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, 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, with shocks to trade barriers explaining almost nothing. For about half of the 22 countries in our analysis the shocks were primarily from abroad rather than domestic. In contrast, changes in relative GDP's were largely the consequence of domestic shocks to intertemporal preferences.

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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) 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 period 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, GDP, 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

[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.

the shocks to 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 factor accumulation 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.

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 (2013) (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.

Our paper builds on two other papers in open economy macroeconomics. We follow Stockman and Tesar (1995) by including shocks to intertemporal preferences as well as to technology to capture some key features of the data. Like Boileau (1999), we explain the greater volatility of trade by recognizing that a large share of what is traded consists of durable intermediates rather than final goods.

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 can extract the model's underlying shocks from data on production, trade, and prices. 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

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

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 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 by 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. The 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 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.

[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).

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.

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

[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.

random variable $a^j_{i,t}$ with distribution

$$F^j_{i,t}(a|s^t) = \Pr\left[a^j_{i,t} \leq a\right] = e^{-T^j_{i,t}(s^t)a^{-\theta^j}}, \tag{1}$$

drawn independently for each z^j across countries i. Here, $T^j_{i,t}(s^t) > 0$ is a parameter that reflects 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] Nonmanufacturing are undifferentiated and not traded. Country i's efficiency producing nonmanufactures 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 nonmanufacturing bundle in amount $C^N_{i,t}(s^t)$ 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:

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

[14]Because there are a continuum of manufacturing goods, $T^j_{i,t}(s^t)$ summarizes all the variation in the realizations of efficiencies across states s^t in country i for $j \in \Omega_M$. 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 $\psi^j \geq 0$ and $\psi^N + \psi^S + \psi^D = 1$. The lifetime utility of the representative agent in country i is:

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

where ρ is a constant discount factor and $\phi_{i,t}\left(s^t\right)$ is the intertemporal preference 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 $p^j_{i,t}\left(s^t\right)$, $j \in \Omega_M$, and (v) the price of the nonmanufactured good $p^N_{i,t}\left(s^t\right)$. 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 a claim on one unit of the numéraire 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 $q\left(s^{t+1}|s^t\right)$ in state s^t of a claim 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:

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

4. Consumers make a set of consumption choices $\{C_{i,t}^{N}(s^t), K_{i,t}^{S}(s^{t-1}), K_{i,t}^{D}(s^{t-1})\}$ in each country i in each state s^t to maximize (3) subject to the lifetime intertemporal budget constraint:

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

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:

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

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 $c_{i,t}^{j}(s^t)$, is given by:

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

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:

$$p_{n,t}^j(z^j, s^t) = \min_i \left\{ \frac{c_{i,t}^j(s^t) d_{ni,t}^j(s^t)}{a_{i,t}^j(z^j, s^t)} \right\}.$$

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:

$$\pi_{ni,t}^j(s^t) = T_{i,t}^j(s^t) \left[\frac{c_{i,t}^j\left(s^t\right) d_{ni,t}^j(s^t)}{p_{n,t}^j(s^t)/\varphi^j} \right]^{-\theta^j}, \tag{8}$$

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, the price index for manufactures $j \in \Omega_M$ in country n is:[15]

$$p_{n,t}^j(s^t) = \varphi^j \left[\sum_{i=1}^{I} T_{i,t}^j(s^t) \left(c_{i,t}^j(s^t) d_{ni,t}^j(s^t) \right)^{-\theta^j} \right]^{-1/\theta^j}, \tag{9}$$

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 $p_{i,t}^N\left(s^t\right) = c_{i,t}^N\left(s^t\right)/A_{i,t}^N\left(s^t\right)$.

4.1.2 Intertemporal Choices

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

$$p_{i,t}^j(s^t) \iota_{i,t}^j(s^t) K_{i,t}^j(s^{t-1}) = \left(p_{i,t}^j(s^t)\right)^{\frac{-\alpha^j}{1-\alpha^j}} \left(\alpha^j \chi^j Q_{i,t}^j(s^t)\right)^{\frac{1}{1-\alpha^j}} K_{i,t}^j(s^{t-1}), \tag{10}$$

where

$$Q_{i,t}^j\left(s^t\right) = \sum_{s'} q\left(s'|s^t\right) v_{i,t+1}^j(s') \tag{11}$$

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

[15] 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 in country i of sector j gross production 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 from sector j and use by each sector l of intermediates from each sector j:

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

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, $Y_{i,t}^{F}(s^t) = w_{i,t}\left(s^t\right)L_i$.[16] Clearing the market for each manufacturing sector $j\in\Omega_M$ requires that the value of production in each country i equal global demand:

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

[16] 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, $D^N_{i,t+1}$, 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 $\hat{\phi}^W_{t+1}$.[17]

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:

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

Expression (26) allows us to relate changes in final spending on manufactures around the world to world spending on nonmanufactures. 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 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

[17] 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.

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 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 $q_{t+1}(s^{t+1})$.[18] 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

[18]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.[19]

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 the five sets of outcomes to these 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:

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

[19] 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 for agents to have acted as they did. 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) delivers an expression for the change in wages:

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

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.[20]

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 implied by our model.

[20]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 $D^N_{i,t+1}$ 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.[21]

We calculate the input-output coefficients β_i^j and γ_i^{jl} from the 2009 edition of the OECD's country tables.[22] To determine β_i^j, we divide total value added in sector j of country i by that sector's total output. To determine γ_i^{jl}, we divide total spending in country i in sector j on inputs from sector l by sector j'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).[23] 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

[21] 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).

[22] 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.

[23] 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.[24] (The higher variation in changes in trade barriers, and hence the greater frequency of increases as well as large declines, partly reflects the shorter period of the recession.) There was a slight decline in global 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.[25] The decline is particularly sharp for durables.[26] 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.[27]

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.

[24]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 $\hat{A}_{i}^{D}$.

[25]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.

[26]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.

[27]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.[28] 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 manufacturing 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

[28] 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, 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.[29]

[29]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 covary with the declines in trade.

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 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

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, as discussed in Footnote 24. 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 for only 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.

collapse in global trade and manufacturing production, it was the major factor for individual 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. Shocks to trade frictions, productivities, and nonmanufacturing deficits do very little.

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.[30]

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 7. The exceptions are France 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

[30] 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 only for a subset of countries over which nonmanufacturing deficits will typically not 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.

the 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 in manufactures. 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.[31] 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.[32]

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

[31]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.

[32]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.

rather than data. We can ask about the cumulative contribution, say, of declining trade barriers 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.[33]

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 a decline in the value of capital caused the stunning collapse in trade and in manufacturing production that accompanied the global recession. Our results thus support 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 trade collapse. 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 propagating the collapse in manufacturing around the world.

We think that our analysis opens up exciting possibilities in the modeling of macroeconomic fluctuations and international trade to understand better where shocks originate and how they spread from country to country. It suggests some promising avenues for future research, both in terms of expanding the scope of this analysis and in terms of furthering the methodology.

The analysis can readily be extended to include trade in nonmanufactures, such as services, agriculture, and, particularly critical for macroeconomic fluctuations, oil. Also straightforward is adapting it to incorporate additional factors of production and unemployment.[34] It can also be extended to incorporate nonmanufacturing durables such as real estate. In assuming global asset market completeness, the current framework eliminates any role for financial market frictions in creating or in propagating macroeconomic fluctuations. In treating competition as perfect it

[33] 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.

[34] 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.

rules out such phenomena as pricing to market. Incorporating asset market incompleteness or imperfect competition would allow the framework to address a much wider range of issues.

We have used the framework to disentangle the forces acting on trade and manufacturing production around the world over the past decade. In providing this anatomy, the methodology does not provide a window into the future. To use the framework to look forward requires a better understanding the time-series properties of the model's underlying shocks, which are hard to discern from our narrow window over this turbulent period. We await more data. 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 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	0.79	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.

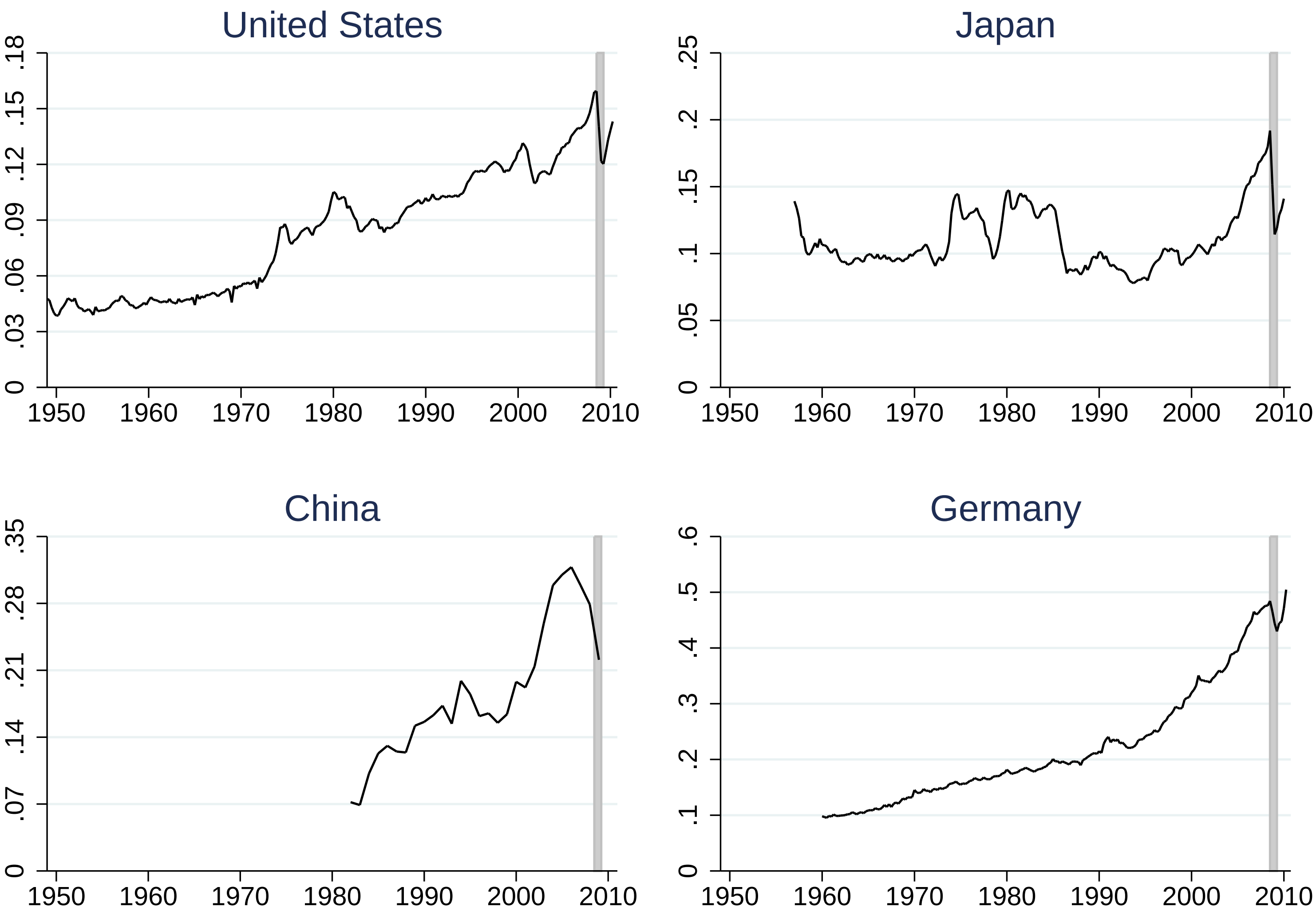

Figure 1: Trade-GDP Ratio in the Four Largest Economies

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.

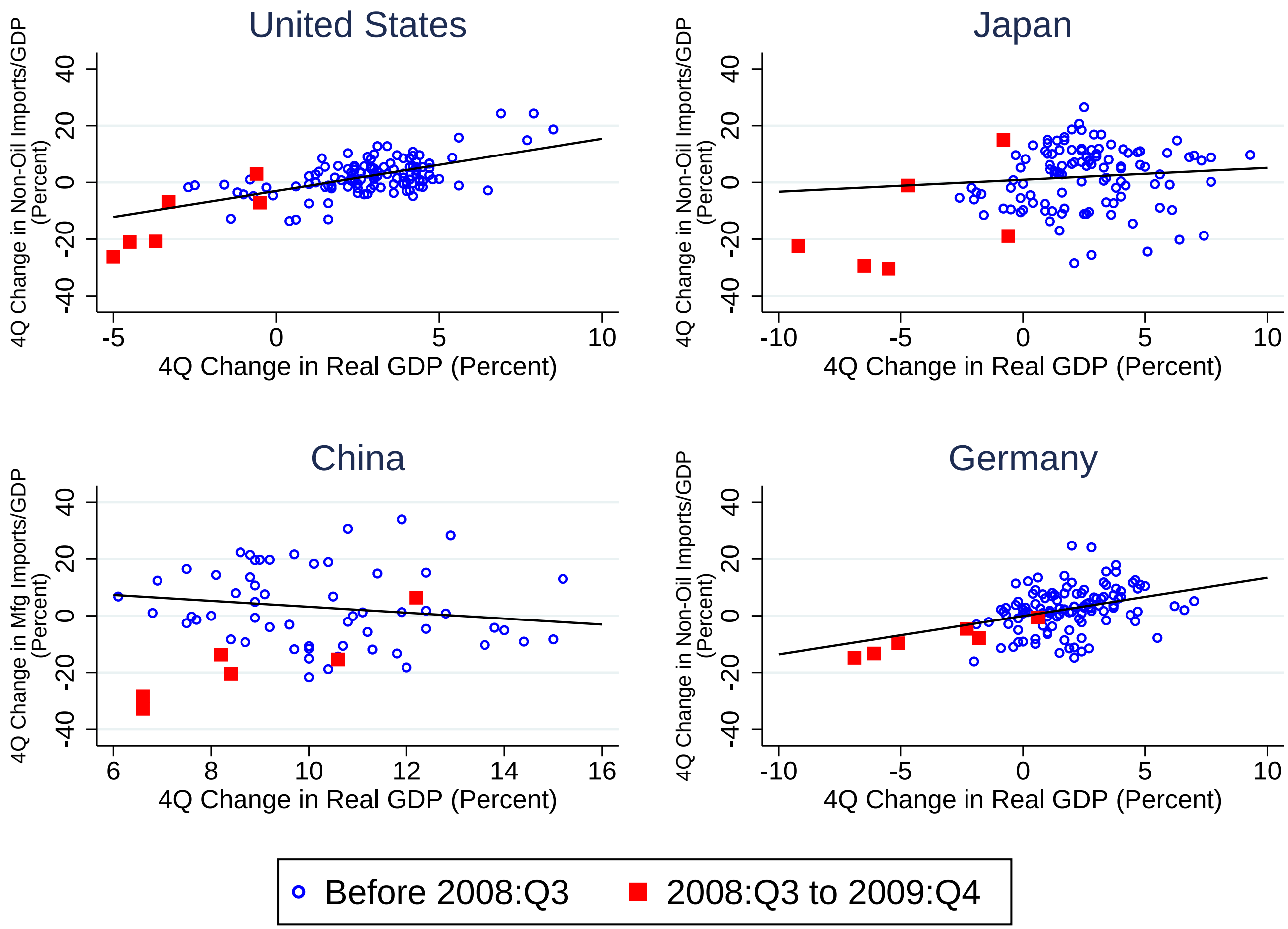

Figure 2: Cyclical Properties of Trade in the Four Largest Economies

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.

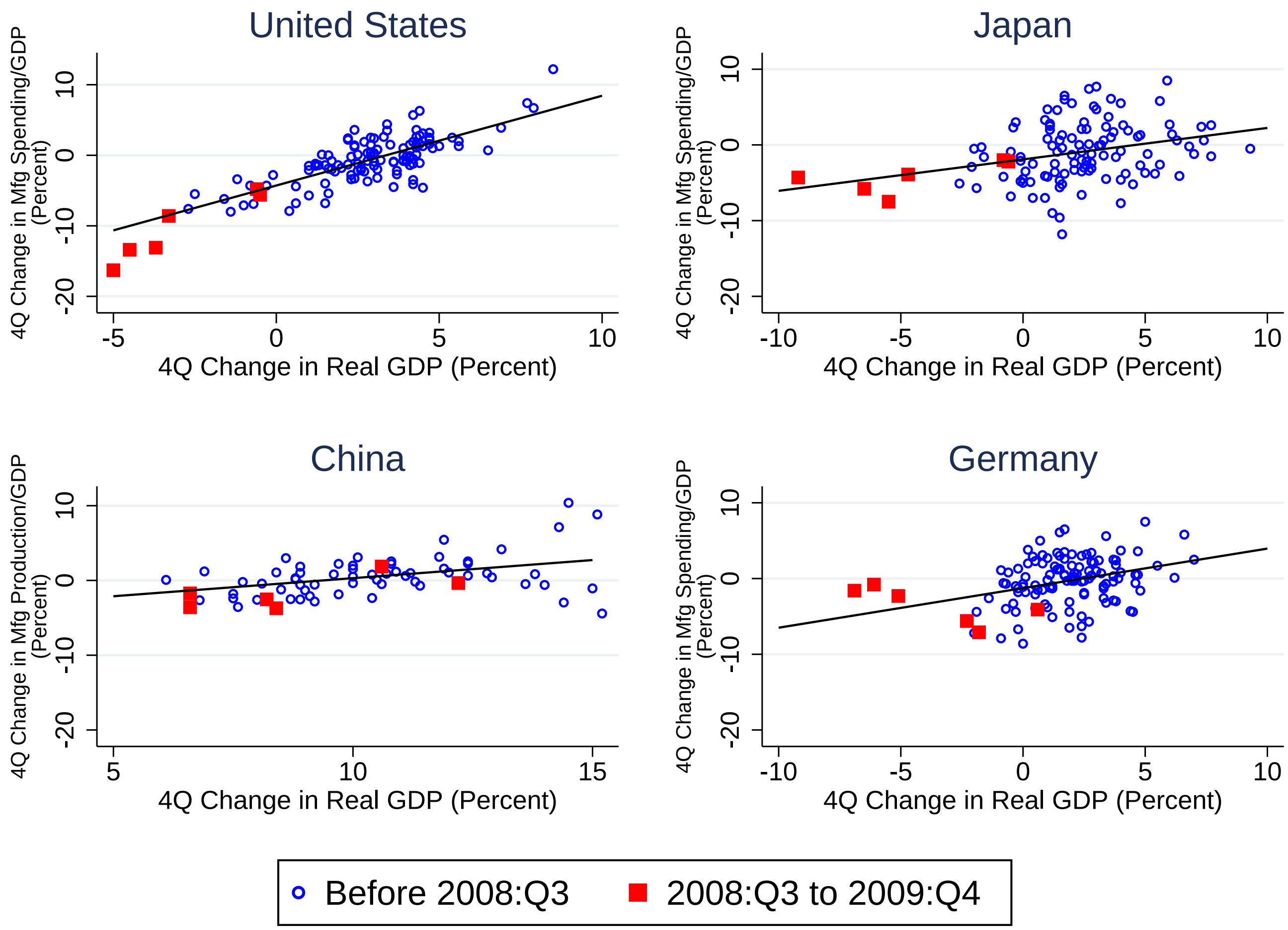

Figure 3: Cyclical Properties of Manufacturing in the Four Largest Economies

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.

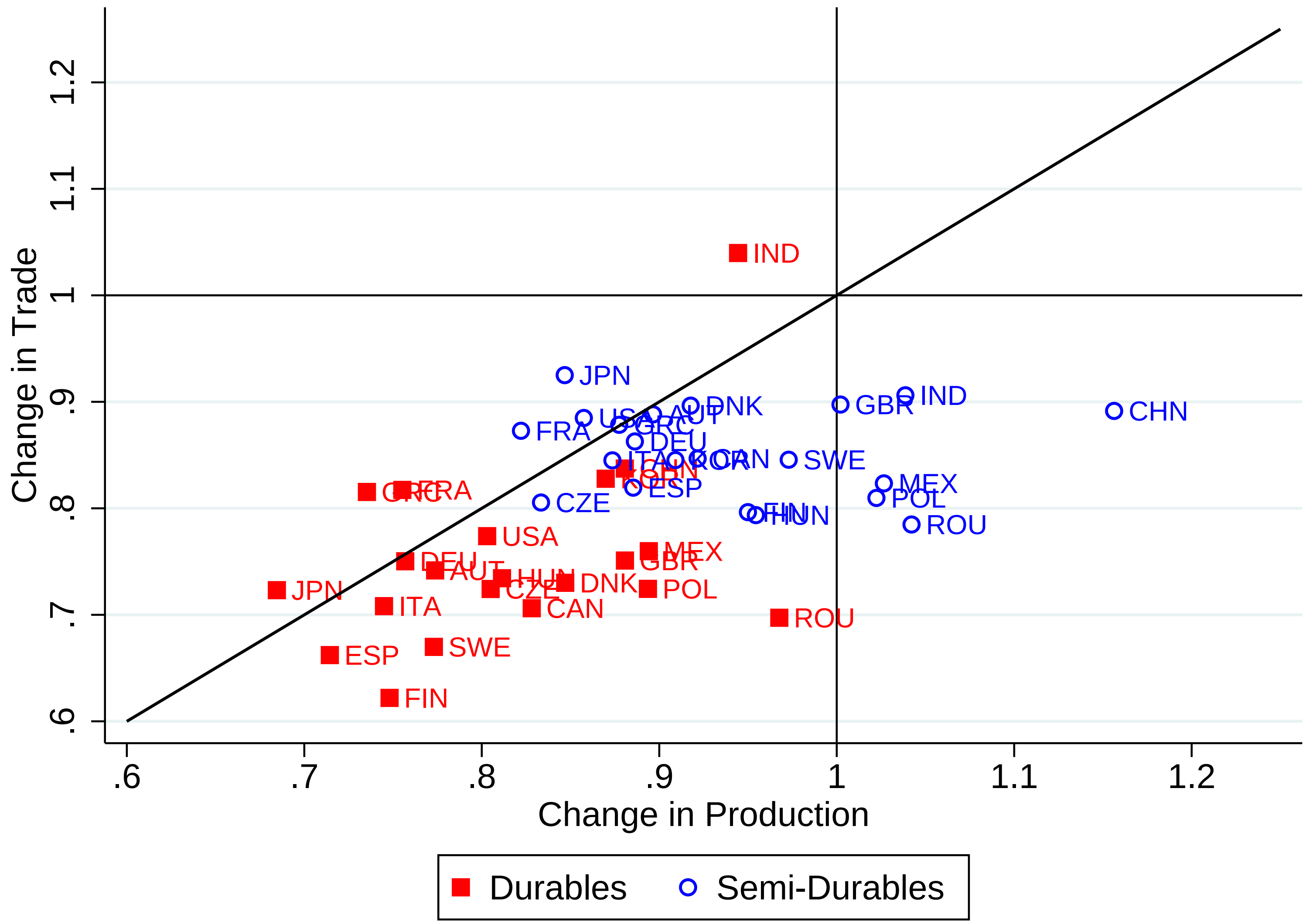

Figure 4: Changes in Manufacturing Trade and Production by Sector

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

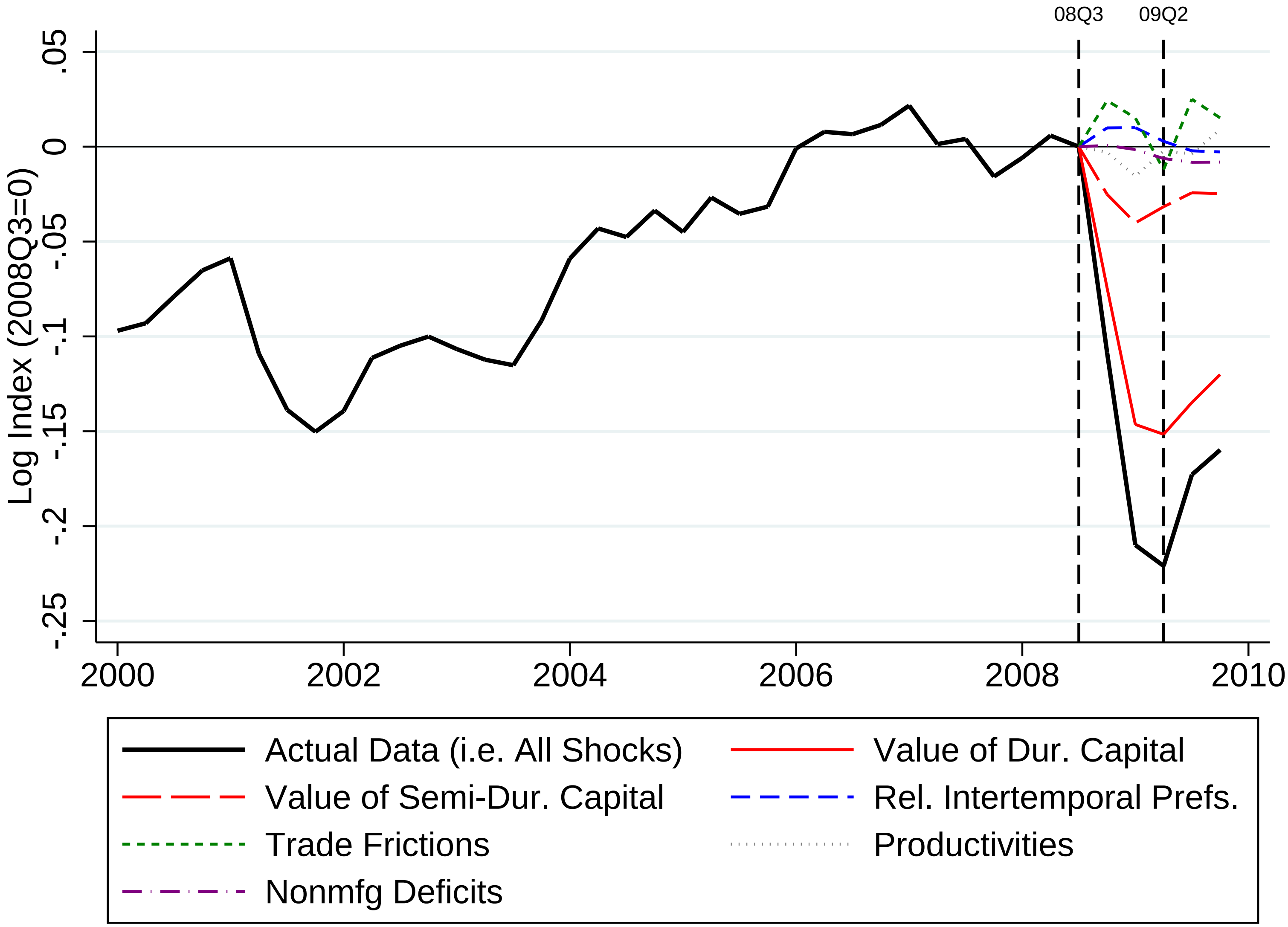

Figure 5: Actual and Counterfactual Evolution of Global Trade

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).

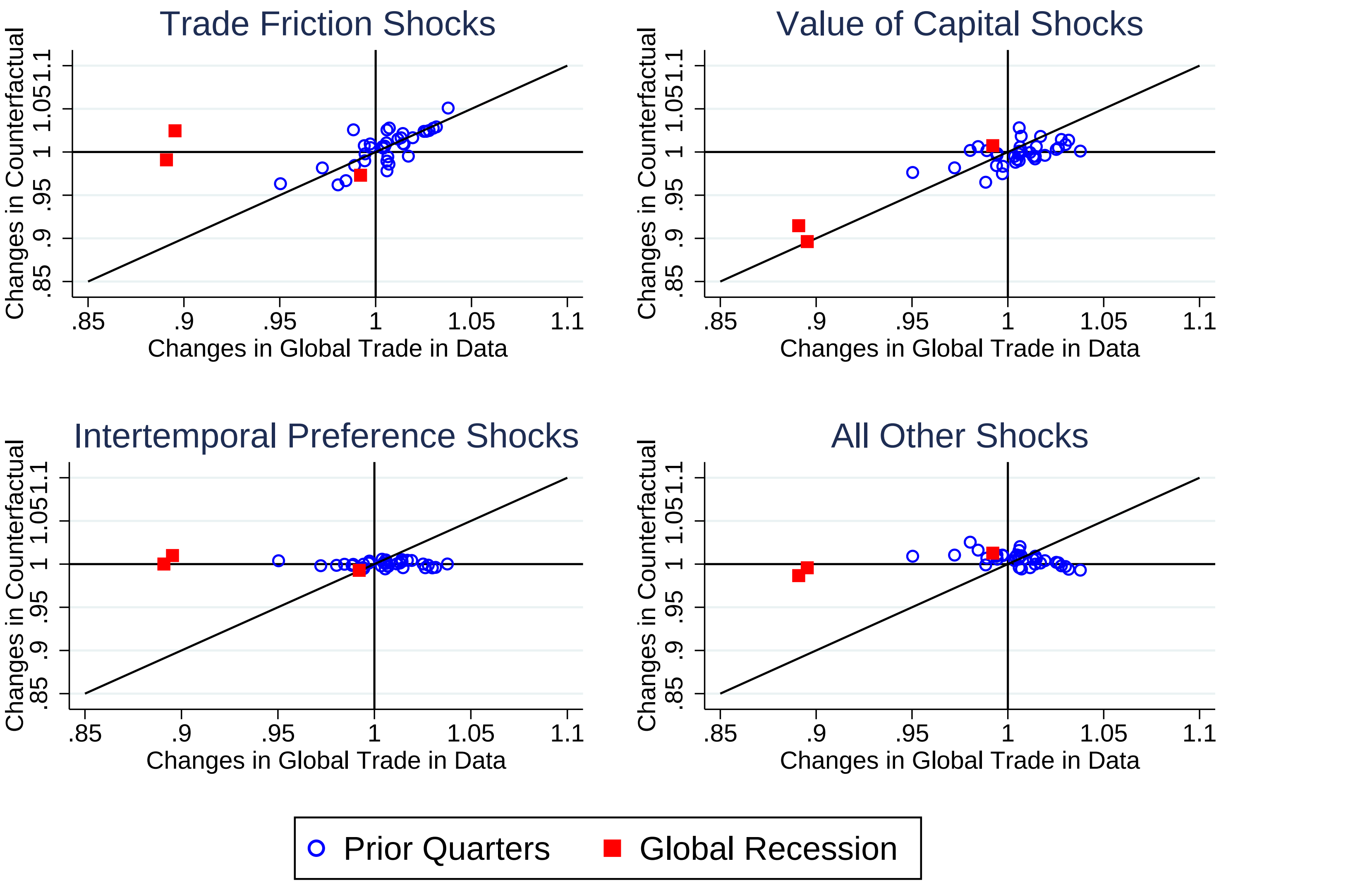

Figure 6: Time-Series Explanatory Power of Various Shocks for Global Trade

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.

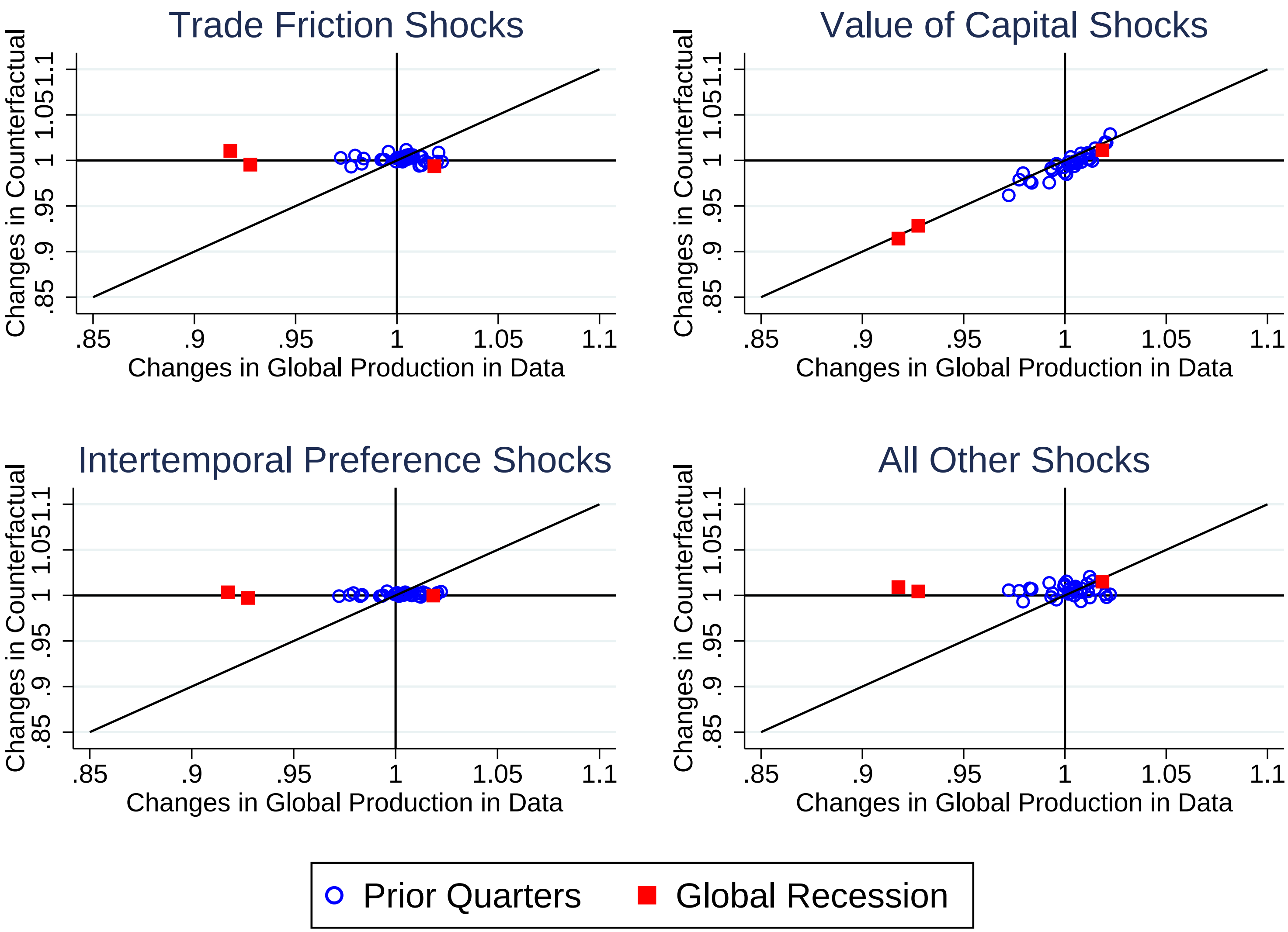

Figure 7: Time-Series Explanatory Power of Various Shocks for Global Production

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.

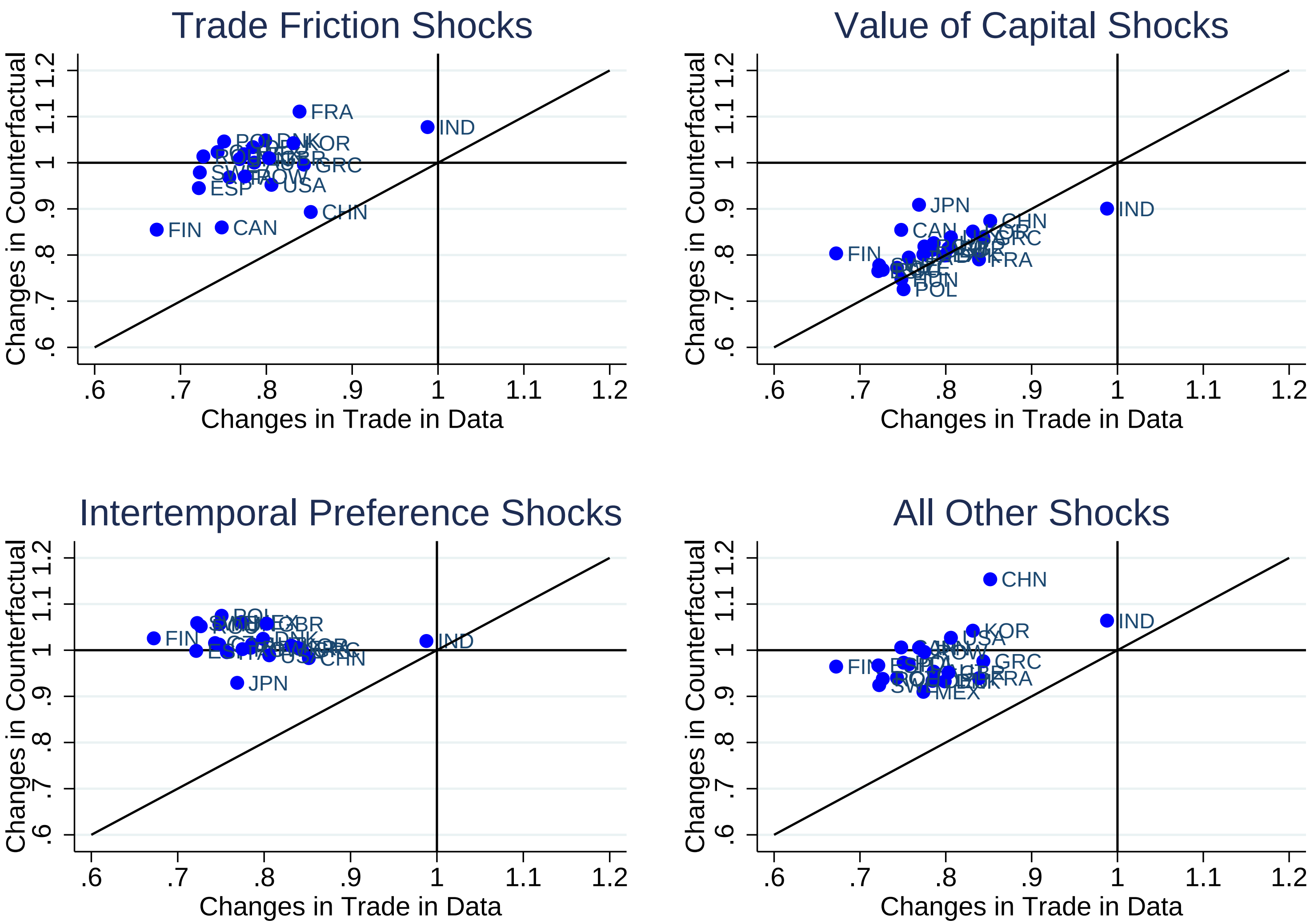

Figure 8: Cross-Sectional Explanatory Power of Various Shocks for Trade during the Global Recession

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.

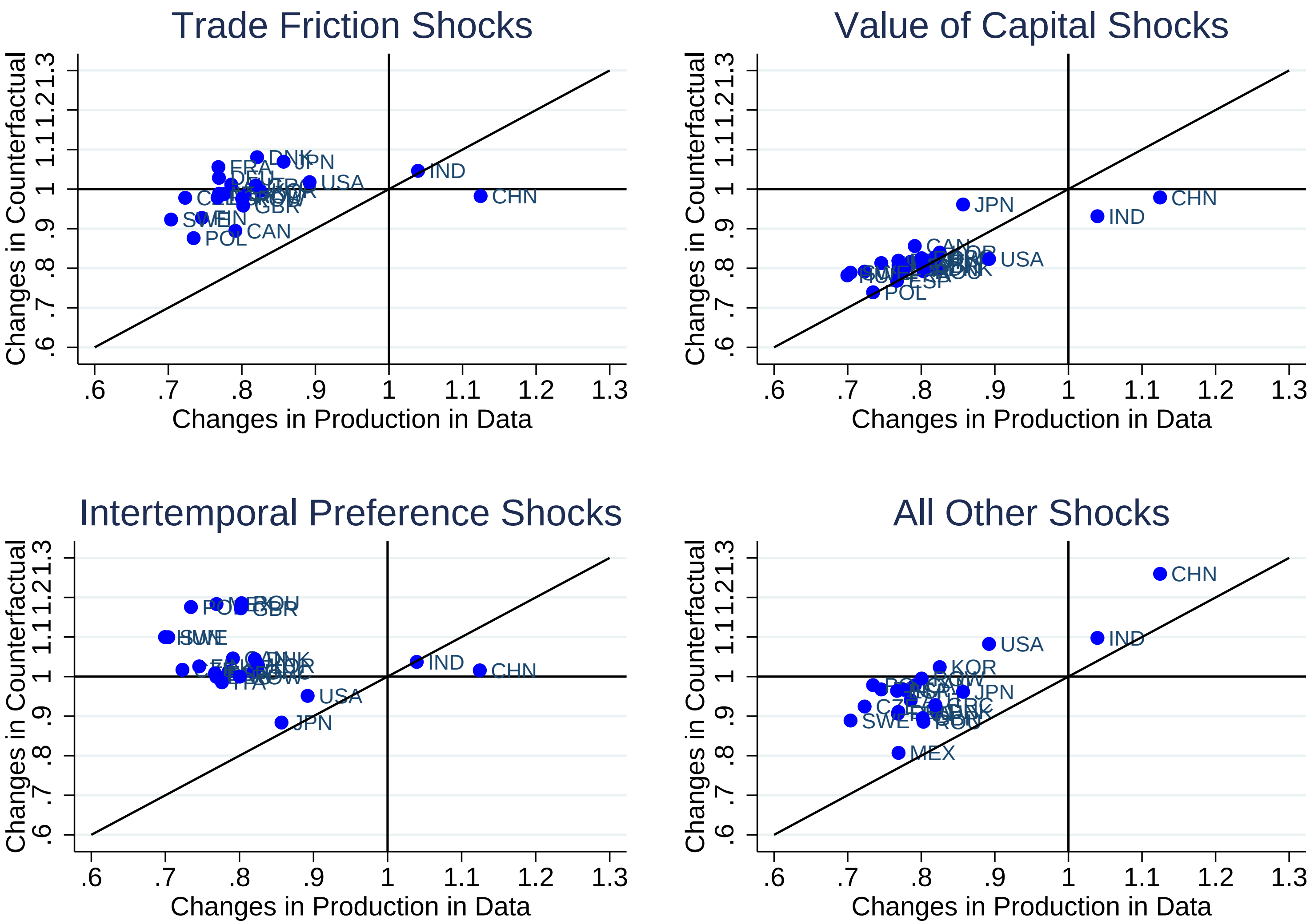

Figure 9: Cross-Sectional Explanatory Power of Various Shocks for Production during the Global Recession

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.

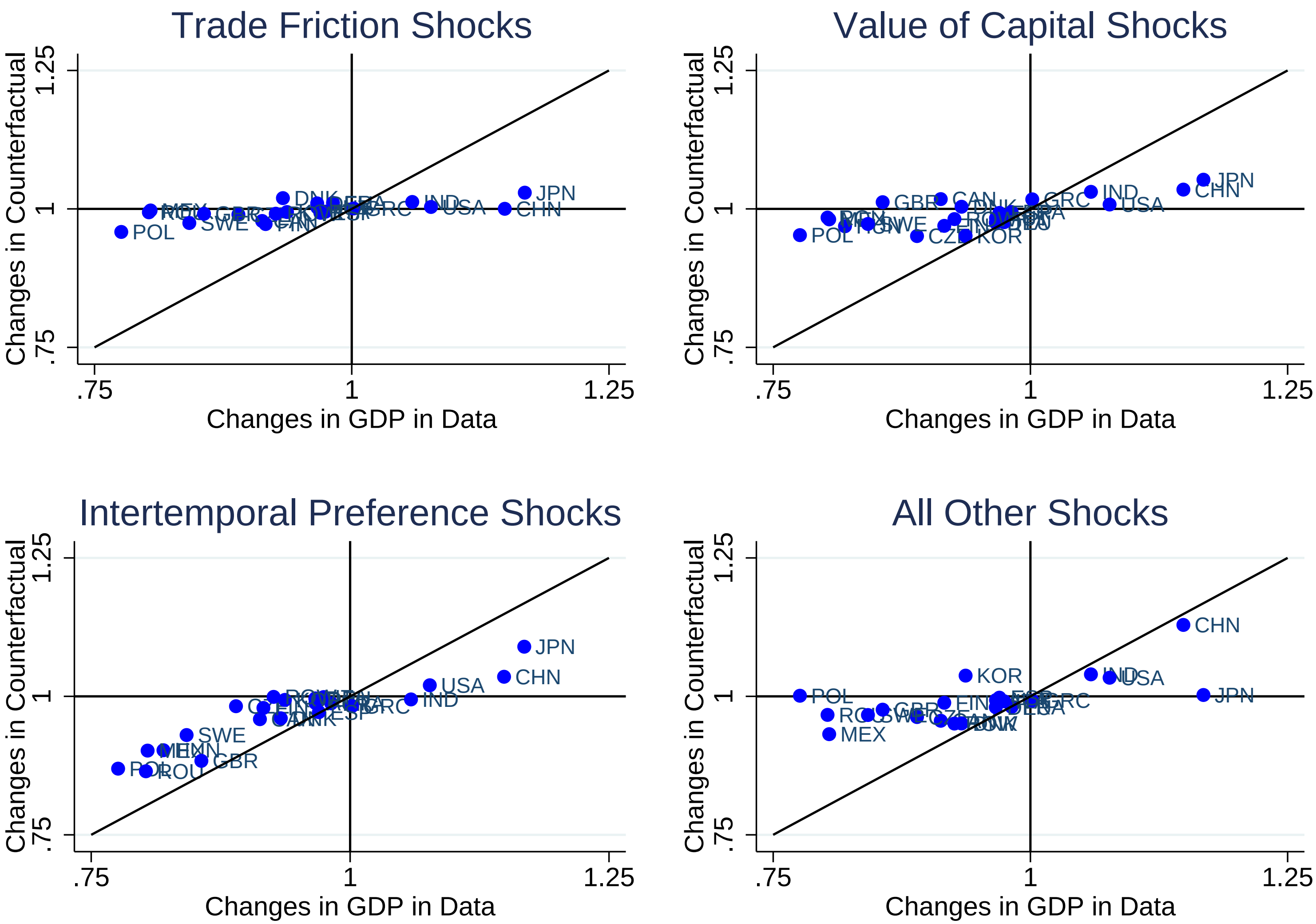

Figure 10: Cross-Sectional Explanatory Power of Various Shocks for GDP during the Global Recession

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.

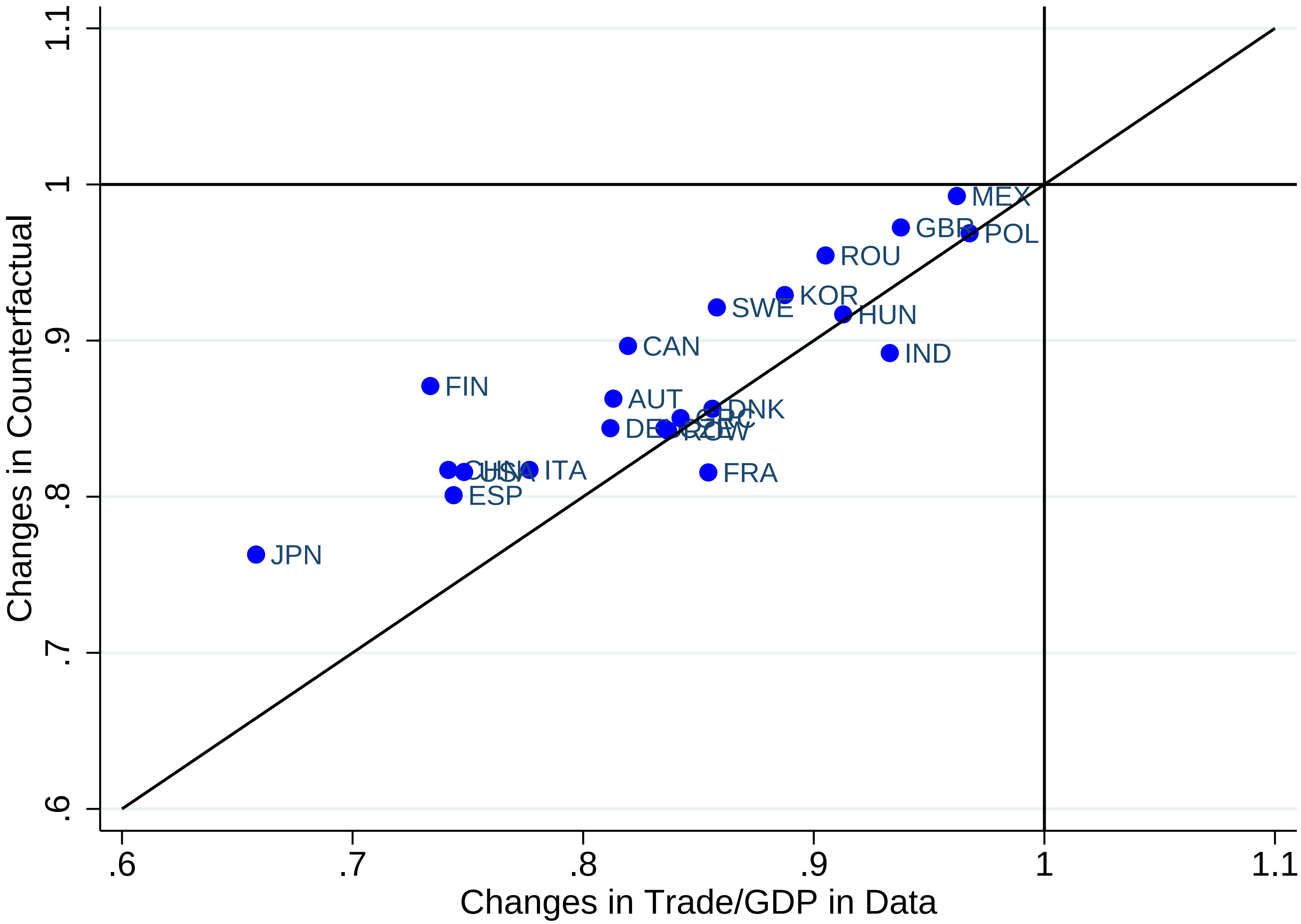

Figure 11: Explanatory Power of Value of Capital and Intertemporal Demand Shocks for Trade/GDP during the Global Recession

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.

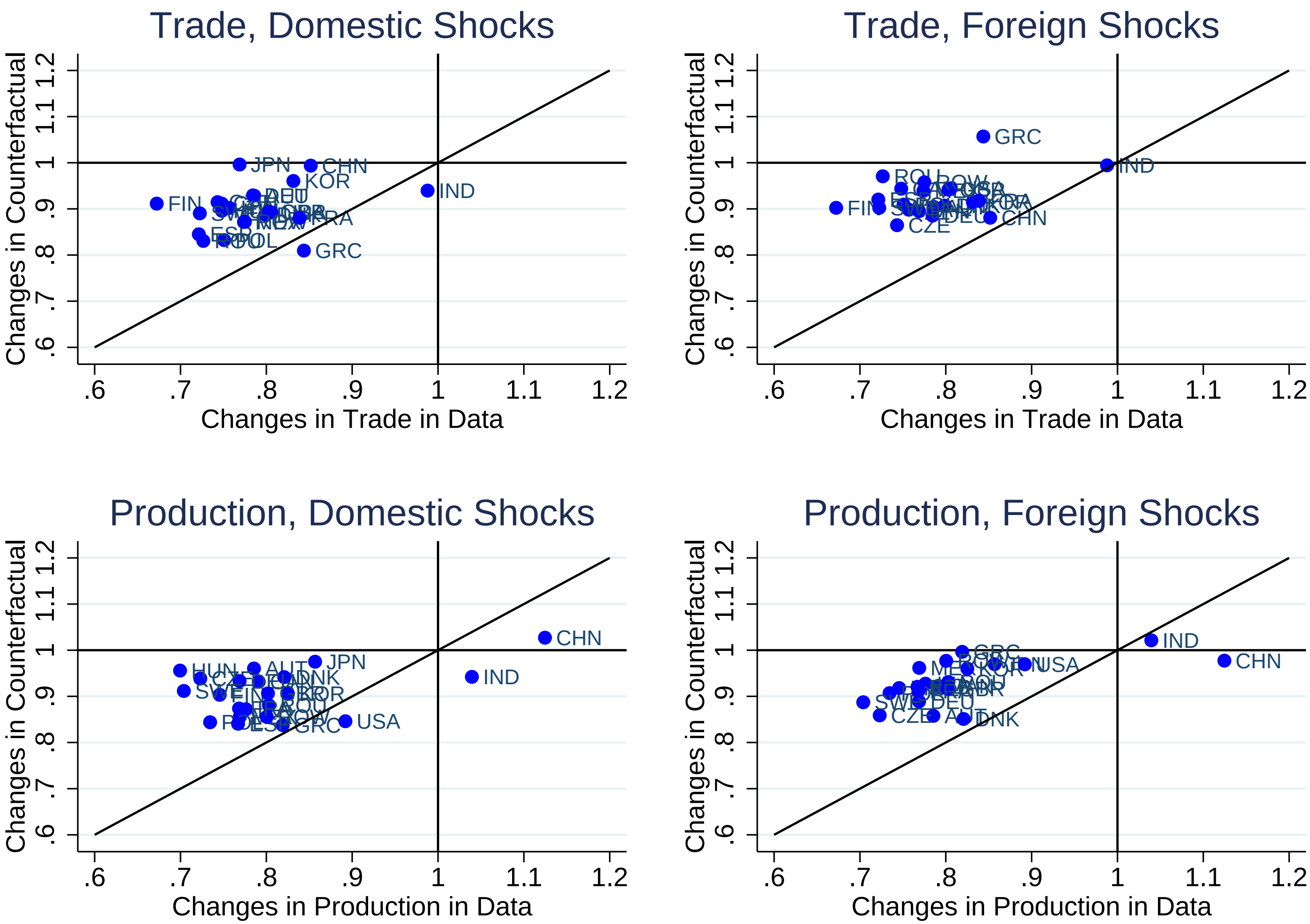

Figure 12: Cross-Sectional Explanatory Power of Foreign and Domestic Value of Capital Shocks during the Global Recession

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.

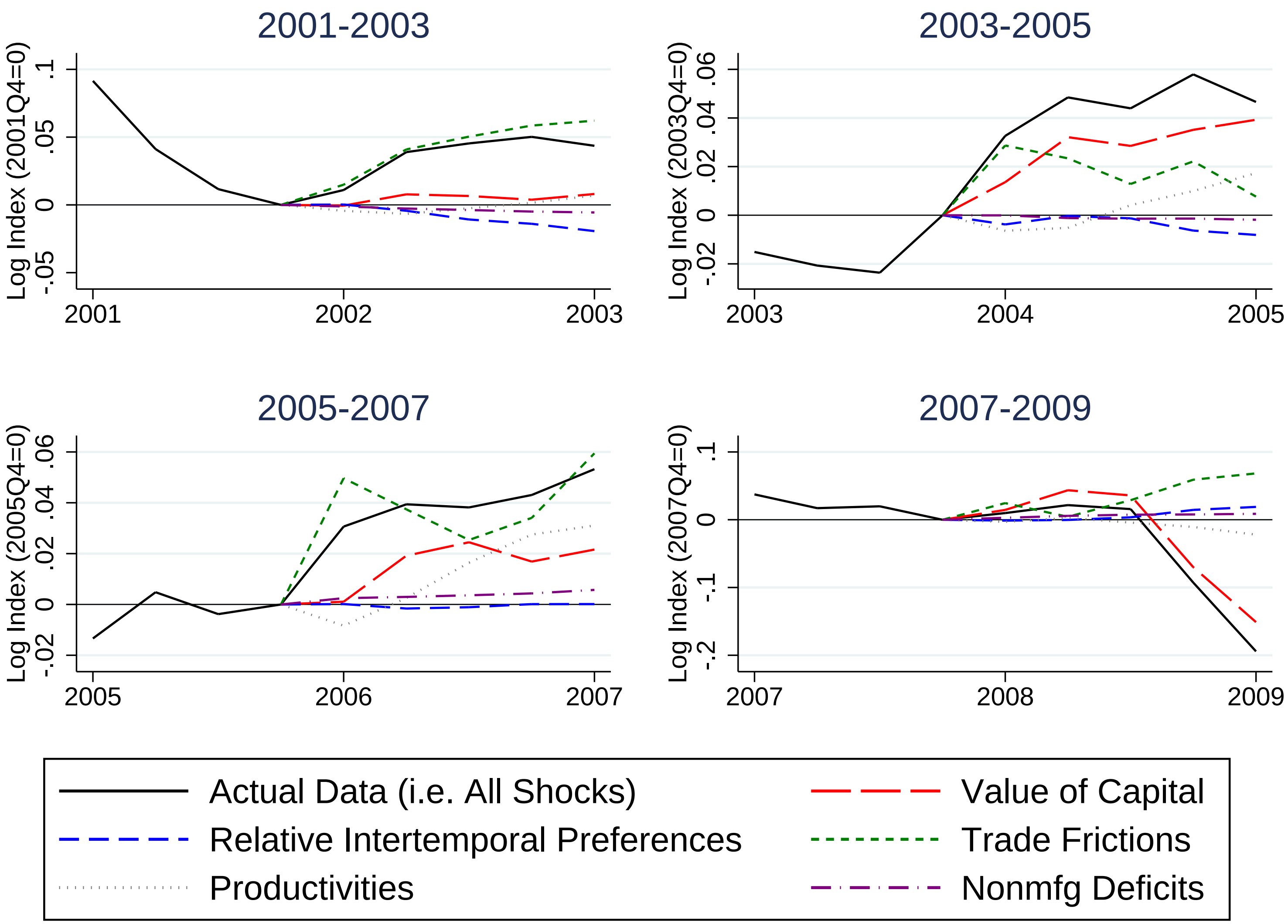

Figure 13: Actual and Counterfactual Evolution of Global Trade, Dynamic Counterfactuals in Various Periods

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