99	-0.01	0.07

Table 3: Value of Capital, Intertemporal Demand, and Nonmanufacturing Deficit Shocks

Notes: Global Recession is 2008:Q3 to 2009:Q2. Prior Period begins in 2000:Q1 with exceptions documented in Appendix Section A. Shocks are annualized. The nonmanufacturing trade deficit shock is the quarterly difference in the deficit divided by GDP at the beginning of the quarter, averaged over the period. Shocks to the value of capital for the World are calculated as a investment-weighted average of the country shocks including the adjustment cost parameter $\left(\hat{Q}_i^{j*}\right)^{\frac{1}{1-\alpha^j}}$, raised to the power $1-\alpha^j$. Intertemporal demand and nonmanufacturing deficit shocks are nonmanufacturing spending-weighted and GDP-weighted averages of the country shocks.

	Trade / World GDP in 2008:Q3 (percent)	Change $\left(\frac{2009{:}Q2}{2008{:}Q3}\right)$ in Trade in Various Counterfactuals						
		All Shocks (i.e. Data)	**Change in Capital** $\left(\hat{K}_i^{D*}, \hat{K}_i^{S*}\right)$	**Trade Friction Shocks** $\left(\hat{d}_{ni}^{D}, \hat{d}_{ni}^{S}\right)$	**Productivity Shocks** $\left(\hat{A}_i^{D}, \hat{A}_i^{S}\right)$	**Value of Capital Shocks** $\left(\hat{Q}_i^{D*}, \hat{Q}_i^{S*}\right)$	**Relative Intertemporal Preferences** $\left(\hat{\phi}_i^{*}\right)$	**Nonmfg Deficits** $\left(D_i^{N}\right)$
World	**17.8**	**0.79**	**1.00**	**0.99**	**1.00**	**0.83**	**1.00**	**0.99**
Austria	0.3	0.79	1.00	1.00	0.96	0.83	1.01	0.99
Canada	0.5	0.75	0.99	0.86	1.00	0.85	1.01	1.00
China	1.8	0.85	1.00	0.89	1.16	0.87	0.98	0.99
Czech Republic	0.2	0.74	1.00	1.02	0.94	0.77	1.02	1.00
Denmark	0.2	0.80	0.99	1.05	0.92	0.80	1.02	1.00
Finland	0.1	0.67	1.00	0.86	0.97	0.80	1.03	1.00
France	0.9	0.84	0.99	1.11	0.94	0.79	1.01	0.99
Germany	2.0	0.78	1.00	1.03	0.94	0.81	1.01	0.99
Greece	0.1	0.84	0.99	1.00	0.97	0.84	1.00	0.99
Hungary	0.2	0.75	1.00	1.94	0.54	0.75	1.06	0.99
India	0.2	0.99	1.01	1.08	1.07	0.90	1.02	1.01
Italy	0.8	0.76	0.99	0.97	0.97	0.79	1.00	0.99
Japan	0.9	0.77	1.00	1.01	1.02	0.91	0.93	0.99
Mexico	0.4	0.77	1.00	1.02	0.91	0.80	1.06	1.00
Poland	0.3	0.75	1.00	1.05	0.98	0.73	1.07	0.99
Romania	0.1	0.73	1.00	1.01	0.94	0.77	1.05	1.00
South Korea	0.6	0.83	1.01	1.04	1.06	0.85	1.01	0.99
Spain	0.5	0.72	0.98	0.94	0.97	0.77	1.00	0.98
Sweden	0.3	0.72	1.00	0.98	0.93	0.78	1.06	1.00
United Kingdom	0.8	0.80	1.00	1.01	0.95	0.81	1.06	1.00
United States	2.2	0.81	0.99	0.95	1.03	0.84	0.99	0.99
Rest of World	4.5	0.78	1.00	0.97	0.99	0.82	1.00	1.00

Table 4: Trade over the Global Recession

Notes: The column Change in Capital reports the effect of investment in the previous period, with no contemporaneous shocks. The subsequent columns report the effect of individual sets of shocks with all other shocks suppressed (but including the effect of the change in capital). The reported effects are the product of effects from three one-quarter simulations each reinitialized with actual data from the previous quarter.

	Trade			Production			GDP		
	Actual	**Counterfactuals**		**Actual**	**Counterfactuals**		**Actual**	**Counterfactuals**	
	$\frac{2009{:}Q2}{2008{:}Q3}$	Only Shocks to		$\frac{2009{:}Q2}{2008{:}Q3}$	Only Shocks to		$\frac{2009{:}Q2}{2008{:}Q3}$	Only Shocks to	
		Other Ctys	This Cty		Other Ctys	This Cty		Other Ctys	This Cty
Austria	0.79	0.88	0.93	0.79	0.83	0.97	0.97	0.99	0.99
Canada	0.75	0.99	0.79	0.79	0.94	0.86	0.91	1.03	0.89
China	0.85	0.89	1.02	1.12	0.98	1.19	1.15	1.04	1.13
Czech Republic	0.74	0.85	0.92	0.72	0.84	0.90	0.89	0.97	0.93
Denmark	0.80	0.90	0.93	0.82	0.83	1.02	0.93	1.01	0.94
Finland	0.67	0.90	0.79	0.75	0.90	0.86	0.92	1.00	0.93
France	0.84	0.92	0.96	0.77	0.90	0.89	0.98	1.02	0.97
Germany	0.78	0.88	0.94	0.77	0.87	0.92	0.97	0.99	0.99
Greece	0.84	1.08	0.82	0.82	0.99	0.84	1.00	1.05	0.96
Hungary	0.75	0.85	0.92	0.70	0.82	0.89	0.82	0.98	0.85
India	0.99	1.03	1.05	1.04	1.02	1.07	1.06	1.05	1.02
Italy	0.76	0.90	0.89	0.78	0.91	0.87	0.97	1.01	0.97
Japan	0.77	0.91	0.89	0.86	0.95	0.91	1.17	1.04	1.13
Mexico	0.77	1.00	0.81	0.77	0.99	0.79	0.80	1.04	0.78
Poland	0.75	0.90	0.88	0.73	0.89	0.85	0.78	1.00	0.78
Romania	0.73	0.97	0.82	0.80	0.92	0.91	0.80	1.02	0.80
South Korea	0.83	0.92	0.98	0.83	0.95	0.92	0.94	1.02	0.94
Spain	0.72	0.92	0.82	0.77	0.91	0.86	0.97	1.02	0.95
Sweden	0.72	0.90	0.85	0.70	0.87	0.84	0.84	1.00	0.85
United Kingdom	0.80	0.95	0.89	0.80	0.91	0.91	0.86	1.02	0.85
United States	0.81	0.96	0.88	0.89	0.95	0.94	1.08	1.05	1.03
Rest of World	0.78	0.97	0.85	0.80	0.97	0.84	0.93	1.00	0.93

Table 5: Impact of Direct and Indirect Shocks

Notes: The counterfactual columns labeled "Other Ctys" report the effects of all shocks involving other countries but suppressing shocks that influence the row country directly. The columns labeled "This Cty" report the effects of all shocks directly involving the row country but suppressing all other shocks. The reported effects are the product of effects from three one-quarter simulations each reinitialized with actual data from the previous quarter.

	Trade			Imports			Exports		
	Actual	**Counterfactuals**		**Actual**	**Counterfactuals**		**Actual**	**Counterfactuals**	
	$\frac{2009{:}Q2}{2008{:}Q3}$	Only Shocks to Other Ctys	Only Shocks to This Cty	$\frac{2009{:}Q2}{2008{:}Q3}$	Only Shocks to Other Ctys	Only Shocks to This Cty	$\frac{2009{:}Q2}{2008{:}Q3}$	Only Shocks to Other Ctys	Only Shocks to This Cty
Austria	0.79	0.88	0.93	0.82	1.03	0.83	0.76	0.75	1.03
Canada	0.75	0.99	0.79	0.78	1.09	0.74	0.71	0.87	0.86
China	0.85	0.89	1.02	0.93	1.10	0.95	0.81	0.80	1.05
Czech Republic	0.74	0.85	0.92	0.74	0.97	0.82	0.75	0.75	1.01
Denmark	0.80	0.90	0.93	0.75	1.04	0.76	0.84	0.77	1.12
Finland	0.67	0.90	0.79	0.67	1.09	0.65	0.67	0.75	0.92
France	0.84	0.92	0.96	0.84	1.09	0.81	0.83	0.75	1.13
Germany	0.78	0.88	0.94	0.80	1.06	0.81	0.77	0.76	1.04
Greece	0.84	1.08	0.82	0.84	1.21	0.71	0.85	0.70	1.20
Hungary	0.75	0.85	0.92	0.72	0.95	0.81	0.77	0.76	1.03
India	0.99	1.03	1.05	0.99	1.28	0.84	0.99	0.75	1.35
Italy	0.76	0.90	0.89	0.74	1.09	0.70	0.77	0.74	1.06
Japan	0.77	0.91	0.89	0.83	1.17	0.71	0.73	0.77	1.02
Mexico	0.77	1.00	0.81	0.75	1.13	0.69	0.80	0.86	0.96
Poland	0.75	0.90	0.88	0.72	1.06	0.71	0.78	0.73	1.08
Romania	0.73	0.97	0.82	0.66	1.14	0.62	0.84	0.71	1.18
South Korea	0.83	0.92	0.98	0.76	1.05	0.79	0.88	0.83	1.13
Spain	0.72	0.92	0.82	0.69	1.07	0.66	0.77	0.73	1.06
Sweden	0.72	0.90	0.85	0.72	1.07	0.72	0.73	0.77	0.96
United Kingdom	0.80	0.95	0.89	0.82	1.12	0.77	0.78	0.75	1.06
United States	0.81	0.96	0.88	0.80	1.13	0.71	0.81	0.75	1.15
Rest of World	0.78	0.97	0.85	0.76	1.10	0.72	0.79	0.81	1.03

Table 6: Impact of Direct and Indirect Shocks

Notes: The counterfactual columns labeled "Other Ctys" report the effects of all shocks involving other countries but suppressing shocks that influence the row country directly. The columns labeled "This Cty" report the effects of all shocks directly involving the row country but suppressing all other shocks. The reported effects are the product of effects from three one-quarter simulations each reinitialized with actual data from the previous quarter.

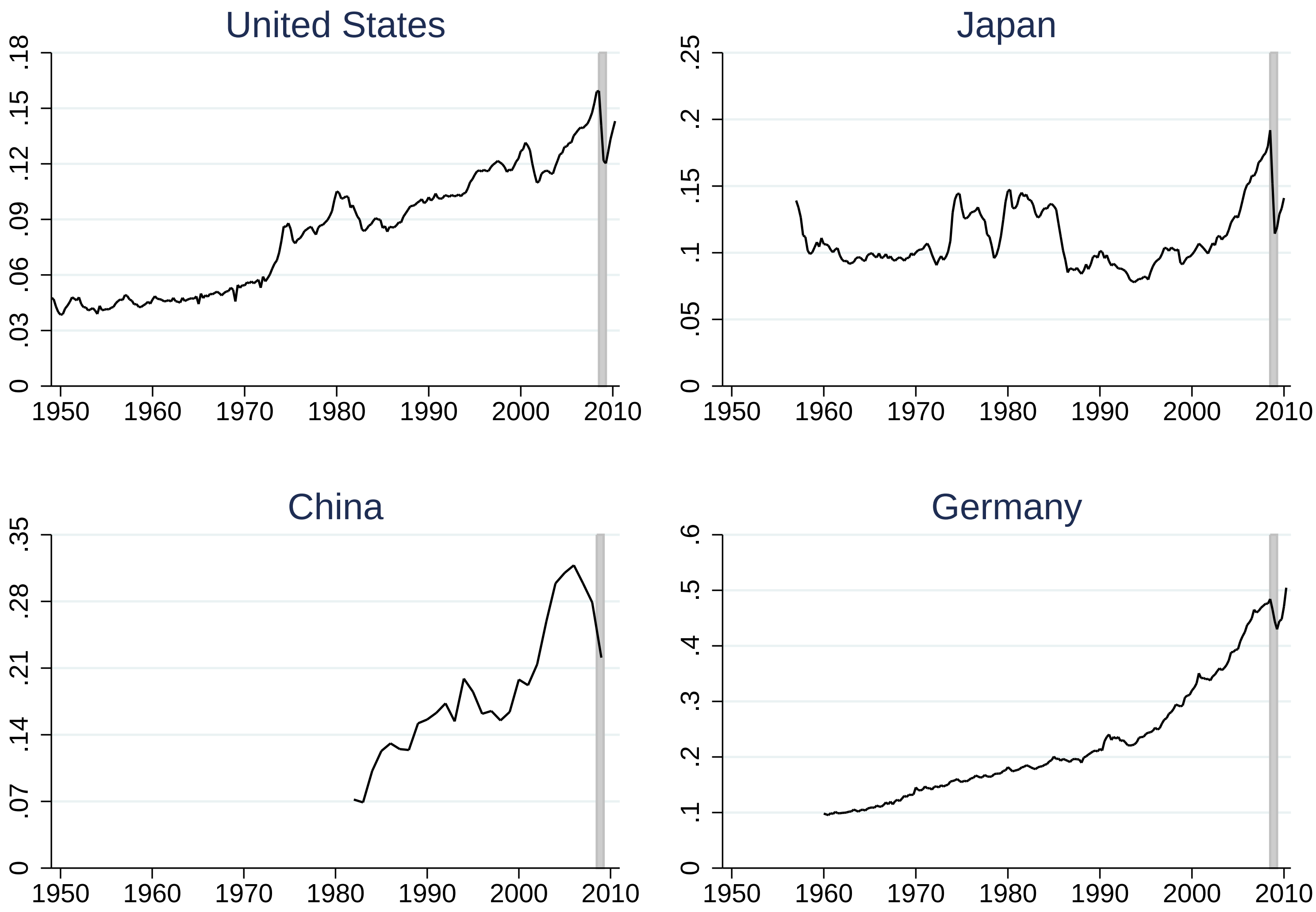

Figure 1: Trade-GDP Ratio in the Four Largest Economies

Notes: The shaded bars highlight 2008:Q3 to 2009:Q2. Trade is measured as (exports+imports)/2. Data are quarterly except for China, which are annual. See Appendix Section A for details.

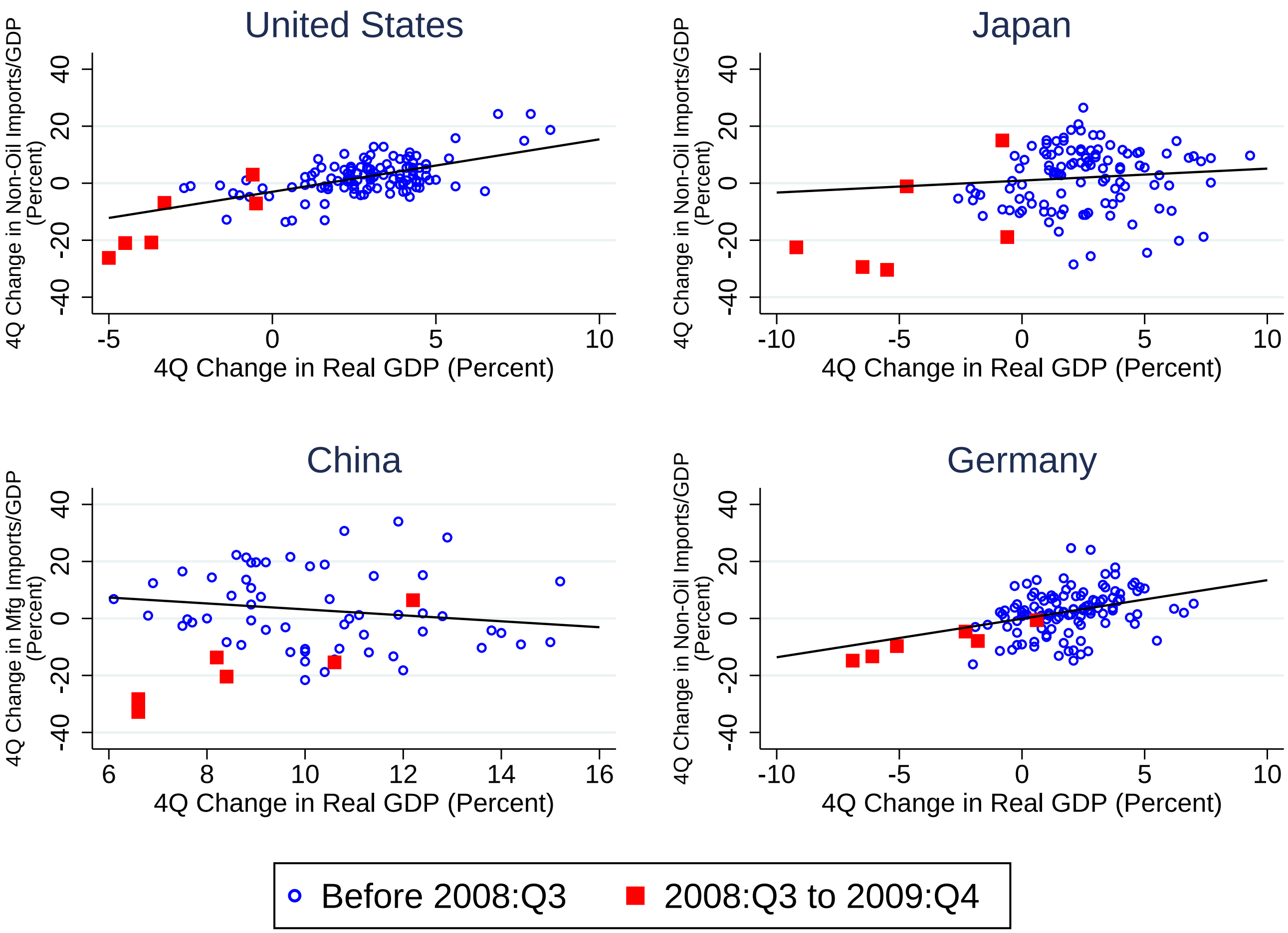

Figure 2: Cyclical Properties of Trade in the Four Largest Economies

Notes: Scales differ across the four countries and the measure of imports differs for China. The beginning quarter for the United States and Germany is 1979:Q1, for Japan 1981:Q1, and for China 1993:Q1. Data limitations force us to report manufacturing imports relative to GDP for China. See Appendix Section A for details.

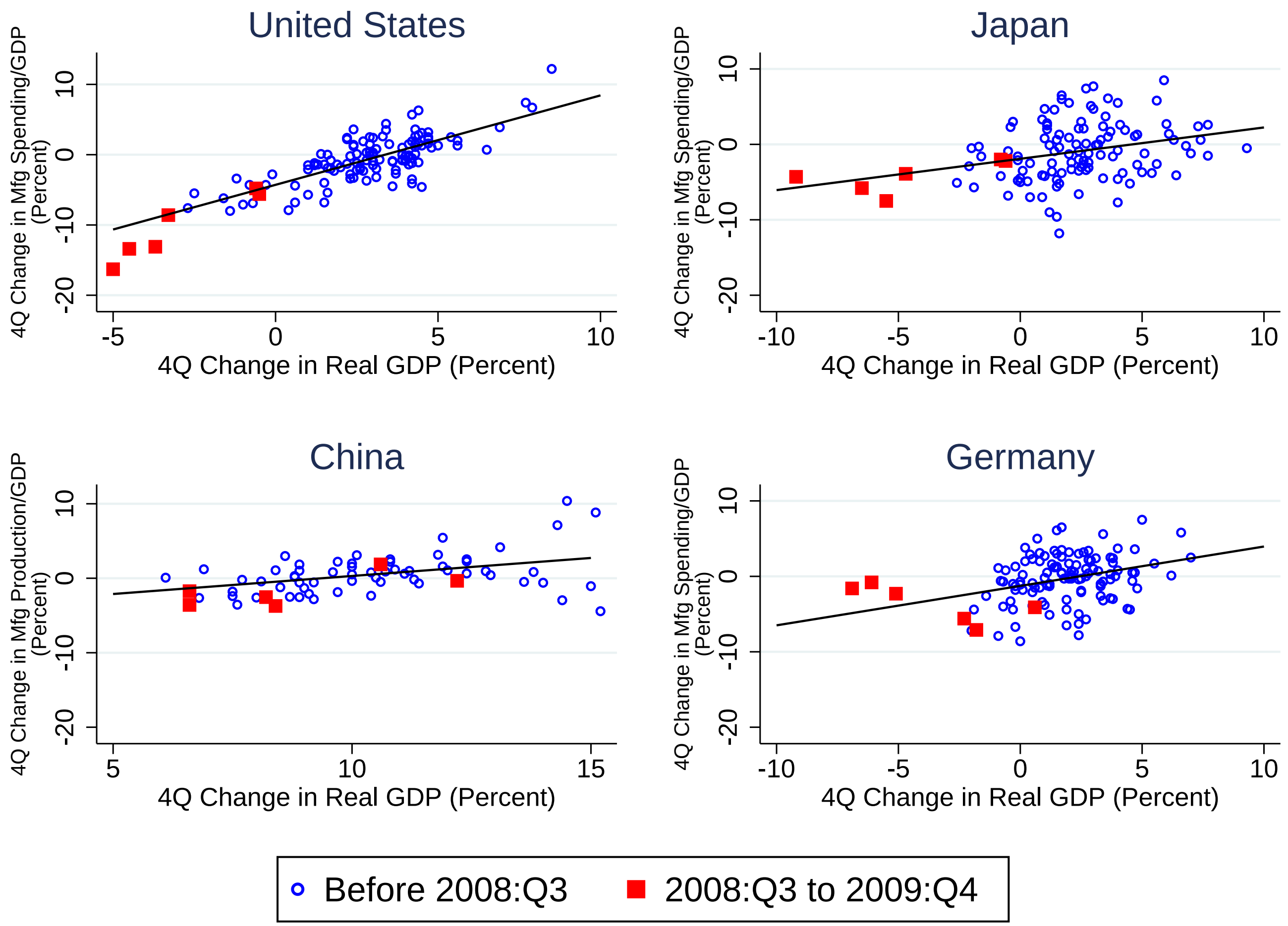

Figure 3: Cyclical Properties of Manufacturing in the Four Largest Economies

Notes: Scales differ across the four countries and the measure of manufacturing activity differs for China. Data limitations force us to report manufacturing production relative to GDP for China. See Appendix Section A for details.

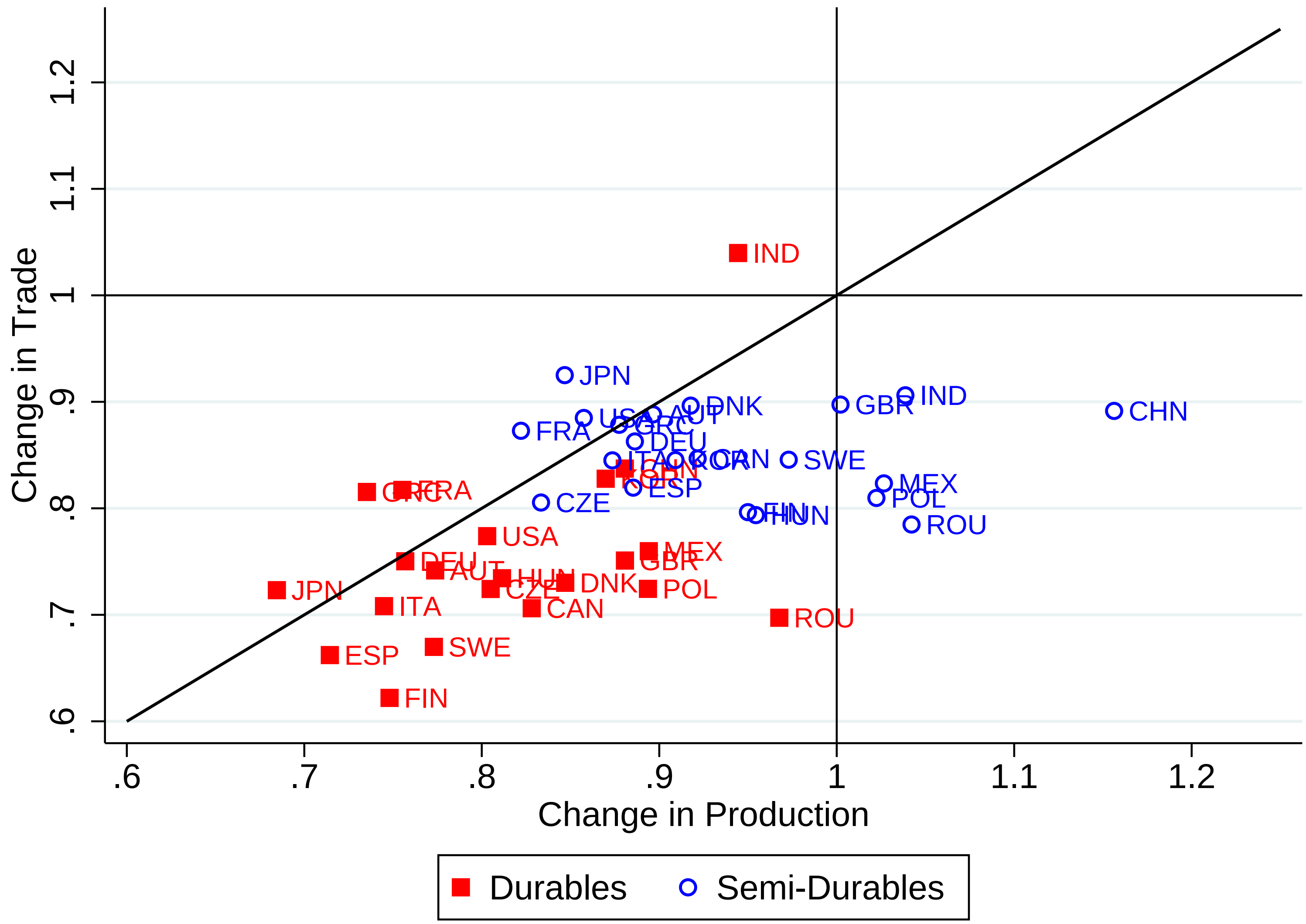

Figure 4: Changes in Manufacturing Trade and Production by Sector

Notes: Observations are for the ratio of the value for 2009:Q2 to that for 2008:Q3, so that 1 implies no change.

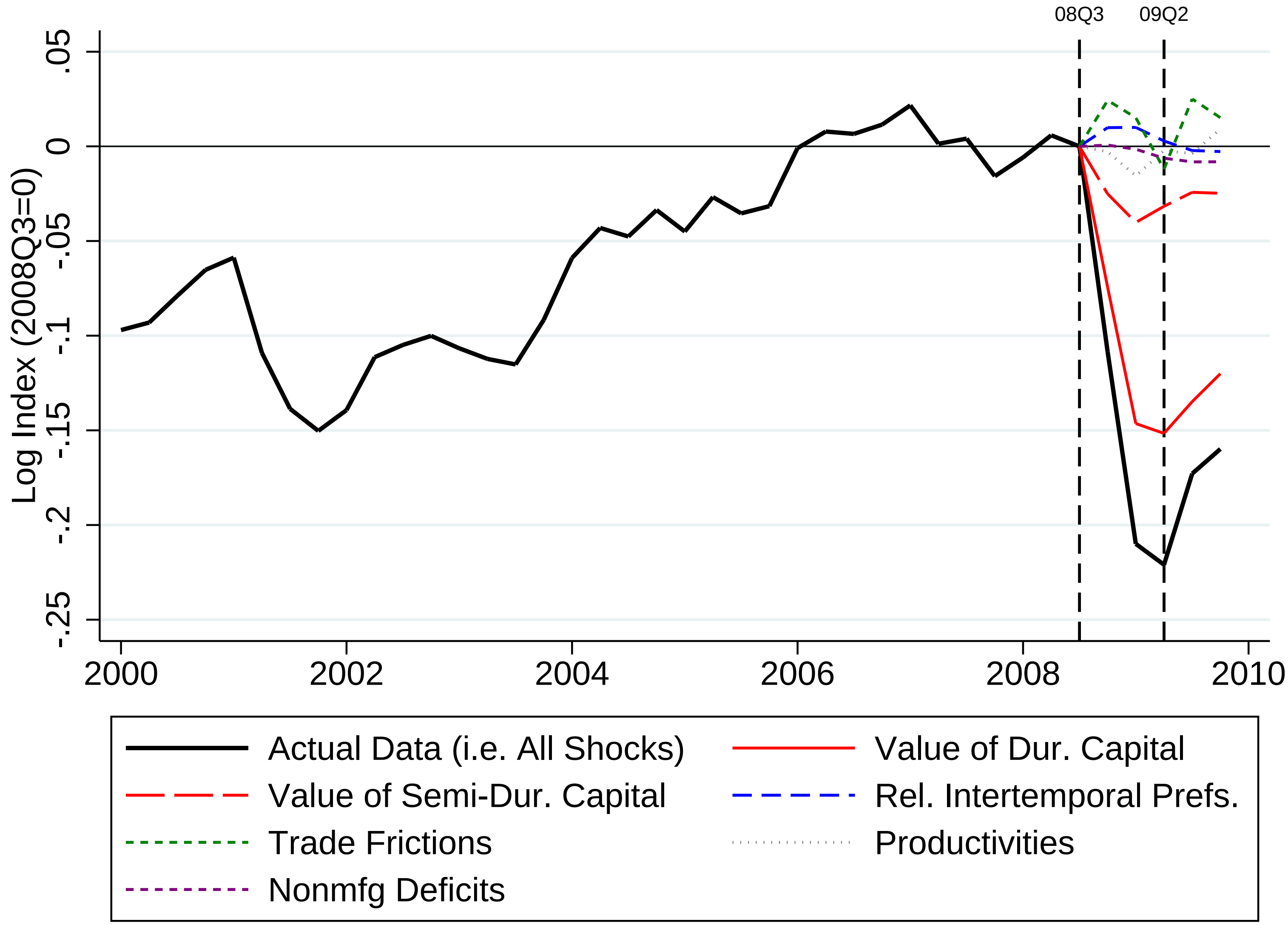

Figure 5: Actual and Counterfactual Evolution of Global Trade

Notes: Lines beginning in 2008:Q3 represent counterfactual outcomes with the indicated shocks at their calibrated values and all other shocks unchanged (i.e., 1, except for the nonmanufacturing deficits, which are held at their 2008:Q3 values).

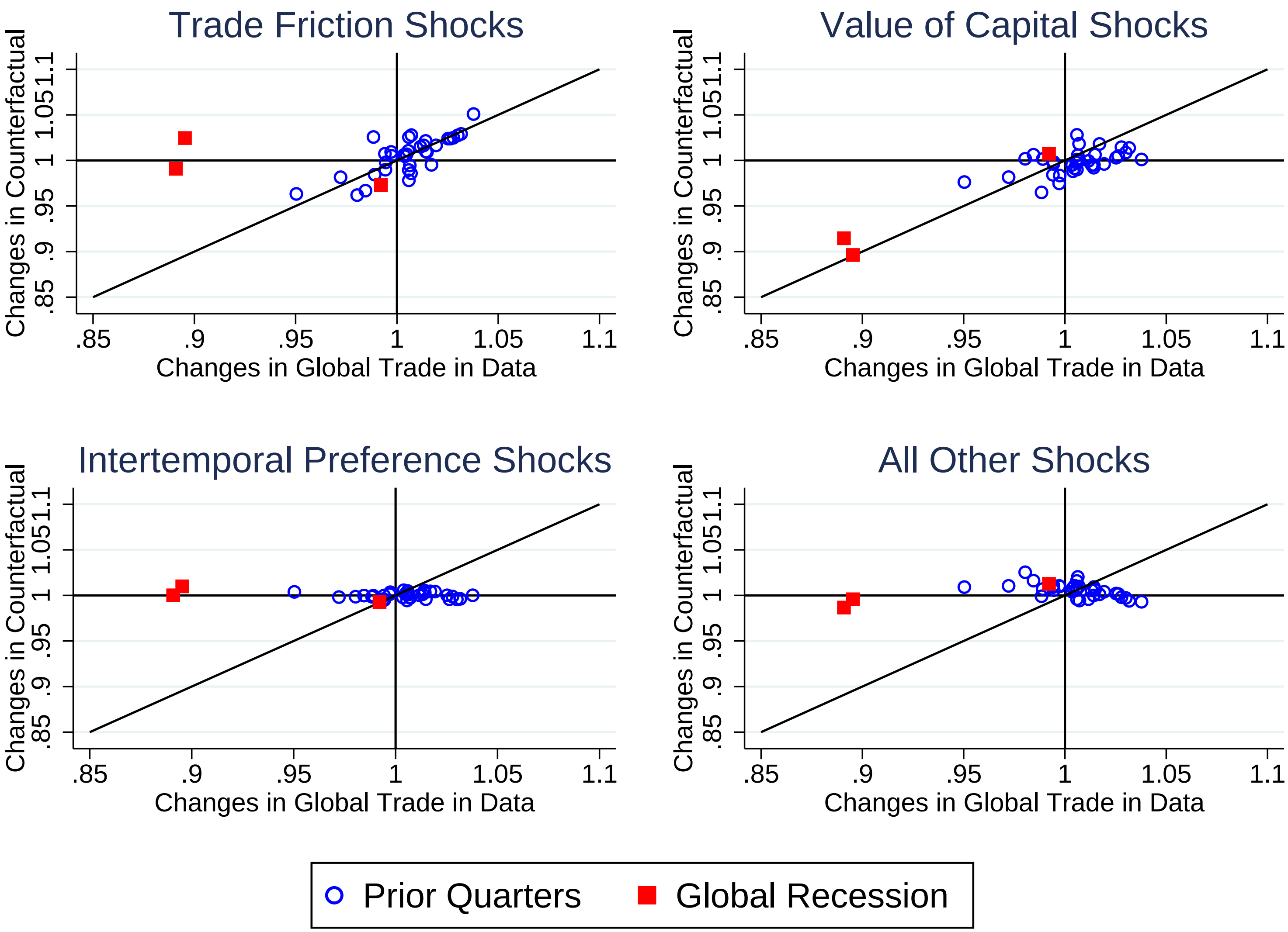

Figure 6: Time-Series Explanatory Power of Various Shocks for Global Trade

Notes: The figures plot, against the actual quarterly changes in global trade, the changes that would have occurred with only the indicated shocks. The solid red squares represent the three quarterly changes from 2008:Q3 to 2009:Q2.

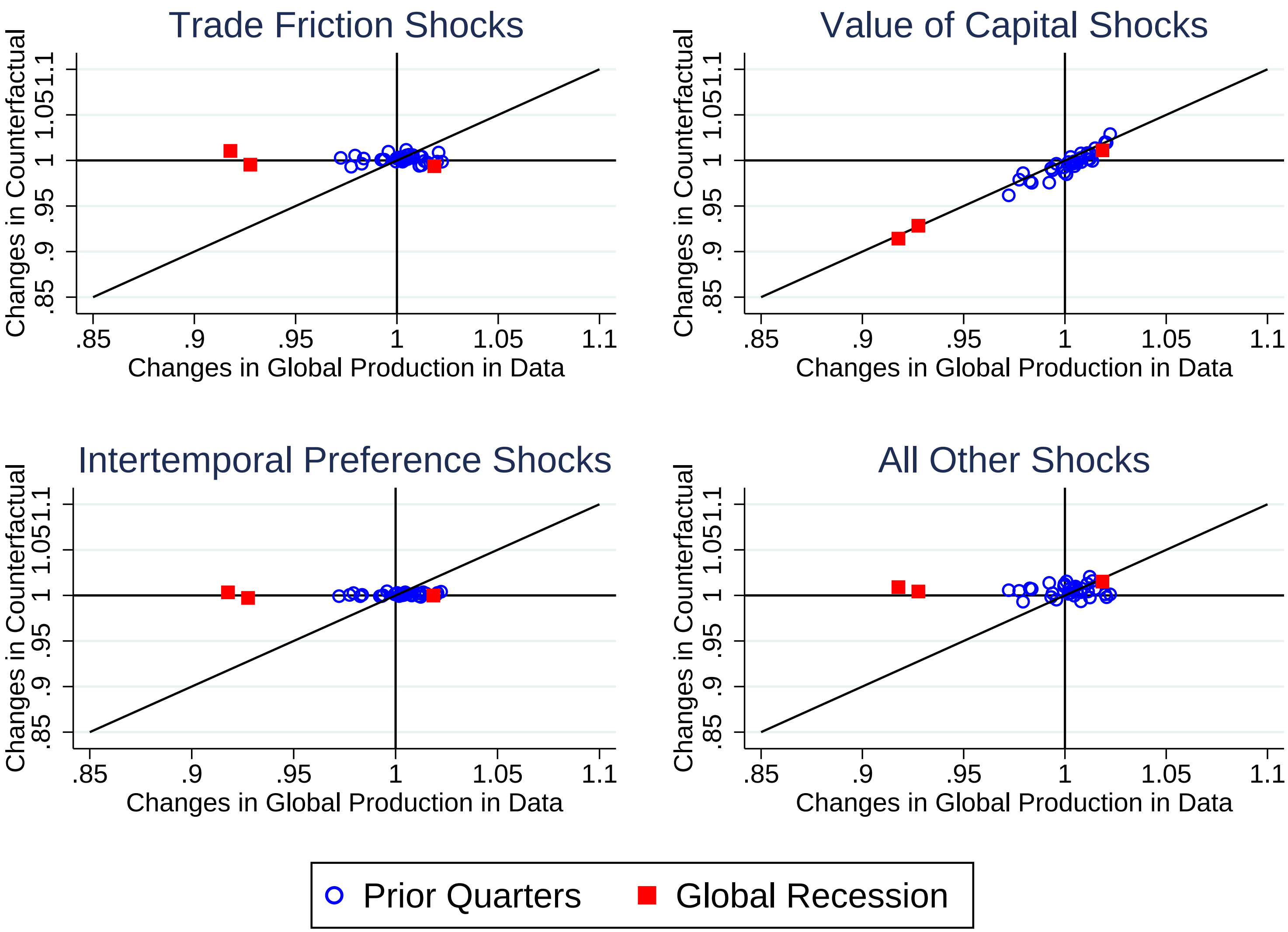

Figure 7: Time-Series Explanatory Power of Various Shocks for Global Production

Notes: The figures plot, against the actual quarterly changes in global manufacturing production, the changes that would have occurred with only the indicated shocks. The solid red squares represent the three quarterly changes from 2008:Q3 to 2009:Q2.

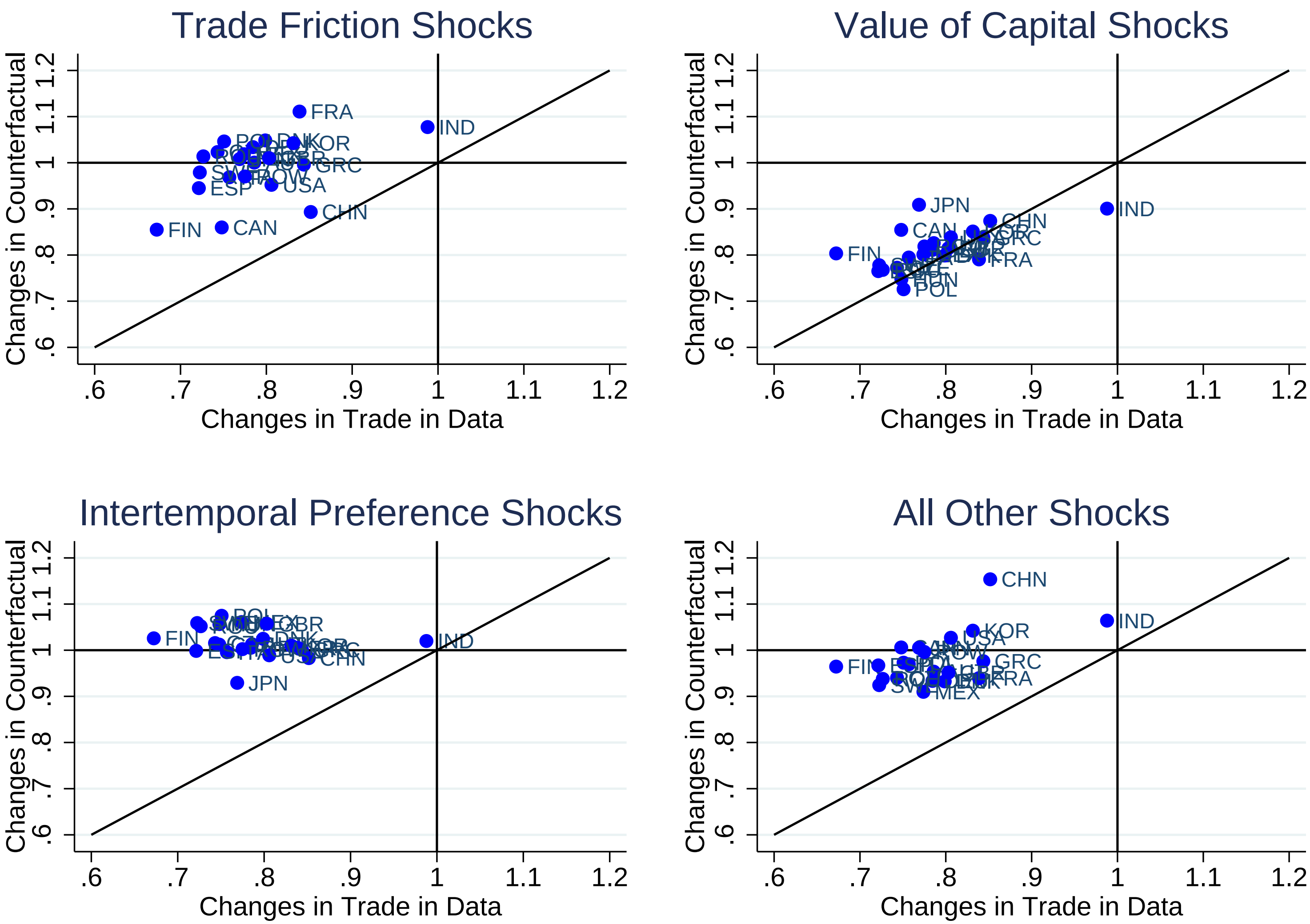

Figure 8: Cross-Sectional Explanatory Power of Various Shocks for Trade during the Global Recession

Notes: The figures plot, against the actual quarterly changes in a country's trade, the changes that would have occurred with only the indicated shocks.

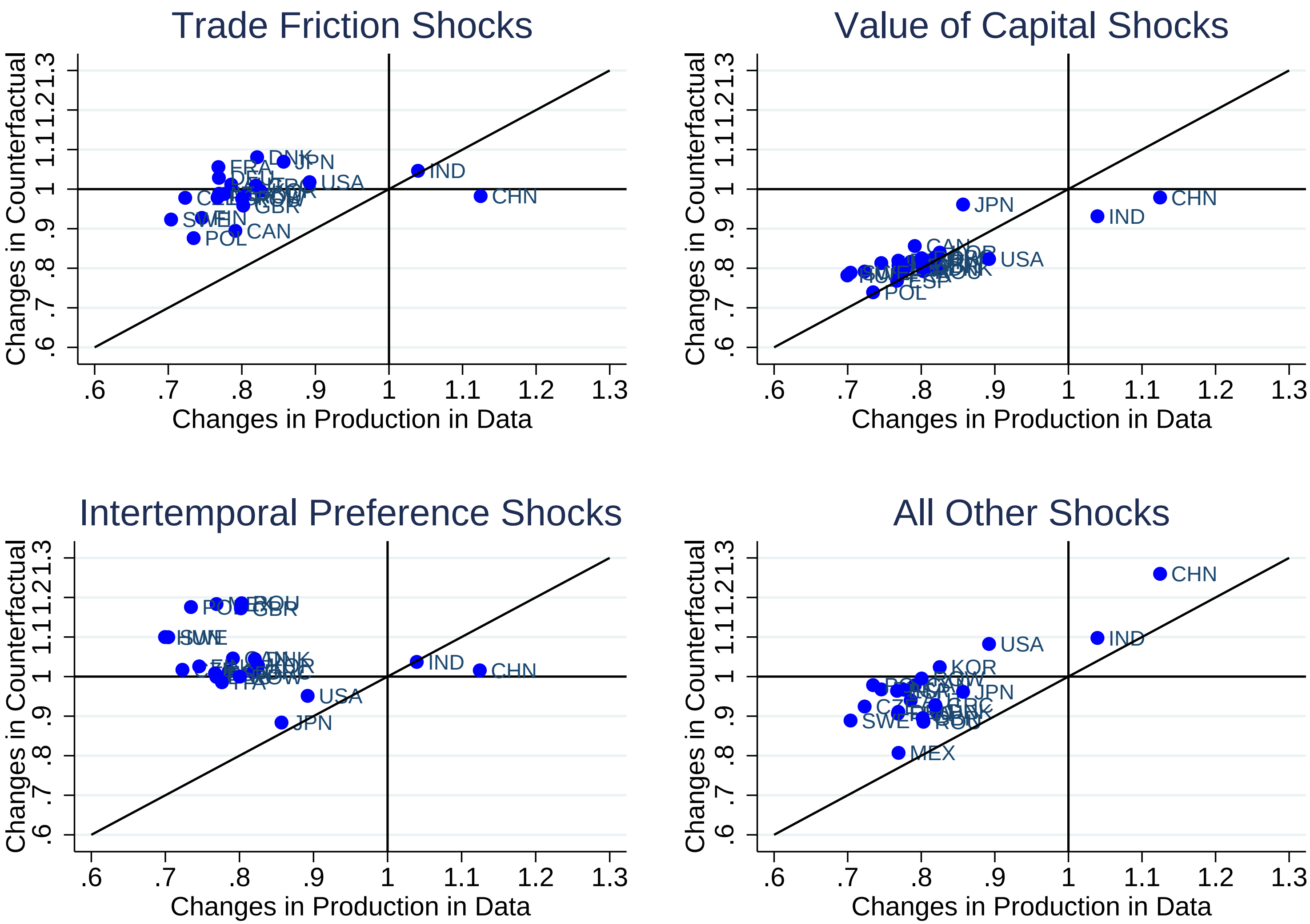

Figure 9: Cross-Sectional Explanatory Power of Various Shocks for Production during the Global Recession

Notes: The figures plot, against the actual quarterly changes in a country's production, the changes that would have occurred with only the indicated shocks.

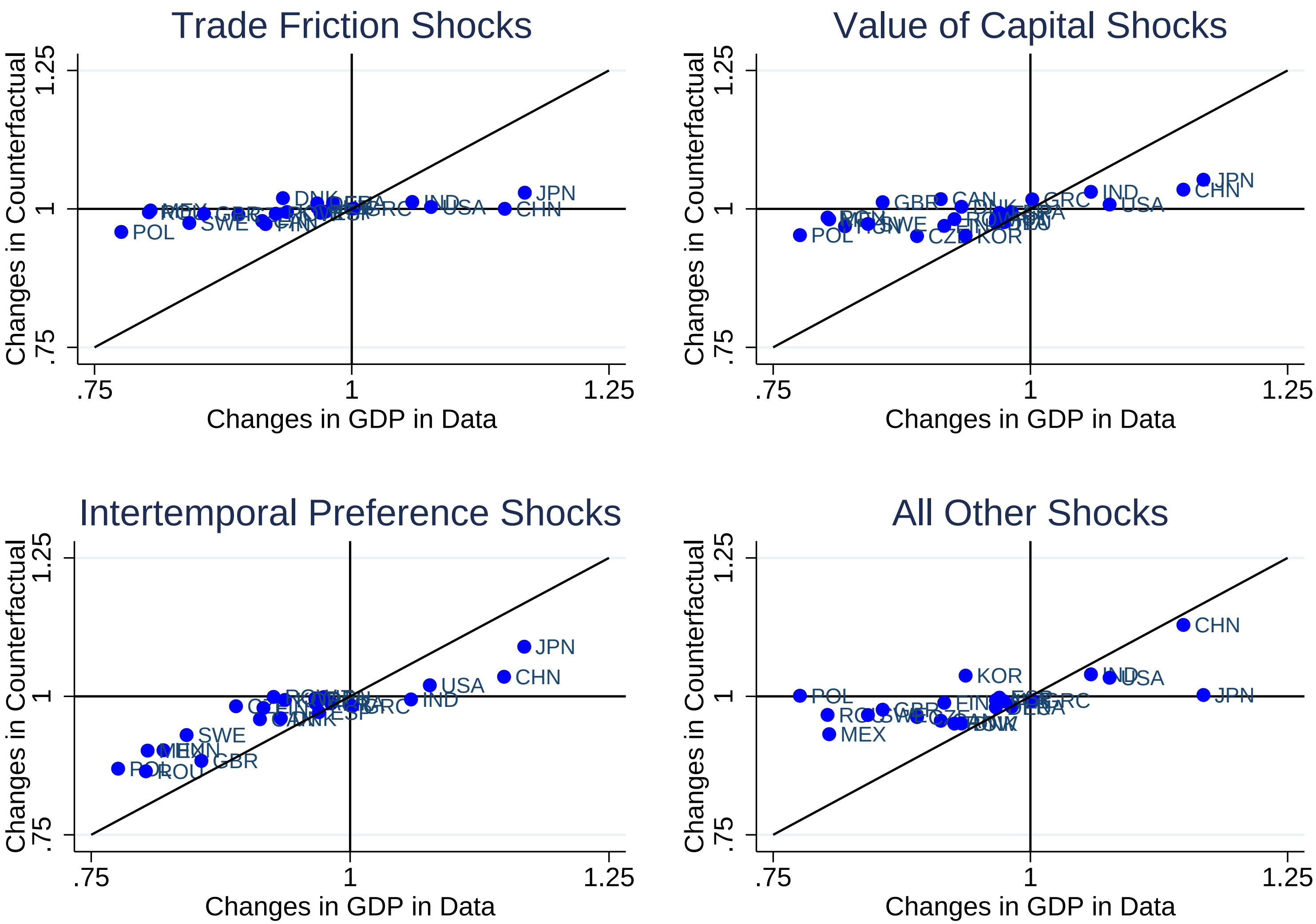

Figure 10: Cross-Sectional Explanatory Power of Various Shocks for GDP during the Global Recession

Notes: The figures plot, against the actual quarterly changes in a country's GDP, the changes that would have occurred with only the indicated shocks.

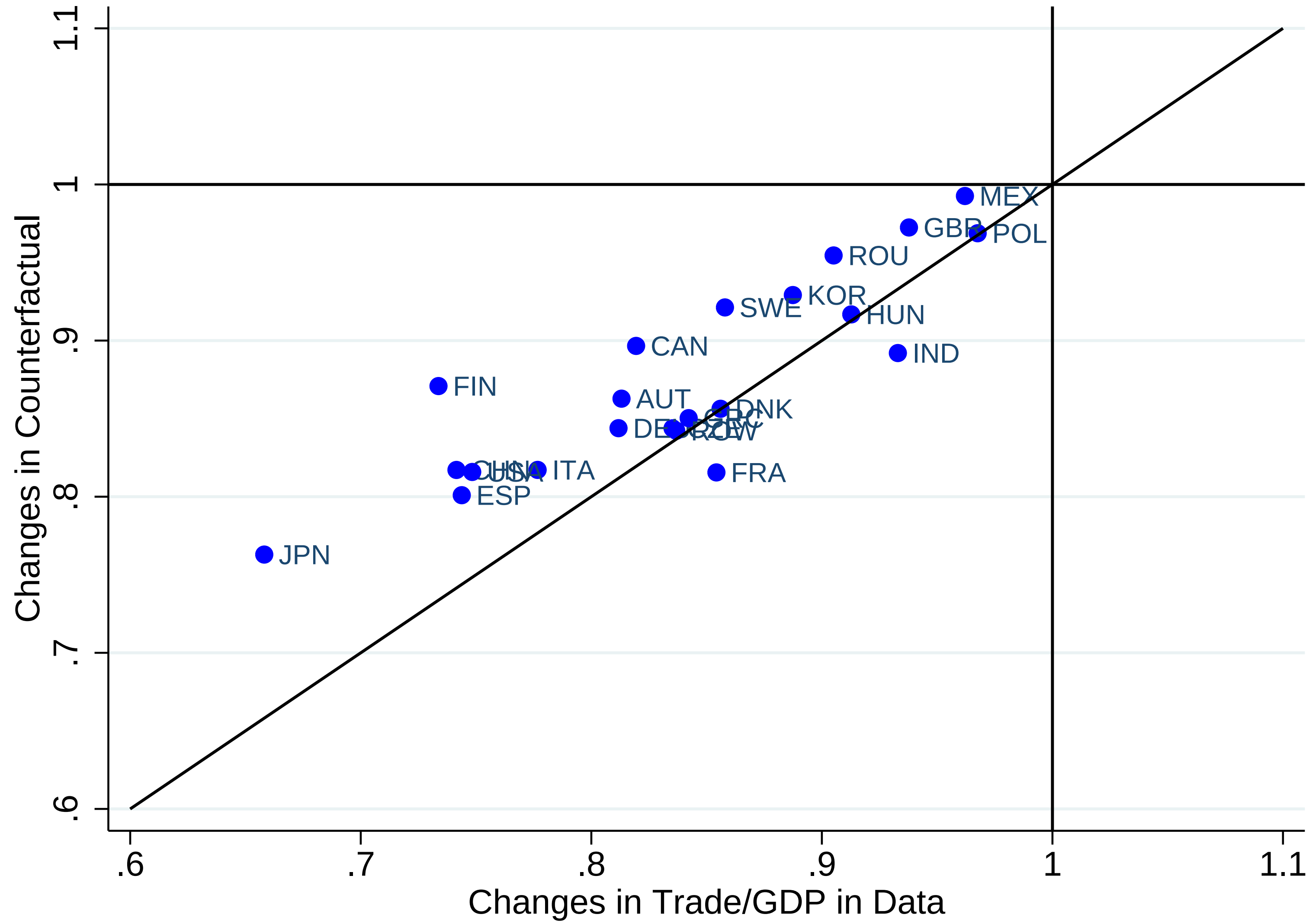

Figure 11: Explanatory Power of Value of Capital and Intertemporal Demand Shocks for Trade/GDP during the Global Recession

Notes: The figures plot, against the actual quarterly changes in a country's Trade/GDP, the changes that would have occurred with shocks to the value of capital and to intertemporal demand.

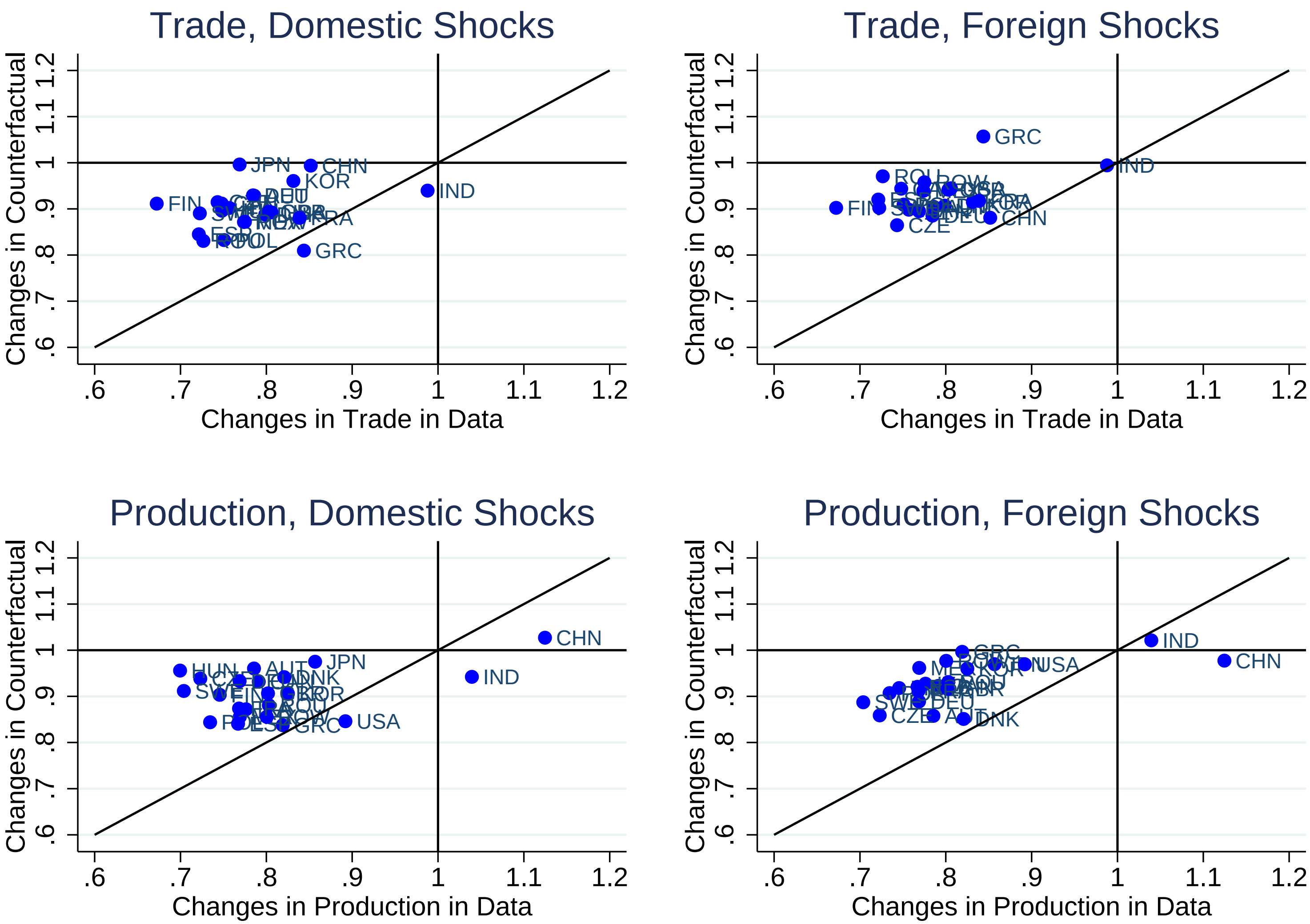

Figure 12: Cross-Sectional Explanatory Power of Foreign and Domestic Value of Capital Shocks during the Global Recession

Notes: The figure plots, against the actual quarterly changes in a country's trade (top two panels) or production (bottom two panels), the changes that would have occurred with only domestic (left-hand panels) or foreign (right-hand panels) value of capital shocks.

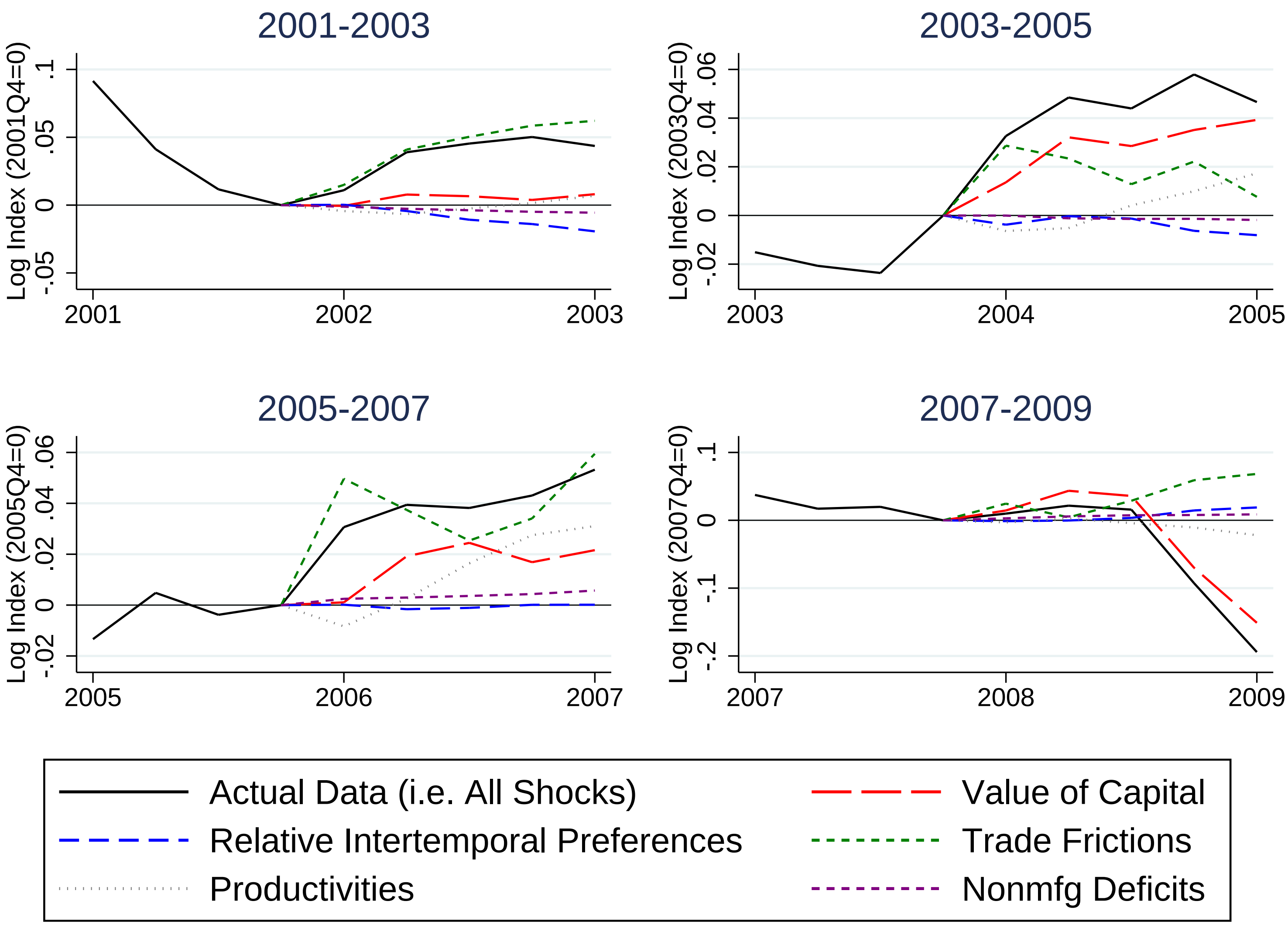

Figure 13: Actual and Counterfactual Evolution of Global Trade, Dynamic Counterfactuals in Various Periods

Notes: Solid lines represent actual data. Non-solid lines report dynamic counterfactuals.

Trade and the Global Recession

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Online Appendix

May 2013

In Appendix Section A we describe our data sources and the construction of all variables used in our analysis. In Appendix Section B we outline the procedure to solve for a counterfactual equilibrium.

A Data Description

Our analysis involves 22 countries (21 actual countries and "Rest of World") across 3 sectors (semi-durable manufactures, durable manufactures, and nonmanufactures). For the two manufacturing sectors we assemble data on trade, production, and prices. We back out measures for the nonmanufacturing sector based on aggregate GDP and net exports of goods and services, as explained below. Unless otherwise noted, our data are quarterly, seasonally-adjusted, in U.S. dollars.[36] The dataset covers the period 2000:Q1 to 2009:Q4.[37]

A.1 Trade Data

We construct the trade data from monthly observations for each 2-digit harmonized system (HS) category, available from the Global Trade Atlas Database. For each of our 21 actual countries we retain the observations on the value of its total imports, its total exports, and its imports from each of the other 20 actual countries.

[36] Trade and production data were translated to U.S. Dollars using exchange rates at the monthly frequency from the OECD.Stat database and from the IMF's International Financial Statistics (IFS) database.

[37] Our full sample of countries does not extend all the way back. For example, in Figure 13 the earliest periods include France and China in Rest of World because we lack data on those countries back to 2000.

A.1.1 Mapping to Industries

We aggregate the relevant 2-digit HS categories into semi-durable and durable manufactures. The first step is to map the data into 2-digit International Standard Industrial Classification (ISIC Rev. 3) codes. To do so, we start with a concordance of 6-digit HS codes to 2-digit ISIC, available from the World Bank's World Integrated Trade Solution (WITS) website. This concordance was then merged with COMTRADE data on the volume of world trade at the 6-digit level for 2007-2008. From this merged dataset we calculate the proportion of world trade in each HS 2-digit category to assign to each 2-digit ISIC category.

The next step is to apply a concordance that maps 2-digit ISIC codes into our durable and semi-durable manufacturing industries.[38] Appendix Table A.1 shows the resulting levels of exports/GDP and imports/GDP, for each of our sectors and countries in 2008:Q1 and 2009:Q1.

A.1.2 Seasonal Adjustment

We separately seasonally adjust the monthly data on total imports, total exports, and bilateral imports, for each of our two sectors. The reason that we seasonally adjust the trade data is to make them comparable to our measures of monthly manufacturing production, which were more widely available in a seasonally adjusted form. After seasonal adjustment, we aggregate the trade data to the quarterly frequency.

A.1.3 Rest of World

We measure trade with Rest of World as a residual. Each actual country's bilateral imports from Rest of World is the difference between its total imports and its imports from each of the other 20 actual countries. Likewise, Rest of World's imports from each actual country is the difference between that country's total exports and what the other 20 report importing from it. Note that trade involving Rest of World is constructed from seasonally adjusted series, so is not separately seasonally adjusted. Hence bilateral imports of a single country will add up (over its 21 partners) to that country's total imports.[39]

[38] Our definition of manufacturing consists of ISIC industries 15 through 36, excluding 23 (petroleum). Table A.2 shows the closely-related mapping from Input-Output industries to our 2 manufacturing sectors (as well as nonmanufactures).

[39] Total imports of Rest of World are simply the sum of what each of the 21 actual countries reports exporting to it.

A.2 Production Data

Measuring the value of manufacturing production posed a challenge for us since data are available only annually for most countries, a frequency that would have limited our ability to evaluate the global recession. Monthly indexes of industrial production can serve as useful indicators of fluctuations in manufacturing output, but do not contain information about the value of production that we require to integrate domestic production with the value of international trade (to construct manufacturing absorption, for example). Our solution is to start with the annual value of production, apportioning it within years based on monthly indexes of industrial production (IP) and producer price indexes (PPI).[40]

A.2.1 Monthly IP and PPI

Our main source of data on monthly IP and PPI indexes by industry is Datastream. Unfortunately, series for the same set of industries are not available in each country. We use three different approaches to get the sectoral breakdown that we need. In all cases we also retain the series for aggregate manufacturing as well.

For a few countries Datastream reports IP or PPI series on aggregates similar to our durable manufacturing and semi-durable manufacturing sectors. For Canada, China, and the United States IP is reported this way while the PPI is reported this way in China and the United States.[41] We use these series directly in our temporal disaggregation procedure described below.

For many countries IP and PPI are reported instead for multiple manufacturing industries as well as for aggregate manufacturing (or occasionally total industry, which includes mining and utilities). In these cases we construct our own durable and semi-durable aggregates. First we regress the log of the aggregate measure on the log of each of the industry measures. Then we use the coefficients from this regression as weights in constructing our two aggregates from the underlying industry-level series.[42]

In a number of cases we can take advantage of another aggregation that is commonly reported: (i) capital goods and durable consumer goods, which are clearly durable manufactures, (ii) nondurable consumer goods, which are clearly semi-durables, and (iii) intermediates, which must be allocated across durables and semi-durables using a regression procedure like the one described

[40] Our basic approach is an application of temporal disaggregation, which was studied from the 1950's by, among others, Milton Friedman (see Friedman, 1962).

[41] For China the series are actually labeled "Heavy Industry" and "Light Industry." The key difference appears to be the treatment of the chemicals industry, which is included in heavy industry while elsewhere we have included it in semi-durable manufactures.

[42] We dropped countries from our analysis when the regression analysis described above did not yield a good fit (as judged by a high R-squared and coefficients that sum to close to 1).

above. In these cases we retain the resulting five aggregate series throughout the process of temporal disaggregation.

A.2.2 Annual Data

The annual value of gross manufacturing production for each sector and country are taken from the OECD Structural Analysis Database (STAN) and the United Nations National Accounts and Industrial Statistics Database (UNIDO).[43] These data are available at the level of 2-digit ISIC industries.[44] We aggregate to the level of semi-durable and durable manufactures using the same concordance that we applied to the trade data (the second of the two concordances described above). We also aggregate to the level of capital goods, durable consumer goods, non-durable consumer goods, durable intermediate goods, and non-durable intermediate goods in order to accomodate those countries in which the monthly data are available in this form. Finally, we also retain the manufacturing total, as we do for the the monthly data.

A.2.3 Temporal Disaggregation

We exploit our monthly IP and PPI series to temporally disaggregate our annual values of production to a monthly frequency using an adaptation of the Chow-Lin procedure (see Chow and Lin, 1971). We follow Di Fonzo (2003) in treating the relationship between the value of annual production and monthly IP and PPI indices as log-linear rather than linear. We impose unit elasticities so that the value of production rises in proportion to real output and to the price of output.[45] We use the disaggregation procedure to generate a predicted monthly series for the value of production. Generally, there will be a gap between the actual annual value of production and the sum of the 12 predicted monthly values. The procedure apportions this gap equally to each monthly predicted value. The result is an internally consistent monthly series that sums to the actual annual data. A shortcoming is that the resulting series often displays artificial jumps from December to January due to the residual corrections being identical across months in the same year but different across months in different years. Hence, we follow Fernandez (1981) and redistribute the gap in a way that allows for serial correlation in the monthly residuals,

[43] For China, Chang-Tai Hsieh provided us with data on manufacturing production by 4-digit industry from the census of manufacturing production. We used these data to determine the shares of durables and semi-durables, then multiplied these shares by the manufacturing total from http://chinadataonline.org.

[44] 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.

[45] As a robustness check, we also estimate these elasticities from a regression of annual production levels on the appropriately accumulated sum of the monthly indicators. Our results are quite robust to this alternative.

thereby eliminating these jumps. Exact details of our procedures are available from the authors on request.[46]

We run this procedure for each manufacturing sector separately (either our 2 sectors or the 5 industry aggregates described above), as well as for total manufacturing, which we use as a benchmark. To get the sectoral series, we multiply the sector shares (implied by our estimates) by our total manufacturing benchmark. In the end, we have monthly series for durable and semi-durable manufacturing production which are consistent with published annual levels of total manufacturing production in each country.[47]

A.3 Price Measures

Using the monthly PPI's from the temporal disaggregation procedure described above, we construct quarterly price indices for durable and semi-durable manufactures. We can thus create series of quarterly growth rates, which is what we require for our analysis. Since there is no PPI series for Rest of World, we set price changes there equal to the average of the quarterly growth rates across our 21 actual countries.

A.4 Macro Data

Quarterly data on GDP and net exports of goods and services are from the Economist Intelligence Unit (EIU).[48] For Rest of World we us annual data from the IMF World Economic Outlook Database assuming constant quarterly growth.

A.5 Introductory Data and Figures

We calculate global trade/GDP, referred to in the introduction, using all available quarterly data on countries' trade and nominal GDP from the IFS. The first three figures also use data from other sources:

[46] The procedure was adapted from the code in Quilis, Enrique. "A Matlab Library of Temporal Disaggregation and Interpolation Methods: Summary," 2006.

[47] As a check on our procedure we compare our monthly fitted series to actual monthly U.S. Census Bureau data for the values of durable and semi-durable manufacturing shipments (the United States is among the few countries with such monthly data). The U.S. monthly data are collected in the M3 manufacturing survey. Though M3 data are available through 2009, we only use data for 1995-2007, using our procedure to extrapolate over the following two years using only the monthly indexes of IP and PPI. Appendix Figure A.3 shows the results. Whether we impose unit elasticities or estimate them (the alternative), we do an excellent job of capturing the out-of-sample decline in production during the global recession.

[48] The overall goods and services deficit for India prior to 2005 was available when we first downloaded the data in 2008 but then was removed when we subsequently updated the data. We use these earlier reported deficit values together with the updated Indian deficit data from 2005 onward.

- Figure 1: U.S. quarterly data are from the BEA national accounts. Japan's quarterly data are from the IMF's IFS database. Germany's quarterly data are from SourceOECD. Data on China are annual and are from IFS. Trade for the United States, Germany, and Japan is in goods and services, while China's is just goods.

- Figure 2: Data are from Datastream. We report overlapping four-quarter percent changes, starting in 1979 for Germany and the United States, 1981 for Japan, and 1994 for China. For the United States, Japan, and Germany, imports exclude petroleum, petroleum products, crude, and partly refined petroleum. For China, imports exclude all nonmanufactures.

- Figure 3: Data are from Datastream. We report overlapping four-quarter percent changes. For the United States, manufacturing spending is the sum of non-farm non-financial business capital spending, personal consumption expenditures on durables, and half of personal consumption expenditures on non-durables (half because it includes some non-manufactures and services). For Japan, manufacturing spending is the sum of business expenditure on new plant and equipment, household expenditure on durable goods, and household expenditure on semi-durables. For China, manufacturing production is the GDP of secondary industry. For Germany, growth in manufacturing spending to GDP is one third of the growth rate of machinery and equipment investment to GDP plus two-thirds of the growth rate of retail sales including motor vehicles and petrol to GDP.[49]

[49] OECD data accessed from http://www.oecd-ilibrary.org/content/data/data-00285-en has German gross investment in "Transport equipment" and "Other machinery and equipment" equal to 8.1 percent of GDP in 2007, while final household consumption expenditure on "Durable goods" and "Non-durable goods" equaled 20.6 percent of GDP. Household spending therefore accounts for a greater share of manufacturing spending than does investment spending.

B Numerical Procedure

Consider solving a counterfactual in quarter $t+1$, given all endogenous variables dated t, shocks dated $t+1$, and changes in capital dated $t+1$. Here we outline the steps to solve for an equilibrium.

In the first step, given an $I \times 1$ vector of wage changes $\hat{w}_{t+1}$, we solve the system of equations (29) for changes in prices. Equations (28) deliver changes in trade shares. We denote the levels in $t+1$ by $\pi_{ni}^{j}(\hat{w}_{t+1})$.

Second, given the price changes calculated above, we can solve for changes in final spending on each type of manufactured good. To do so, we define the $I \times 1$ vectors $\hat{\mathbb{X}}_{t+1}^{F,j} = \left[\hat{X}_{1,t+1}^{F,j}, ..., \hat{X}_{I,t+1}^{F,j}\right]^{T}$, for $j \in \Omega_M$. We guess a value for each $\hat{\mathbb{X}}_{t+1}^{F,j}$ and iterate on the system of equations (30) and (26) to find the solution. We denote the $t+1$ levels by the vector $\mathbb{X}^{F,j}(\hat{w}_{t+1})$.

Third, we solve for $\hat{X}_{t+1}^{F,N}$ from (26), which from (31) gives $\hat{X}_{i,t+1}^{F,N}$ for each country i. We stack the $t+1$ levels in the vector $\mathbb{X}^{F,N}(\hat{w}_{t+1})$.

Fourth, we solve for total spending (including spending on intermediates) on each type of manufactured good in each country, which we denote with a $2I \times 1$ vector

$$\mathbb{X}_{t+1} = [X_{1,t+1}^{D}, ..., X_{I,t+1}^{D}, X_{1,t+1}^{S}, ..., X_{I,t+1}^{S}]^{T}.$$

We also form a trade matrix $\Pi^{j}(\hat{w}_{t+1})$, with $\pi_{ni}^{j}(\hat{w}_{t+1})$ in its n'th row and i'th column. We combine the matrices for $j \in \Omega_M$ to form:

$$\mathbf{\Pi}(\hat{w}_{t+1}) = \begin{bmatrix} \Pi^{D}(\hat{w}_{t+1}) & 0 \\ 0 & \Pi^{S}(\hat{w}_{t+1}) \end{bmatrix}.$$

We denote the vector of nonmanufacturing trade deficits by $D_{t+1}^{N} = [D_{1,t+1}^{N}, ..., D_{I,t+1}^{N}]^{T}$. Stacking equations (22) we have:

$$\mathbb{X}_{t+1} = \left[\mathbb{X}^{F,D}(\hat{w}_{t+1})^{T}, \mathbb{X}^{F,S}(\hat{w}_{t+1})^{T}\right]^{T} + \left[\mathbf{\Pi}(\hat{w}_{t+1})\tilde{\Gamma}\right]^{T}\mathbb{X}_{t+1} - \tilde{\boldsymbol{\xi}}\left[\mathbb{X}^{F,N}(\hat{w}_{t+1}) - D_{t+1}^{N}\right], \quad \text{(A.1)}$$

with

$$\tilde{\Gamma} = \begin{bmatrix} \tilde{\gamma}_1^{DD}(1-\widetilde{\beta}_1^{D}) & 0 & 0 & \tilde{\gamma}_1^{DS}(1-\widetilde{\beta}_1^{D}) & 0 & 0 \\ 0 & \ddots & 0 & 0 & \ddots & 0 \\ 0 & 0 & \tilde{\gamma}_I^{DD}(1-\widetilde{\beta}_I^{D}) & 0 & 0 & \tilde{\gamma}_I^{DS}(1-\widetilde{\beta}_I^{D}) \\ \tilde{\gamma}_1^{SD}(1-\widetilde{\beta}_1^{S}) & 0 & 0 & \tilde{\gamma}_1^{SS}(1-\widetilde{\beta}_1^{S}) & 0 & 0 \\ 0 & \ddots & 0 & 0 & \ddots & 0 \\ 0 & 0 & \tilde{\gamma}_I^{SD}(1-\widetilde{\beta}_I^{S}) & 0 & 0 & \tilde{\gamma}_I^{SS}(1-\widetilde{\beta}_I^{S}) \end{bmatrix},$$

and

$$\tilde{\boldsymbol{\xi}} = \begin{bmatrix} \xi_1^D & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & \xi_I^D \\ \xi_1^S & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & \xi_I^S \end{bmatrix},$$

where ξ_i^j is given by (18). We can obtain the solution $\mathbb{X}(\hat{w}_{t+1})$ to (A.1) using matrix algebra:

$$\mathbb{X}(\hat{w}_{t+1}) = \left(I_{2I\times 2I} - \left[\boldsymbol{\Pi}(\hat{w}_{t+1})\tilde{\Gamma}\right]^T \right)^{-1} \left(\left[\mathbb{X}^{F,D}(\hat{w}_{t+1})^T, \mathbb{X}^{F,S}(\hat{w}_{t+1})^T\right]^T - \tilde{\boldsymbol{\xi}} \left[\mathbb{X}^{F,N}(\hat{w}_{t+1}) - D_{t+1}^N\right] \right).$$

The last step is to check that the wage changes $\hat{w}_{t+1}$, which we took as given in the first step, satisfy the equilibrium conditions. Decomposing the solution for total spending above as

$$\mathbb{X}(\hat{w}_{t+1}) = \left[\mathbb{X}^D(\hat{w}_{t+1})^T, \mathbb{X}^S(\hat{w}_{t+1})^T\right]^T,$$

we can check (32), comparing the vector of deficits D_{t+1}^N with

$$\sum_{l\in\Omega} \mathbb{X}^{F,l}(\hat{w}_{t+1}) - \mathbf{Y}^F \hat{w}_{t+1} - \sum_{j\in\Omega_M} \left[I_I - \Pi^j(\hat{w}_{t+1})^T\right] \mathbb{X}^j(\hat{w}_{t+1}), \tag{A.2}$$

where

$$\mathbf{Y}^F = \begin{bmatrix} Y_{1,t}^F & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & Y_{I,t}^F \end{bmatrix}.$$

We adjust downward our guess of $\hat{w}_{i,t+1}$ for countries i in which (A.2) exceeds $D_{i,t+1}^N$, adjusting upward our guess of $\hat{w}_{i,t+1}$ otherwise, subject to the normalization

$$1 = \sum_{i=1}^{I} Y_{i,t}^F \hat{w}_{i,t+1}.$$

If wage changes need to be adjusted, we return to the first step above, repeating all five steps until (32) is satisfied.

For most of our exercises, we repeat the procedure above at date $t+2$, using data for our initial conditions at $t+1$. For the dynamic counterfactuals in the last section, we use the date $t+1$ equilibrium values as the new initial conditions for calculating the the date $t+2$ counterfactual, and use equilibrium investment at date $t+1$ to update capital stock changes using (37).

	2008:Q3 Values (percent)						Change $\left(\frac{2009:Q2}{2008:Q3}\right)$ in					
	Exports / GDP			Imports / GDP			Exports / GDP			Imports / GDP		
	All	Dur	S-Dur	All	Dur	S-Dur	All	Dur	S-Dur	All	Dur	S-Dur
World	**17.8**	**12.3**	**5.5**	**17.8**	**12.3**	**5.5**	**0.79**	**0.76**	**0.86**	**0.79**	**0.76**	**0.86**
Austria	41.8	29.8	12.0	37.3	25.5	11.9	0.79	0.74	0.90	0.84	0.80	0.93
Canada	18.6	12.8	5.9	22.3	16.0	6.3	0.77	0.73	0.86	0.86	0.81	0.99
China	31.3	22.9	8.4	16.8	12.3	4.4	0.70	0.68	0.77	0.81	0.82	0.79
Czech Republic	64.0	51.6	12.4	55.6	40.1	15.5	0.84	0.82	0.90	0.83	0.80	0.91
Denmark	28.4	15.3	13.1	28.5	18.1	10.4	0.90	0.83	0.99	0.81	0.74	0.92
Finland	32.4	23.0	9.5	26.4	18.9	7.5	0.74	0.68	0.87	0.73	0.68	0.87
France	18.8	11.4	7.4	19.7	12.4	7.4	0.85	0.83	0.89	0.86	0.84	0.89
Germany	38.0	27.2	10.9	26.9	18.0	8.9	0.80	0.77	0.87	0.83	0.79	0.92
Greece	5.8	2.7	3.1	19.7	11.4	8.3	0.85	0.78	0.90	0.84	0.82	0.87
Hungary	62.3	49.1	13.2	58.0	43.0	14.9	0.94	0.92	1.02	0.88	0.86	0.92
India	9.8	5.2	4.6	12.9	8.7	4.2	0.93	0.99	0.87	0.93	0.97	0.84
Italy	21.9	14.6	7.4	18.9	11.7	7.2	0.79	0.75	0.87	0.76	0.69	0.87
Japan	15.8	13.5	2.3	9.2	5.8	3.3	0.63	0.61	0.75	0.71	0.65	0.82
Mexico	20.0	16.8	3.2	23.0	16.7	6.3	1.00	0.98	1.09	0.93	0.91	0.99
Poland	28.7	20.7	8.0	30.5	20.2	10.3	1.01	0.97	1.10	0.93	0.89	1.00
Romania	19.7	13.7	6.0	32.7	21.1	11.6	1.05	1.04	1.05	0.82	0.76	0.94
South Korea	42.2	34.6	7.6	29.9	22.2	7.7	0.94	0.95	0.92	0.81	0.78	0.88
Spain	15.6	9.6	6.0	19.9	12.6	7.4	0.79	0.75	0.86	0.71	0.63	0.83
Sweden	33.1	23.6	9.6	27.9	19.2	8.7	0.86	0.79	1.03	0.85	0.80	0.98
United Kingdom	14.4	9.3	5.0	19.0	12.2	6.8	0.91	0.85	1.03	0.96	0.90	1.06
United States	7.9	5.6	2.3	10.5	7.5	3.0	0.76	0.73	0.81	0.74	0.71	0.83
Rest of World	14.6	8.8	5.8	19.9	14.4	5.6	0.86	0.80	0.94	0.82	0.79	0.90

Table A.1: Sectoral and Total Imports /GDP and Exports / GDP

Notes: Growth in all variables is expressed relative to global GDP.

Manufacturing		Nonmanufacturing	
Durables		(1)	Agriculture, hunting, forestry, and fishing
(1)	Wood and products of wood and cork	(2)	Mining and quarrying (energy)
(2)	Other non-metallic mineral products	(3)	Mining and quarrying (non-energy)
(3)	Iron & steel	(4)	Coke, refined petroleum products, and nuclear fuel
(4)	Non-ferrous metals	(5)	Production, collection, and distribution of electricity
(5)	Fabricated metal products, except machinery & equipment	(6)	Manufacture of gas; distribution of gaseous fuels through mains
(6)	Machinery & equipment, nec	(7)	Steam and hot water supply
(7)	Office, accounting, & computing machinery	(8)	Collection, purification, and distribution of water
(8)	Electrical machinery & apparatus, nec	(9)	Construction
(9)	Radio, television, & communication equipment	(10)	Wholesale & retail trade; repairs
(10)	Medical, precision, & optical instruments	(11)	Hotels & restaurants
(11)	Motor vehicles, trailers, & semi-trailers	(12)	Land transport; transport via pipelines
(12)	Building & repairing of ships & boats	(13)	Air transport
(13)	Aircraft & spacecraft	(14)	Water transport
(14)	Railroad equipment & transport equipment nec	(15)	Supporting and auxiliary transport activities; activities of travel agencies
(15)	1/2 of Manufacturing nec; recycling (including Furniture)	(16)	Post and telecommunications
		(17)	Finance & insurance
		(18)	Real estate activities
		(19)	Renting of machinery & equipment
Semi-Durables		(20)	Computer & related activities
(1)	Food products, beverages, & tobacco	(21)	Research & development
(2)	Textiles, textile products, leather, & footwear	(22)	Other business activities
(3)	Pulp, paper, & paper products	(23)	Public administration & defense; compulsory social security
(4)	Chemicals excluding pharmaceuticals	(24)	Education
(5)	Pharmaceuticals	(25)	Health & social work
(6)	Rubber & plastics products	(26)	Other community, social, & personal services
(7)	1/2 of Manufacturing nec; recycling (including Furniture)	(27)	Private households with employed persons & extra-territorial organizations & bodies

Table A.2: Sector Definitions in the OECD Input-Output Tables

Notes: Authors' classifications of the 48 sectors included in the OECD input-output tables, with one sector ("Manufacturing nec; recycling (including Furniture)") split evenly between durables and semi-durables.

		Change $\left(\frac{2009:Q2}{2008:Q3}\right)$ in Production in Various Counterfactuals						
	Production / World GDP in 2008:Q3 (percent)	All Shocks (i.e. Data)	Change in Capital $\left(\hat{K}_i^{D*}, \hat{K}_i^{S*}\right)$	Trade Friction Shocks $\left(\hat{d}_{ni}^{D}, \hat{d}_{ni}^{S}\right)$	Productivity Shocks $\left(\hat{A}_i^{D}, \hat{A}_i^{S}\right)$	Value of Capital Shocks $\left(\hat{Q}_i^{D*}, \hat{Q}_i^{S*}\right)$	Relative Intertemporal Preferences $\left(\hat{\phi}_i^{*}\right)$	Nonmfg Deficits $\left(D_i^N\right)$
World	**61.2**	**0.87**	**1.00**	**1.00**	**1.03**	**0.86**	**1.00**	**1.00**
Austria	0.4	0.79	1.00	1.01	0.95	0.82	1.01	0.98
Canada	1.0	0.79	0.99	0.89	0.95	0.86	1.05	1.02
China	9.5	1.12	1.03	0.98	1.27	0.98	1.02	1.02
Czech Republic	0.4	0.72	1.00	0.98	0.93	0.79	1.02	1.00
Denmark	0.2	0.82	0.99	1.08	0.89	0.80	1.04	1.01
Finland	0.3	0.75	1.00	0.93	0.97	0.81	1.03	0.99
France	2.3	0.77	0.99	1.06	0.92	0.78	1.00	0.98
Germany	4.2	0.77	1.00	1.03	0.93	0.82	1.00	0.98
Greece	0.2	0.82	0.99	1.01	0.94	0.83	1.01	0.97
Hungary	0.2	0.70	1.00	1.80	0.49	0.78	1.10	0.98
India	1.1	1.04	1.02	1.05	1.12	0.93	1.04	1.00
Italy	2.5	0.78	0.99	0.99	0.97	0.80	0.99	0.98
Japan	5.4	0.86	0.99	1.07	0.98	0.96	0.88	0.97
Mexico	1.1	0.77	1.00	0.99	0.80	0.81	1.18	1.00
Poland	0.6	0.73	0.99	0.88	0.99	0.74	1.18	0.98
Romania	0.2	0.80	1.00	0.98	0.89	0.79	1.19	1.00
South Korea	2.2	0.83	1.01	1.00	1.05	0.84	1.03	0.98
Spain	1.4	0.77	0.98	0.98	0.98	0.77	1.01	0.97
Sweden	0.5	0.70	1.00	0.92	0.90	0.79	1.10	0.99
United Kingdom	1.5	0.80	1.00	0.96	0.90	0.81	1.17	0.99
United States	9.6	0.89	0.98	1.02	1.10	0.82	0.95	0.97
Rest of World	16.4	0.80	1.00	0.98	0.96	0.83	1.00	1.03

Table A.3: Production over the Global Recession

Notes: The column Change in Capital reports the effect of investment in the previous period, with no contemporaneous shocks. The subsequent columns report the effect of individual sets of shocks with all other shocks suppressed (but including the effect of the change in capital). The reported effects are the product of effects from three one-quarter simulations each reinitialized with actual data from the previous quarter.

	GDP / World GDP in 2008:Q3 (percent)	Change $\left(\frac{2009:Q2}{2008:Q3}\right)$ in GDP in Various Counterfactuals						
		All Shocks (i.e. Data)	**Change in Capital** $\left(\hat{K}_i^{D*}, \hat{K}_i^{S*}\right)$	**Trade Friction Shocks** $\left(\hat{d}_{ni}^{D}, \hat{d}_{ni}^{S}\right)$	**Productivity Shocks** $\left(\hat{A}_i^{D}, \hat{A}_i^{S}\right)$	**Value of Capital Shocks** $\left(\hat{Q}_i^{D*}, \hat{Q}_i^{S*}\right)$	**Relative Intertemporal Preferences** $\left(\hat{\phi}_i^{*}\right)$	**Nonmfg Deficits** $\left(D_i^{N}\right)$
World	**100**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
Austria	0.7	0.97	1.00	1.00	0.98	0.98	0.99	1.01
Canada	2.6	0.91	1.00	0.98	0.98	1.02	0.96	0.97
China	7.6	1.15	1.01	1.00	1.12	1.03	1.04	1.03
Czech Republic	0.4	0.89	1.00	0.99	0.96	0.95	0.98	1.00
Denmark	0.6	0.93	1.00	1.02	0.97	1.00	0.96	0.98
Finland	0.5	0.92	1.00	0.97	0.97	0.97	0.98	1.00
France	4.8	0.98	1.00	1.01	0.97	0.99	0.99	1.01
Germany	6.1	0.97	1.00	1.01	0.97	0.98	1.00	1.01
Greece	0.6	1.00	1.00	1.00	0.98	1.02	0.98	1.01
Hungary	0.3	0.82	1.00	1.18	0.84	0.97	0.90	1.01
India	2.1	1.06	1.01	1.01	1.03	1.03	0.99	1.02
Italy	3.8	0.97	1.00	1.00	0.99	0.98	1.00	1.00
Japan	7.6	1.17	1.00	1.03	0.99	1.05	1.09	1.01
Mexico	2.0	0.80	1.00	1.00	0.93	0.98	0.90	1.00
Poland	1.0	0.78	1.00	0.96	0.99	0.95	0.87	1.01
Romania	0.4	0.80	1.00	0.99	0.96	0.98	0.86	1.00
South Korea	1.6	0.94	1.01	0.99	1.02	0.95	0.87	1.01
Spain	2.7	0.97	1.00	0.99	0.99	0.99	0.97	1.01
Sweden	0.8	0.84	1.00	0.97	0.96	0.97	0.93	1.01
United Kingdom	4.5	0.86	1.00	0.99	0.97	1.01	0.88	1.00
United States	23.6	1.08	1.00	1.00	1.02	1.01	1.02	1.01
Rest of World	26.0	0.93	1.00	0.99	0.98	0.98	1.00	0.97

Table A.4: GDP over the Global Recession

Notes: The column Change in Capital reports the effect of investment in the previous period, with no contemporaneous shocks. The subsequent columns report the effect of individual sets of shocks with all other shocks suppressed (but including the effect of the change in capital). The reported effects are the product of effects from three one-quarter simulations each reinitialized with actual data from the previous quarter.

	$\hat{d}_i^D$			$\hat{d}_i^S$			$\hat{A}_i^D$			$\hat{A}_i^S$		
	2008 Q4	2009 Q1	2009 Q2	2008 Q4	2009 Q1	2009 Q2	2008 Q4	2009 Q1	2009 Q2	2008 Q4	2009 Q1	2009 Q2
World	**0.97**	**1.01**	**1.01**	**0.98**	**1.00**	**1.02**	**1.00**	**1.00**	**1.02**	**1.01**	**1.00**	**1.01**
Austria	1.02	1.04	0.95	0.99	1.01	0.97	1.02	1.05	0.93	1.00	1.02	0.95
Canada	0.98	1.04	1.05	0.95	1.03	1.05	0.94	1.01	1.05	0.94	0.99	1.02
China	1.00	1.02	1.02	0.96	1.03	1.03	1.06	1.05	1.03	1.02	1.01	1.03
Czech Republic	0.99	0.97	1.03	0.97	0.97	1.01	0.98	0.95	1.06	0.99	0.98	1.00
Denmark	1.07	0.96	1.00	0.98	0.96	0.97	1.07	0.96	0.99	0.98	0.96	0.94
Finland	1.05	1.00	1.03	1.02	1.01	1.01	1.02	0.97	1.00	1.00	0.99	1.01
France	0.97	0.95	1.01	0.99	0.96	1.01	0.98	0.96	1.01	1.00	1.00	1.01
Germany	0.98	0.96	1.02	0.99	0.96	1.03	0.99	0.96	1.02	0.99	0.97	1.02
Greece	0.95	1.02	1.01	0.98	1.01	1.02	0.99	0.97	1.00	0.98	0.97	1.04
Hungary	0.96	0.82	0.88	0.96	0.99	1.01	0.93	0.72	0.85	0.99	0.99	0.99
India	0.96	0.98	0.99	0.98	1.09	0.97	1.00	1.04	1.02	1.02	1.03	0.98
Italy	1.00	1.02	0.99	0.99	1.00	1.01	1	1.01	1.00	1.00	0.99	1.00
Japan	0.86	1.07	1.02	0.98	1.03	0.99	1.00	0.99	1.02	1.00	0.98	1.02
Mexico	0.96	0.97	1.05	0.93	1.01	1.05	0.91	0.88	1.10	0.96	0.94	1.02
Poland	0.99	0.93	1.00	0.95	0.95	1.02	1.01	0.98	1.03	1.00	0.99	1.02
Romania	0.95	0.99	1.02	1.00	0.99	1.04	0.99	0.96	1.03	1.02	0.90	1.00
South Korea	0.93	1.00	1.00	0.92	1.04	1.01	0.95	1.02	1.06	0.98	1.02	1.02
Spain	1.01	1.01	1.00	0.98	1.04	1.00	1.01	1.00	1.00	1.00	1.00	1.00
Sweden	1.03	0.98	1.00	0.99	0.97	1.01	1.00	0.95	1.00	0.97	0.97	1.01
United Kingdom	0.97	1.00	1.02	0.97	0.97	1.02	0.98	0.98	1.00	0.98	0.96	1.00
United States	0.97	1.03	1.03	0.95	1.02	1.03	1.00	1.02	1.00	1.08	1.04	0.99
Rest of World	0.97	1.02	1.01	1.00	1.00	1.02	0.98	1.00	1.01	0.99	0.99	1.01

Table A.5: Trade Friction and Productivity Shocks, Each Quarter of the Recession

Notes: Trade friction shocks are calculated as a trade-weighted average of the bilateral shocks including the Frechet parameter for each import and export partner $\left(\hat{d}_{ni}^j\right)^{-\theta^j}$, raised to the power $-1/\theta^j$. Trade friction and productivity shocks for World are also aggregated across countries analogously, taking into account trade weights and production weights respectively as well as the parameter θ.

	$\hat{Q}_i^{D*}$			$\hat{Q}_i^{S*}$			$\hat{\phi}_i^{*}$			$\Delta \frac{D_i^N}{Y_i}$		
	2008 Q4	2009 Q1	2009 Q2	2008 Q4	2009 Q1	2009 Q2	2008 Q4	2009 Q1	2009 Q2	2008 Q4	2009 Q1	2009 Q2
World	**0.89**	**0.89**	**1.00**	**0.93**	**0.96**	**1.02**	**1.00**	**1.00**	**1.00**	**0.00**	**0.00**	**0.00**
Austria	0.94	0.92	0.96	0.92	0.98	1.00	0.94	0.99	1.04	-0.01	-0.01	0.00
Canada	0.92	0.87	1.01	0.89	0.99	1.03	0.90	0.97	1.05	0.02	0.01	0.00
China	0.76	0.95	1.20	1.16	1.06	0.96	1.09	0.98	0.99	-0.01	-0.02	0.01
Czech Republic	0.80	0.81	1.03	0.84	0.92	1.01	0.97	0.94	1.05	0.00	0.00	0.01
Denmark	0.89	0.87	0.86	0.91	0.96	0.94	0.91	1.00	1.02	0.00	0.01	0.02
Finland	0.87	0.85	0.97	0.93	0.91	1.05	0.91	1.04	1.00	-0.03	0.01	0.01
France	0.83	0.89	1.02	0.90	0.90	1.02	0.95	1.02	1.01	-0.01	0.00	0.00
Germany	0.87	0.92	0.98	0.92	0.98	1.01	0.95	1.02	1.02	-0.01	0.00	-0.01
Greece	0.81	0.93	1.00	0.89	1.00	1.03	0.95	0.98	1.04	-0.01	0.01	-0.01
Hungary	0.71	0.76	0.84	0.81	0.92	1.02	0.88	0.87	1.05	0.00	-0.02	-0.01
India	0.93	0.91	1.02	0.93	1.00	1.06	0.94	1.01	1.03	-0.02	0.01	-0.02
Italy	0.81	0.87	0.96	0.89	0.96	1.05	0.98	1.00	1.02	0.00	-0.02	0.00
Japan	1.10	0.86	0.94	1.15	0.98	0.96	1.23	1.05	0.93	-0.01	-0.02	0.00
Mexico	0.88	0.84	0.96	0.85	0.96	1.04	0.83	0.89	1.05	0.02	-0.01	-0.01
Poland	0.80	0.76	0.96	0.82	0.85	1.04	0.83	0.84	1.04	-0.01	-0.02	0.01
Romania	0.74	0.85	1.03	0.85	0.97	1.03	0.87	0.85	1.01	-0.01	-0.01	0.01
South Korea	0.68	0.88	1.16	0.75	0.96	1.10	0.89	1.02	1.04	-0.04	-0.01	0.00
Spain	0.70	0.64	0.07	0.90	0.98	1.03	0.95	1.00	1.01	-0.01	-0.01	0.00
Sweden	0.78	0.80	0.99	0.84	0.92	1.03	0.86	0.94	1.03	0.00	-0.01	-0.01
United Kingdom	0.83	0.87	1.07	0.87	0.93	1.06	0.86	0.91	1.03	-0.01	0.01	0.00
United States	0.99	0.91	0.93	0.91	0.94	1.02	1.06	1.01	0.97	-0.01	-0.01	0.00
Rest of World	0.85	0.88	1.01	0.87	0.97	1.05	0.95	1.01	1.03	0.02	0.02	0.00

Table A.6: Value of Capital, Intertemporal Demand, and Nonmanufacturing Deficit Shocks, Each Quarter of the Recession

Notes: The nonmanufacturing trade deficit shock is the quarterly difference in the deficit divided by GDP at the beginning of the quarter. Shocks to the value of capital for the World are calculated as a investment-weighted average of the country shocks including the adjustment cost parameter $\left(\hat{Q}_i^{j*}\right)^{\frac{1}{1-\alpha^j}}$, raised to the power $1-\alpha^j$. Intertemporal demand and nonmanufacturing deficit shocks are nonmanufacturing spending-weighted and GDP-weighted averages of the country shocks.

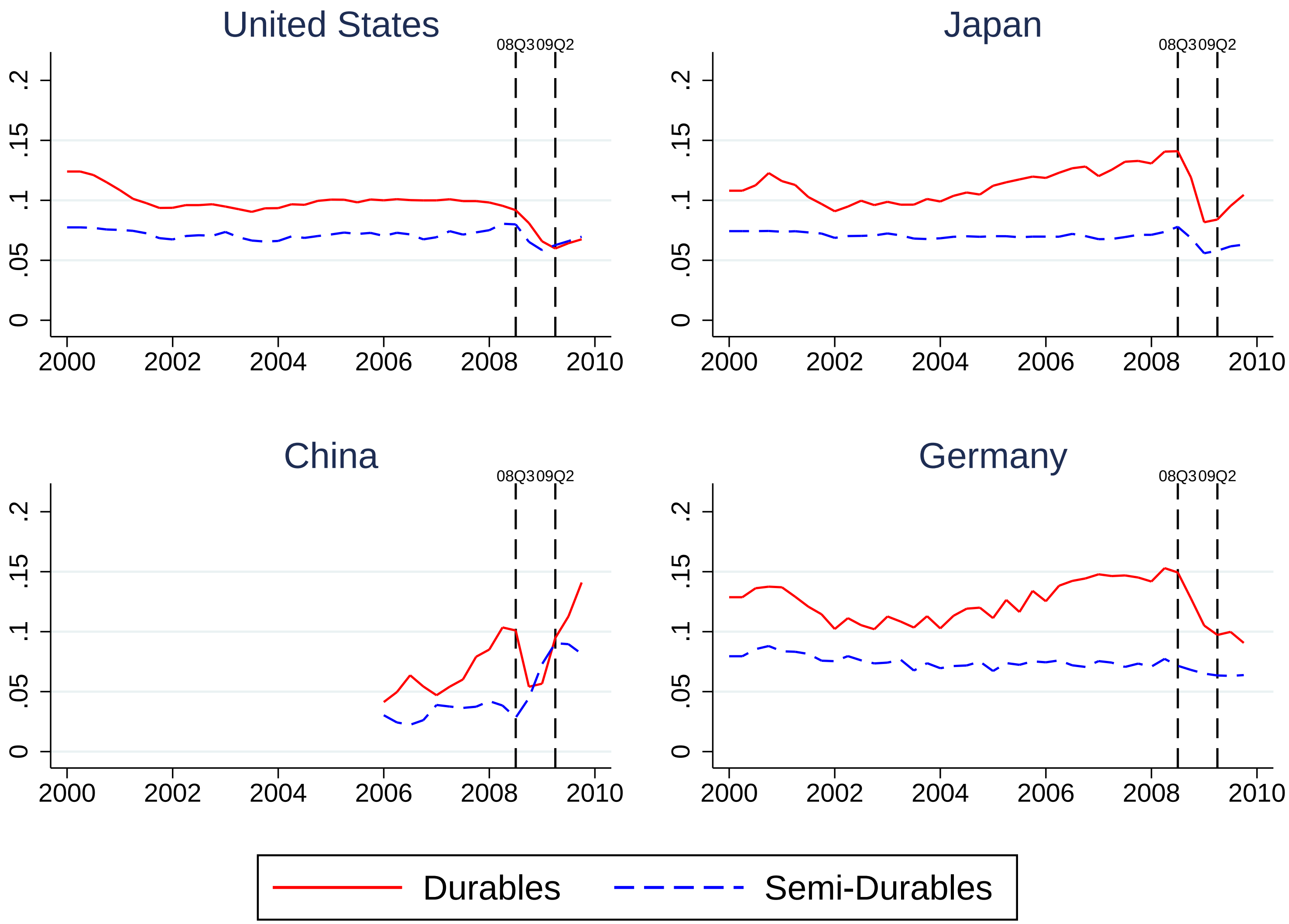
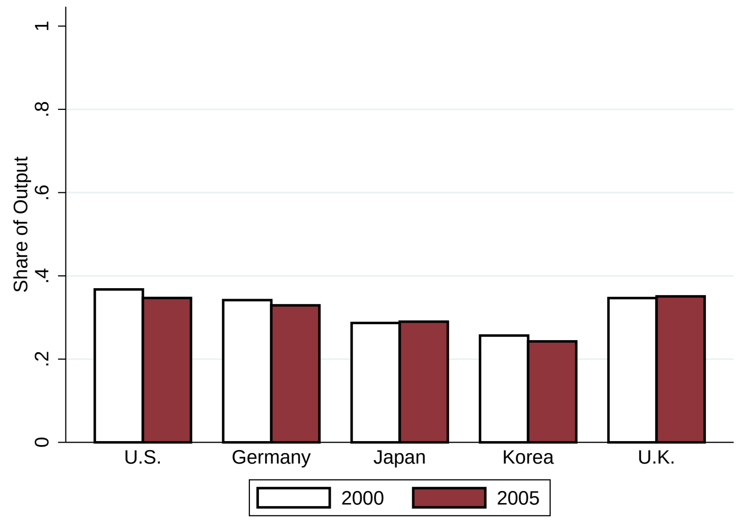
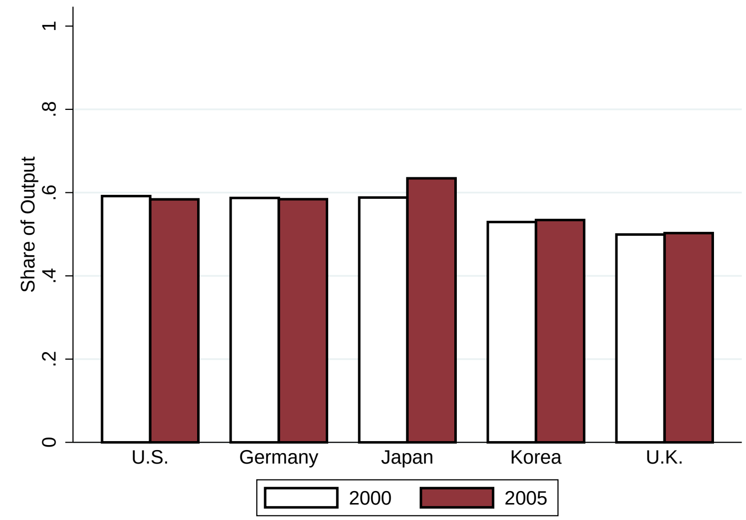


Figure A.1: Investment Spending Shares in the Four Largest Economies

Notes: Shares are investment spending in each sector divided by the sum of total investment spending and consumption spending. See Appendix Section A for details.

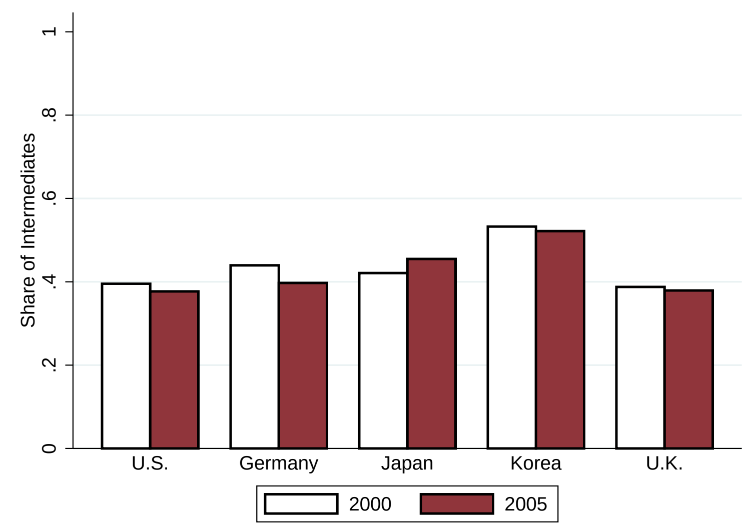


(a) Value Added in Durable Manufacturing



(b) Value Added in Nonmanufacturing

(c) Durable Manufacturing's Share in Nonmanufacturing



(d) Semi-Durable Manufacturing's Share in Semi-Durables

Figure A.2: Sample Input-Output Coefficients $\left(\beta_i^D, \beta_i^S, \gamma_i^{SD}, \gamma_i^{SS}\right)$

Notes: Input-Output coefficients calculated from OECD input-output database, version 2009. See Appendix Table A.2 for sectoral definitions. γ coefficients calculated as spending by one sector on another's output divided by total input purchases at basic prices (i.e. net of taxes on products).

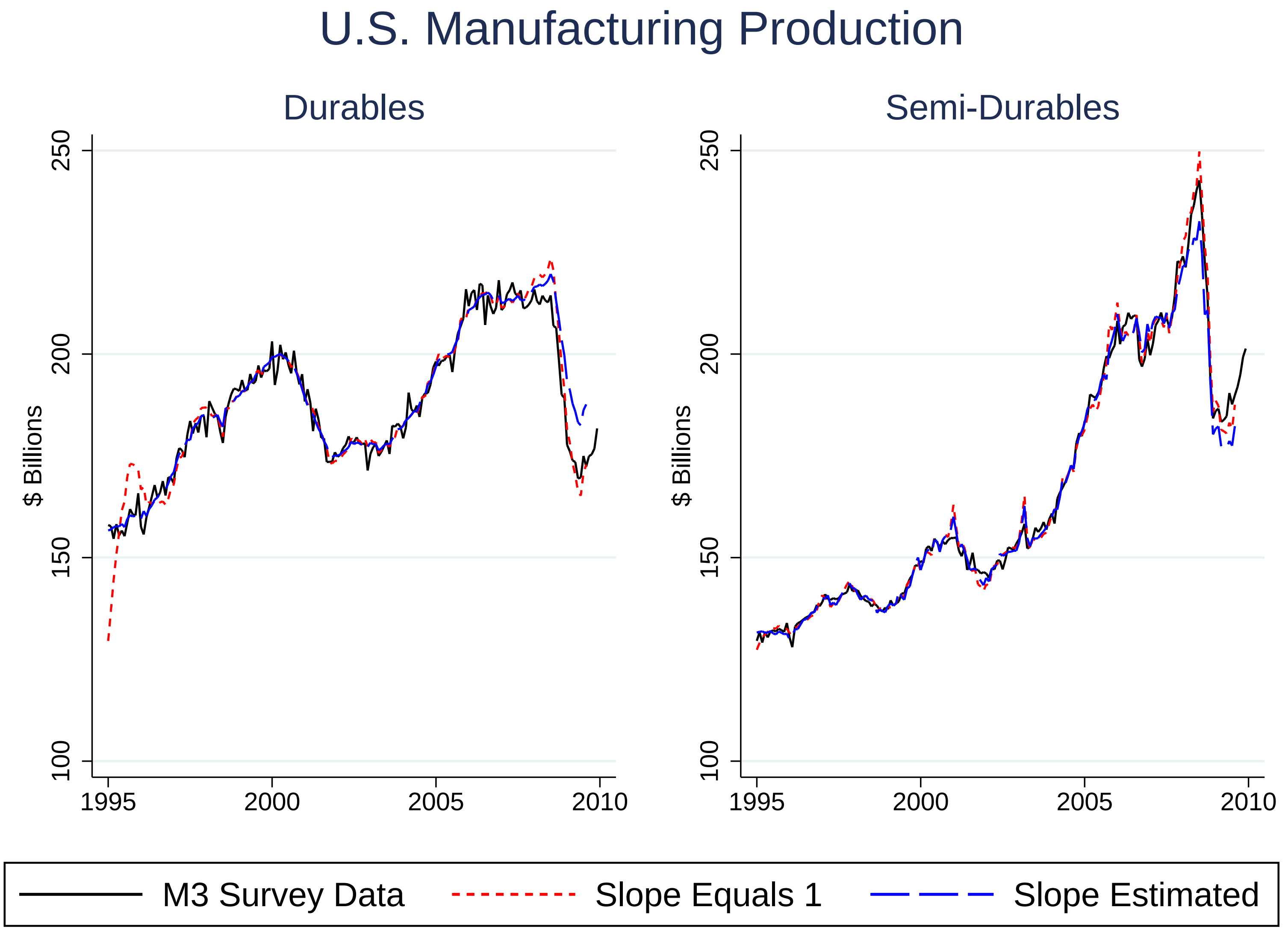


Figure A.3: Checking Accuracy of Temporal Disaggregation Procedure for United States

Notes: Checking procedure with durable (AMDMVS) and non-durable (AMNMVS, which is "semi-durable" using our terminology) 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.

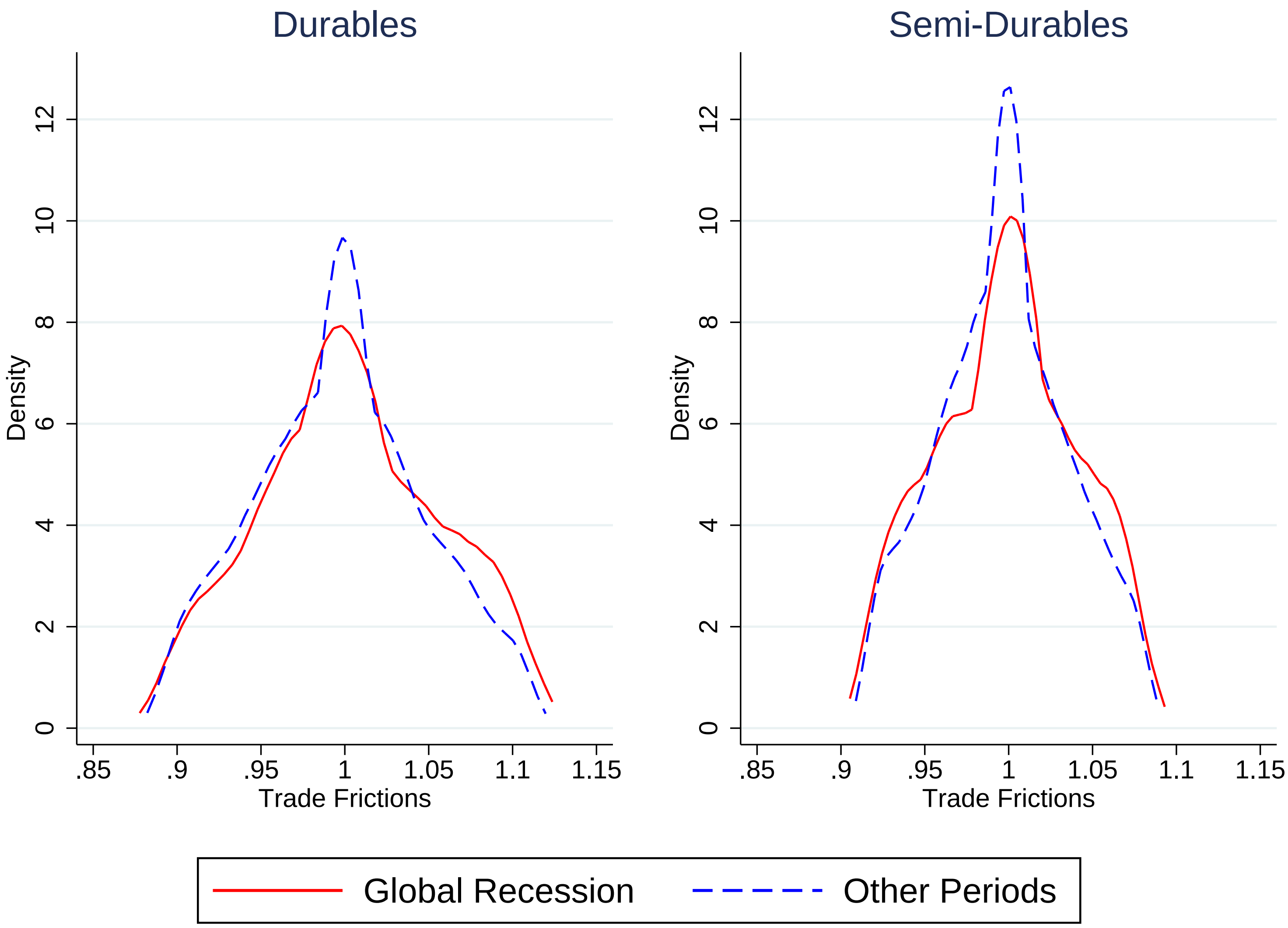


Figure A.4: Density of Bilateral Trade Shocks

Notes: Estimated kernel density of quarterly growth in bilateral trade frictions, separated by good type and by whether during crisis period or otherwise. We omit the top and bottom 5 percent of observations. Note that these values are functions of the assumed technology parameters θ^D and θ^S.

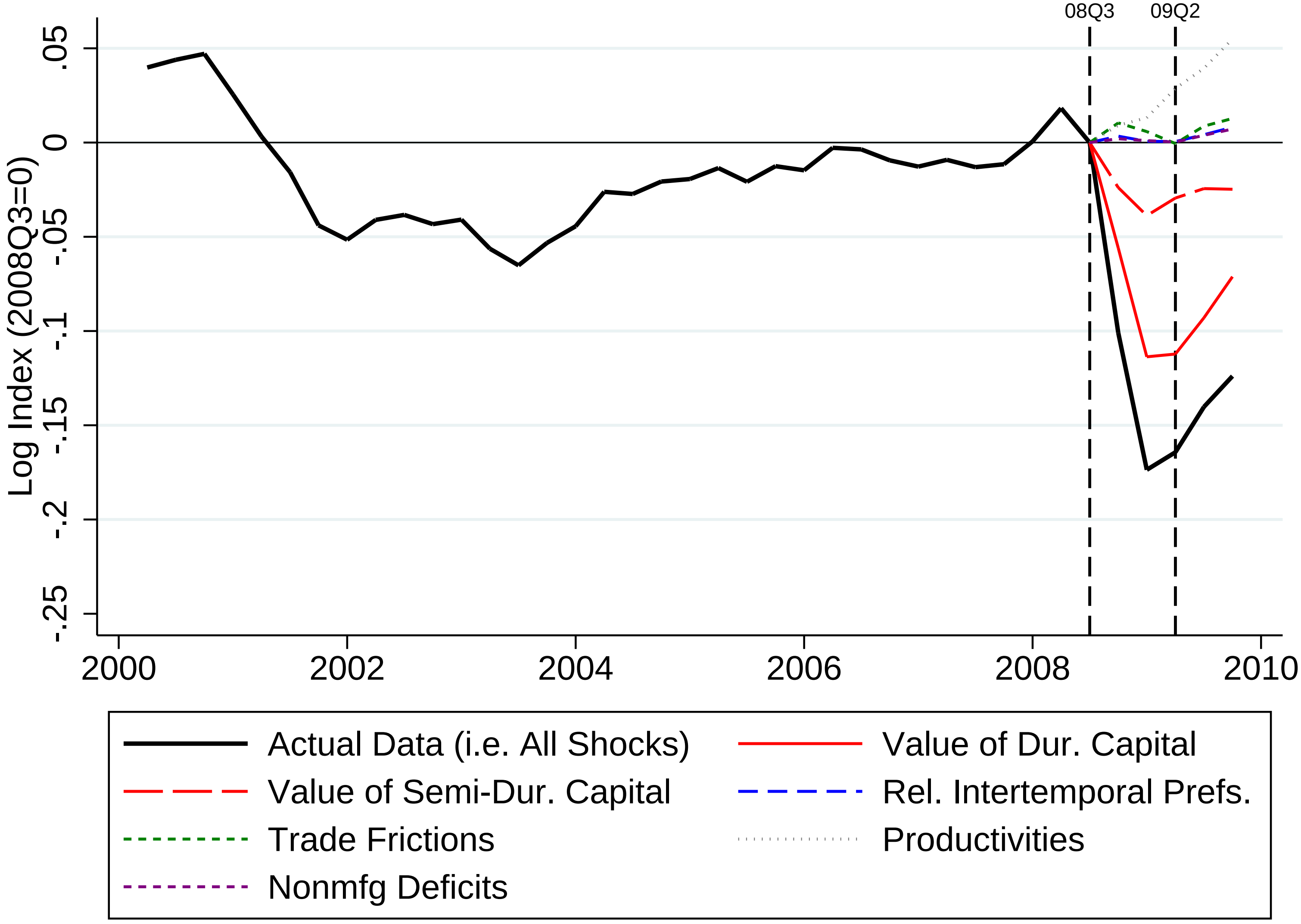


Figure A.5: Actual and Counterfactual Evolution of Global Production

Notes: Lines beginning in 2008:Q3 represent counterfactual outcomes with the indicated shocks at their calibrated values and all other shocks unchanged (i.e., 1, except for the nonmanufacturing deficits, which are held at their 2008:Q3 values).

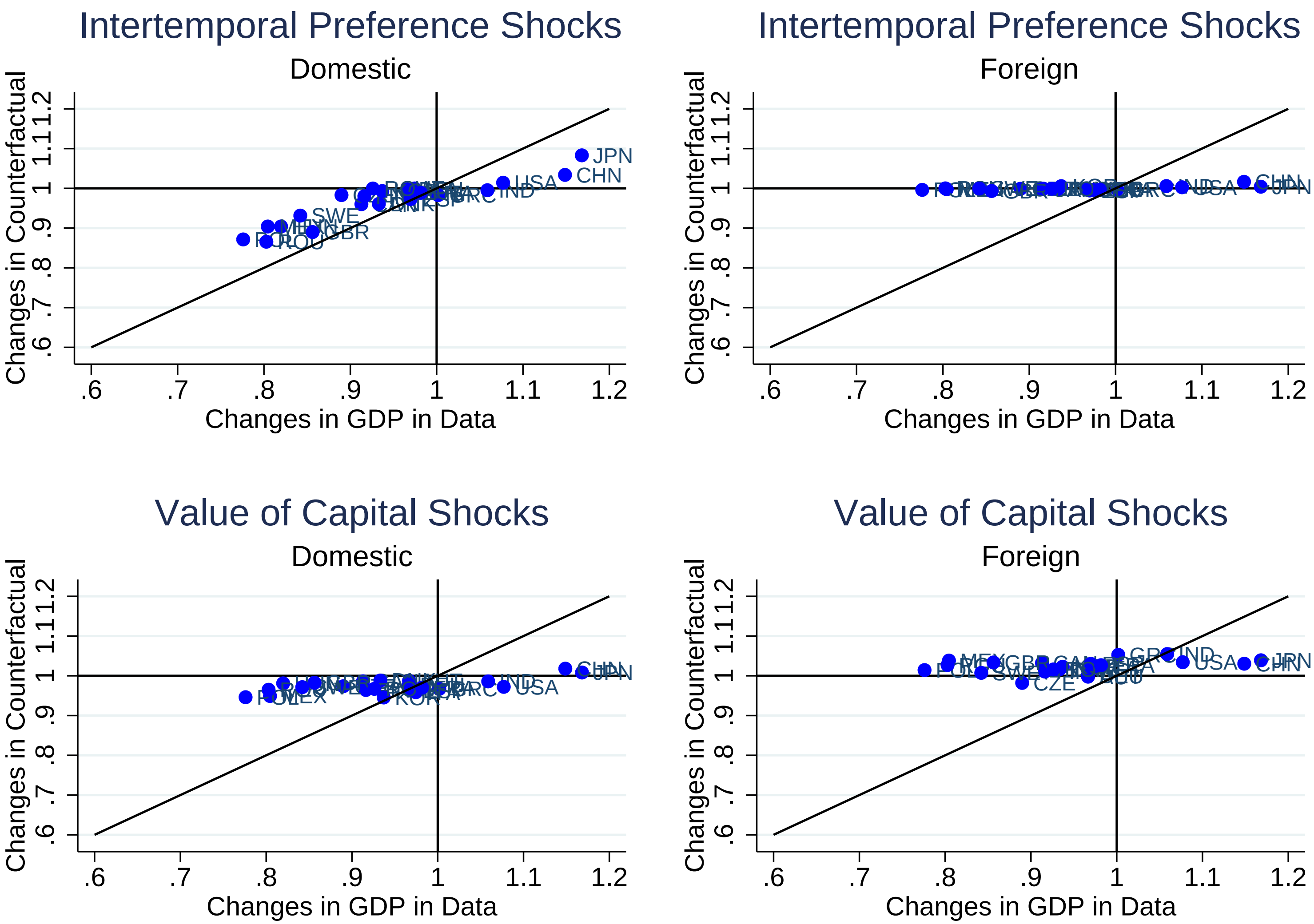


Figure A.6: Cross-Sectional Explanatory Power for GDP by Origin of Shock during the Global Recession

Notes: The figure plots, against the actual quarterly changes in a country's GDP, the changes that would have occurred with only intertemporal demand shocks (top two panels) or investment demand shocks (bottom two panels), of domestic origin (left-hand panels) or of foreign origin (right-hand panels).

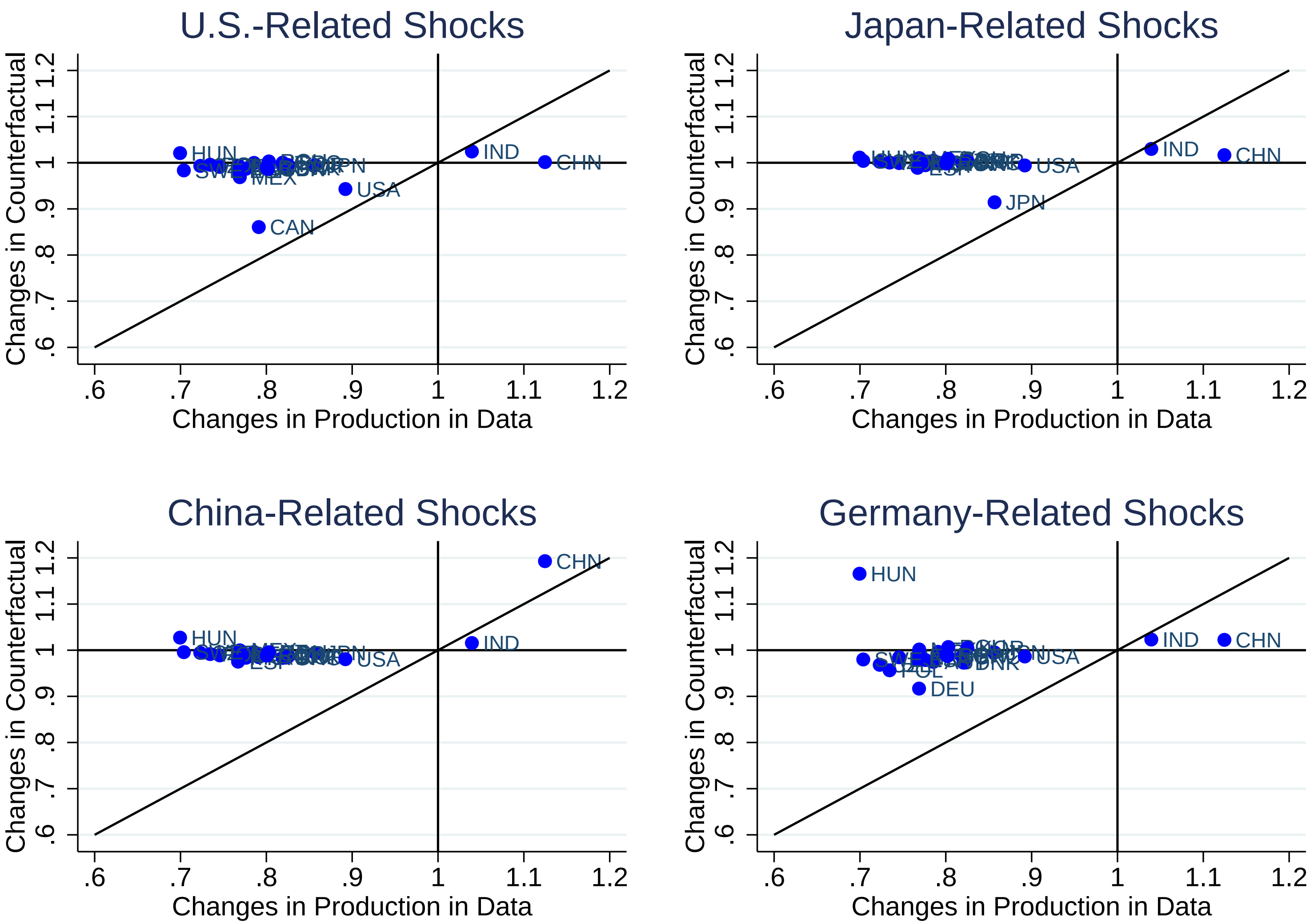


Figure A.7: Cross-Sectional Explanatory Power for Production by Country of Shock during the Global Recession

Notes: The figure plots, against the actual quarterly changes in a country's production, the changes that would have occurred with only shocks from the indicated country.