Trade and the Global Recession*

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Abstract

We develop a dynamic multi-country general equilibrium model to investigate forces acting on the global economy during the Great Recession and ensuing recovery. Our multi-sector framework accounts completely for countries' trade, investment, production, and relative GDPs in terms of different sets of shocks. Apply the model to 21 countries, we investigate the 29 percent drop in world trade during 2008-2009. Declines in the efficiency of investment in durables account for most of this trade collapse. Shocks to trade frictions, productivity, and demand play minor roles. In contrast, a combination of shocks contributed to the trade recovery during 2009-2011.

JEL-Codes: E3, F4, F17.

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1 Introduction

International 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?

Answering this question forces us to confront multiple dimensions of complexity surrounding the global crisis. Some sectors and some countries were hit much harder than others. Trade fell, but trade also played a role in transmitting shocks from one country to another.

To capture this geographical, sectoral, and temporal richness, we attack this question by embedding a multi-sectoral general equilibrium model of international trade into a multi-country real business cycle model. The resulting framework incorporates economic geography, an input-output structure, and capital accumulation. Quantifying this framework, we use it to assess the contribution of different types of shocks occurring in different countries to the collapse of trade. Our framework attributes what happened to five types of country-specific shocks: (i) to the cost of trade with each trading partner, (ii) to productivity in each sector, (iii) to the efficiency of investment in each type of capital, (iv) to aggregate and nondurables demand, and (v) to employment.[2] Through international trade, shocks in one country have implications elsewhere. Through capital accumulation, past shocks affect the future while, through their anticipation, future shocks affect the past.

We apply the framework to a period spanning the run-up to the global recession through the end of the subsequent recovery. We assemble quarterly data on GDP, manufacturing production, construction output, bilateral trade, manufacturing and construction prices, and services deficits for 21 countries (including Rest of World) that encompass the entire globe. We apply our framework to these data to extract time series of the different shocks over the period 2000 to 2012. These backed-out shocks account for all quarterly fluctuations in GDP and production, trade, and prices by sector in each country.

We ask two questions: What type of shocks drove what happened? Where did these shocks

[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. Appendix Figure A.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 fourth quarter of 2008 before beginning a recovery in the third 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 don’t model trade in services, to respect accounting identities we introduce services deficits, which we treat as transfers. This sixth type of shock turns out to play only a very small role.

originate? We look not only at trade, but also at manufacturing production and GDP around the world. We answer these questions through counterfactuals in which only subsets of the shocks operate.[3] Several results stand out.

Declines in the efficiency of investment in durable manufactures, a highly-tradable sector, were the major driver of the overall collapse in trade and in manufacturing production during the global recession. The efficiency of investment in durables for the world as a whole plummeted at an annual rate of 23 percent during the recession, having been flat in the eight years before. These declines in the efficiency of durables investment shifted final spending away from durables and toward the nontraded sectors.[4]

Moreover, cross-country differences in these shocks were the primary determinant of cross-country variation in the decline both in trade and in manufacturing production. For example, China was the only country that experienced growth in durables investment efficiency during the recession and was also the country with the mildest decline in trade and the largest increase in manufacturing production. Romania had the second steepest decline in durables investment efficiency and had the second steepest decline in trade and the third steepest decline in manufacturing production. Our results are in line with a literature, discussed below, pointing to the importance of investment efficiency shocks for fluctuations and for economic growth.

Productivity declines in tradables could also have led to a fall in spending on tradable sectors. With perfect competition, however, negative shocks to productivity in the tradable sectors would also raise the relative prices of tradable goods, which we don't see.[5] In fact, the only sector where we observe significant productivity declines during the recession is the nontradable construction sector, and in only a few countries.

Other types of shocks made much more modest contributions to the trade collapse. Declines in the demand for nondurables (also highly traded) shifted expenditures toward services, which are not traded. Higher trade frictions in a few large countries such as China and the United States caused them to source a larger share of their traded goods domestically.[6]

[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]Declines in the efficiency of investment in (nontraded) structures had the opposite effect of shifting spending toward traded sectors, actually increasing trade. The decline in construction investment efficiency in most countries, however, was modest to nonexistent.

[5]Gopinath, Itskhoki, and Neiman (2012) use the micro data underlying U.S. import and export price indices to characterize the stability of traded goods prices during the trade collapse.

[6]Negative employment shocks and services deficits shocks, taken exogenously from the data, contributed nothing to the global trade decline.

An increase in a country's aggregate demand (relative to the world level) raises spending on consumption of nondurables and services there, leading to higher factor prices, lower exports, higher imports, and higher GDP relative to other countries. Such shocks had a limited impact on trade during the recession, but were the primary source of fluctuations in relative GDPs.

Unlike the decline of trade during 2008-2009, its recovery during 2009-2011 reflected a more balanced contribution of several sets of shocks. Reduced trade frictions played the largest role. The partial recovery in the efficiency of investment in durables was the second most important contributor to the trade recovery, followed by shocks to demand. By 2012, however, global trade relative to GDP had leveled off below its pre-recession peak.

While only some countries experienced declines in efficiency of investment in structures during the recession, a striking feature of the recovery is the failure of these declines to reverse themselves. In several countries, notably Greece, Spain, and the United States, the post-recession declines exceeded the recession ones.

We have developed our framework specifically to diagnose the collapse of trade and manufacturing production during the recession, but our methodology has wide applicability. The open-economy macroeconomics literature has typically aggregated the world into only two or three regions. Our multi-country framework allows us to examine not only the time-series features of world business cycles but their cross-sectional components as well. With data for more periods than are currently available we could estimate the time-series properties of shocks to individual countries. Our equilibrium model would then allow us to examine how shocks in one country relate to outcomes in another, either through trade or because shocks themselves are correlated.

In our particular exercise here we find that the global nature of the recession was primarily the result of simultaneous declines in investment efficiency in many countries. The extent to which an individual country was affected depended both on the severity of the decline domestically and its severity in major export markets. We find, for example, that if the United States had not itself experienced the shocks underlying the global recession, its limited amount of trade would have shielded it from shocks originating elsewhere. For Germany, in contrast, we find that shutting down its own shocks would have barely mitigated its recession. Its trading relationships with the rest of the world meant that shocks elsewhere played a significant role in its downturn.

Our paper proceeds as follows. Section 2 reviews related literature while Section 3 provides an overview of the data. Section 4 presents our model, deriving equilibrium relationships from the solution to a global planner's problem. In Section 5 we show how the equilibrium links six sets of observable outcomes to six sets of underlying shocks. Section 6 describes how to extract these shocks from data on GDP, production, trade, and prices. Section 7 then uses the model to conduct a set of counterfactuals that identify the role of different types of shocks in the global recession. Section 8 concludes.

2 Related Literature

Our work relates to three different literatures. First, our results complement various papers investigating the forces driving the trade collapse during the global recession. Second, our methodology contributes to efforts to integrate quantitative models in macroeconomics and in international trade. Third, we build on the modelling of business cycle fluctuations.

2.1 The Trade Collapse

Baldwin (2009) served as a forum in which a number of researchers put forth various hypotheses for why trade plummeted. Explanations fall into several categories. One attributes the collapse to forces increasing barriers to trade, captured in our analysis by trade friction shocks. 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.[7] Others have cited increased protectionism.[8] Another literature has attributed the collapse in trade to the differential impact of the recession on different sectors of the economy.[9] A third hypothesis is that international vertical supply chains disintegrated.[10]

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

[7] 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 trade collapse.

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

[9] 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 multi-country 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.

[10] 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.

Leibovici and Waugh (2012) also emphasize the relevance of dynamics for trade due to the lags involved in international shipments.

In their survey, Bems, Johnson, and Yi (2013) write "The key to understanding how trade can fall more than GDP lies in understanding how asymmetries in expenditure changes across sectors map to international trade. The global recession saw large declines in spending on final goods (as opposed to services), specifically durable goods." They conclude that the composition of expenditures played a critical role in the collapse and that trade finance and protectionism did not. Our bottom line largely supports their conclusion. We attribute two thirds of the trade collapse to negative shocks to the efficiency of investment in durables and 18 percent to declines in demand for nondurables, both of which shift spending away from tradable goods. Trade frictions account for roughly 14 percent of the decline in global trade relative to GDP, also in line with the literature.[11] What our analysis adds is the ability to trace outcomes in general equilibrium for any country or sector to shocks emanating from any country or sector.

2.2 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 saving 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 tradables as exogenous.

Motivating our assumption of complete markets is Fitzgerald (2012), who embeds a multi-country model with trade barriers into an explicitly dynamic framework. She uses the model to

[11] Our notion of trade frictions includes difficulties in obtaining financing for international transactions as well as increases in protective tariffs. Bems, Johnson, and Yi (2013) offers a range of 15 to 20 percent as a rough consensus for the decline in trade attributable to the financial shock, though this estimate does not isolate the influence of the financial shock on international trade relative to domestic sales. Kee, Neagu, and Alessandro (2013) and Gawande, Hoekman, and Cui (2011) offer evidence that average tariff rates did not increase, or actually fell, during the crisis.

test for asset-market completeness, and, among rich counties, is unable to reject it.

We push the framework much further, 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 saving and investment decisions of households and firms in different countries. We can thus relate what happened to deeper underlying shocks to preferences and technology.

Finally, we build 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.[12]

2.3 Business Cycle Fluctuations

A venerable topic in macroeconomics has been understanding the sources of business cycle fluctuations. In order to focus most transparently on the interactions of trade and domestic fluctuations we assume competitive markets, in the tradition of Kydland and Prescott (1982).[13] While that paper focused on shocks to productivity, more recent contributors have found it fruitful to expand the set of driving processes to account for business cycle regularities.

In particular, Greenwood, Hercowitz, and Huffman (1988) introduce shocks to investment efficiency. In subsequent work, Fisher (2006), Justiniano, Primiceri, and Tambalotti (2010, 2011), Schmitt-Grohe and Uribe (2012), and Jurado (2015) have identified shocks of this type as a major driver of aggregates, particularly investment, over the business cycle.[14] Putting investment efficiency shocks into two-country models, Boileau (2002) finds that these shocks enhance the model's ability to match the observed cross-country correlation of output and the relative volatility of the terms of trade, while Jacob and Peersman (2013) find that they play the lead role in explaining U.S. trade balance dynamics.

The real business cycle literature has sought to uncover the ergodic processes driving business

[12] The dynamic models in Alvarez and Lucas (2009) and Kehoe, Ruhl, and Steinberg (2014) also relate to our work. Alvarez and Lucas (2009) study transition dynamics and steady state responses to tariff changes in a model with balanced trade. Kehoe, Ruhl, and Steinberg (2014) develop a two-country perfect foresight model in which shocks to foreign lending and to productivity can produce declining employment shares in U.S. tradable goods sectors, with implications for the current and future path of trade deficits.

[13] In contrast to the flexible-price environment assumed here, Eaton, Kortum, and Neiman (2013) explore a sticky-wage version of the model to show how the reversals of the deficits in some southern European countries can generate massive unemployment.

[14] Further, Karabarbounis and Neiman (2014, 2015) provide evidence that these shocks play a large role in the declining share of labor compensation in global GDP.

cycles over a long horizon. We zero in on one episode, the recent global recession and recovery. We consequently adopt the business-cycle-accounting strategy of Chari, Kehoe, and McGrattan (2007) which extracts from the data the exact realizations of each of a set of shocks. Given that our analysis incorporates many countries and sectors, applying the states-of-nature approach as in Chari, Kehoe, and McGrattan (2007) would be infeasible. Instead we adopt the perfect-foresight methodology used by Kehoe, Ruhl, and Steinberg (2014).

3 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?[15] To get a handle on the answer, Figure 1 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 2012:Q4. The three observations ending in 2008:Q4 to 2009:Q2, the period we refer to as the global recession, appear as solid squares while the following seven quarters represent the global trade recovery and appear as hollow triangles. Other quarters are hollow circles. We include regression lines based on pre-recession observations. Note that, for Germany and the United States, the slope of the line is distinctly positive and that the observations for the global recession lie close to (though somewhat below) the regression line based on the prior period. They are, of course, at the lower left-hand tail, since 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.

Appendix Figure A.2 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 Germany and the United States 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.

Together Figures 1 and A.2 suggest that, for some of the major world economies, the share of activity that is traded is procyclical, as is the share of manufacturing. But even among these four economies the relationships are heterogeneous.

We explore these correlations in greater detail, both over time and in the cross section, by expanding our sample to 20 countries, which comprise nearly three-fourths of world GDP, com-

[15] Appendix Section A describes the data used here and throughout the paper.

bining all others into a single Rest of World, which we treat as the 21st country. Table 1 lists the countries, reporting their shares of global GDP and trade and the ratios of their own trade (the average of exports and imports) 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 changes from 2008:Q3 to 2009:Q2. To delve further into the role of manufactures, we decompose them into durables and nondurables.[16] Figure 2(a) 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 nondurables 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. Several points stand out. First, the declines in trade and manufacturing production were widespread. Second, the declines in trade and production for durables were more pronounced and more synchronized than for nondurables. Third, the procyclicality of trade and production observed in the time series for individual countries appears in cross-country variation as well. Where production fell more trade fell more.

Figure 2(b) plots the corresponding changes during the recovery from the recession, which we define as 2009:Q2 to 2011:Q1. The picture is largely a mirror image of the recession, though for most countries the revival of trade and manufacturing production was more correlated than in the recession.

Several authors have pointed to sluggishness in construction activity as a factor in the global recession.[17] Figure 2(c) looks at patterns in manufacturing production and construction both in the recession and recovery. The declines in manufacturing production in the recession were much more pronounced than in construction.[18] Remarkably, for most countries construction failed to rebound during the recovery, with many countries including Greece, Spain, and the United States experiencing declines even more extreme than during the recession. In both periods, what happened to a country's construction activity correlates positively with what happened to its manufacturing production.

Figure 2(d) illustrates another remarkable feature of the recession. It looks at the quarter-

[16]Appendix Table A.1 lists the industries we classify as durable and nondurable manufactures (as well as construction and services). 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).

[17]Charles, Hurst, and Notowidigdo (2013) look at U.S. manufacturing and construction employment over the period preceding the recession and during the recession itself. Hoffmann and Lemieux (2014) compare construction employment in Germany, Canada, and the United States over the recession.

[18]Appendix Figure A.3 shows the evolution of the share of final spending on durables, nondurables, and construction in China, Germany, Japan, and the United States over the period 2000:Q1 to 2012:Q4. Note that construction does not appear to be nearly as procyclical.

to-quarter change in each of our 21 countries' share of world GDP (thus suppressing any global cyclicality), where countries' GDPs are translated into a common currency at market exchange rates. The solid line in the figure (we discuss the dashed line later) plots the variance in this change for each quarter starting with 2000:Q2. Note the spike in the recession. Not only did global activity decline in the recession, there was also a major cross-country realignment in incomes.

We now turn to our dynamic multi-country model in which durable and nondurable manufactures take center stage, with a role for construction as well. We then return to these data to quantify our model in order to isolate the factors driving the global collapse of trade and production during the recession.

4 The Model

Our goal is to uncover the complex forces behind the trade collapse and subsequent recovery using a dynamic multi-country general equilibrium model with perfect foresight.

4.1 Technology

We first describe the static technology for production at any date. We then turn to how investment connects endowments of capital across time.

4.1.1 The Static Framework

Our static framework builds on the trade models of Eaton and Kortum (2002), Alvarez and Lucas (2007), and Dekle, Eaton, and Kortum (2008).[19] The economy has $\mathcal{N}$ countries each with four sectors: construction (C), durable manufactures (D), nondurable manufactures (N), and services (S).[20] We let $\Omega = \{C, D, N, S\}$ denote the set of all sectors.

In addition to its labor endowment $L_{i,t}$, at any date t country i has an endowment $K_{i,t}^k$ of capital of type $k \in \Omega_K = \{C, D\}$. At any date households and firms consume the services of these stocks of capital. The output of sectors $k \in \Omega_K$ can serve as investment to build these stocks of capital. In addition, each sector $j \in \Omega$ uses the output of each sector as intermediate inputs. Outputs of nondurables and services (Ω_K^*, the complement of Ω_K) are also used directly for consumption.

Production in each sector combines the services of labor, the services of each type of capital, and intermediates from each of the four sectors. Technology is Cobb-Douglas with constant

[19] Papers that have introduced interindustry interaction into this framework include Shikher (2011) and Caliendo and Parro (2015).

[20] When we connect the model to data, services will represent the largest share of the S sector, although it also includes agriculture and commodities such as petroleum and other raw materials.

returns to scale. In country i, sector j has shares of labor, capital of type k, and intermediates from sector l given by $\beta_i^{L,j}$, $\beta_i^{K,jk}$, and $\beta_i^{M,jl}$ for $j, l \in \Omega$, $k \in \Omega_K$.

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

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

drawn independently for each z across countries i. Here, $T_{i,t}^j > 0$ is a parameter that reflects country i's overall efficiency in producing any good z. The parameter θ is an inverse measure of the dispersion of efficiencies. We treat σ and θ as constant over time, sectors, and countries.[21]

As has been standard in trade models since Ricardo, the endowments of labor and capital are not traded. Trade in the outputs of the four sectors incurs standard iceberg trade costs, so that delivering one unit of a good from country i to country n requires shipping $d_{ni,t}^j \ge 1$ units, with $d_{ii,t}^j = 1$.

4.1.2 Capital Stock Dynamics

Capital of type k accumulates in country i according to:

$$K_{i,t+1}^k = \chi_{i,t}^k \left(I_{i,t}^k\right)^{\alpha^k} \left(K_{i,t}^k\right)^{1-\alpha^k} + \left(1 - \delta^k\right) K_{i,t}^k, \tag{2}$$

where $I_{i,t}^k$ is investment, $\chi_{i,t}^k$ governs the efficiency of investment, $0 < \alpha^k \le 1$ governs adjustment costs, and δ^k is the depreciation rate. In introducing shocks to efficiency of investment we follow recent developments in the business cycle literature described in Section 2.3. Setting $\alpha^k < 1$ means that investment is less efficient when done in a large amount relative to the stock of capital, as in Lucas and Prescott (1971).

4.2 Preferences

At each date t the representative household in country n consumes output of the nondurables and services sectors in amounts $C_{n,t}^N$ and $C_{n,t}^S$. It also consumes the services of the stocks of durables and structures in amounts $K_{n,t}^{H,D}$ and $K_{n,t}^{H,C}$. The utility function aggregates these flows of consumption with Cobb-Douglas weights $\psi_{n,t}^j \ge 0$, where $\psi^C + \psi^D + \psi_{n,t}^N + \psi_{n,t}^S = 1$. Note that we treat the weights on household capital services as fixed across countries and over time, but allow for country-specific shifts between nondurables and services over time. The lifetime utility

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

of the representative agent in country n is:

$$U_n = \sum_{t=0}^{\infty} \rho^t \phi_{n,t} \left(\sum_{j \in \Omega_K^*} \psi_{n,t}^j \ln C_{n,t}^j + \sum_{k \in \Omega_K} \psi^k \ln K_{n,t}^{H,k} \right), \tag{3}$$

where ρ is a constant discount factor and $\phi_{n,t}$ is a shock to preferences for country n at date t, which we refer to as an aggregate demand shock.

4.3 Market Structure and the Planner's Problem

Markets are perfectly competitive and complete. Foresight is perfect. Since there are no market failures, we can reformulate the problem, following Lucas and Prescott (1971), and solve for the market allocation as the solution to a world planner's problem.

The world planner assigns a weight ω_n to the representative consumer in country i. We normalize global demand shocks and weights so that $\sum_{n=1}^{\mathcal{N}} \omega_n \phi_{n,t} = 1$. The planner's objective at date 0 is to maximize:

$$W = \sum_{n=1}^{\mathcal{N}} \omega_n U_n, \tag{4}$$

where she takes as given the initial stocks of each type of capital in each country i, $K_{i,0}^k$.

She is subject to the following sets of constraints:

1. The labor assigned to production of each good z in each sector j in country i at date t, $L_{i,t}^j(z)$, can't exceed the labor endowment $L_{i,t}$:

$$\sum_{j \in \Omega} \int_0^1 L_{i,t}^j(z) dz \leq L_{i,t}.$$

2. Capital of type k assigned to production of each good z in each sector j in country i at date t, $K_{i,t}^{jk}(z)$, along with capital available to households, can't exceed the capital endowment $K_{i,t}^k$:

$$\sum_{j \in \Omega} \int_0^1 K_{i,t}^{jk}(z) dz + K_{i,t}^{H,k} \leq K_{i,t}^k.$$

3. In each country i at each date t the output $y_{i,t}^j(z)$ of good z in sector j can't exceed what's implied by inputs and technology:

$$y_{i,t}^j(z) \leq a_{i,t}^j(z) \left(\frac{L_{i,t}^j(z)}{\beta_i^{L,j}} \right)^{\beta_i^{L,j}} \left(\prod_{k \in \Omega_K} \left(\frac{K_{i,t}^{jk}(z)}{\beta_i^{K,jk}} \right)^{\beta_i^{K,jk}} \right) \left(\prod_{l \in \Omega} \left(\frac{M_{i,t}^{jl}(z)}{\beta_i^{M,jl}} \right)^{\beta_i^{M,jl}} \right),$$

where $M^{jl}_{i,t}(z)$ are intermediates from sector l used to make good z in sector j.

4. The world's use of the output of good z in sector j from country i at date t can't exceed what i produces:

$$\sum_{i=1}^{\mathcal{N}} d^j_{ni,t} x^j_{ni,t}(z) \leq y^j_{i,t}(z),$$

where $x^j_{ni,t}(z)$ is country n's absorption of good z in sector j from country i (and $d^j_{ni,t}$ takes into account what's lost in transport).

5. Country n's total absorption of good z in sector j, $x^j_{n,t}(z)$, can't exceed what it absorbs from each source i:

$$x^j_{n,t}(z) \leq \sum_{i=1}^{\mathcal{N}} x^j_{ni,t}(z).$$

6. Absorption from each sector j in country n (for final use as investment or consumption or for intermediate use), $x^j_{n,t}$, aggregates across the goods for that sector:

$$x^j_{n,t} \leq \left(\int_0^1 x^j_{n,t}(z)^{(\sigma-1)/\sigma} dz \right)^{\sigma/(\sigma-1)}.$$

7. Country n's absorption from sector $l \in \Omega^*_K$ must exceed what its households consume or what it uses as intermediates:

$$\sum_{j \in \Omega} \int_0^1 M^{jl}_{n,t}(z) dz + C^l_{n,t} \leq x^l_{n,t}.$$

8. Country n's absorption from sector $k \in \Omega_K$ must exceed what its firms invest or what it uses as intermediates:

$$\sum_{j \in \Omega} \int_0^1 M^{jk}_{n,t}(z) dz + I^k_{n,t} \leq x^k_{n,t}.$$

9. Capital of type k available in country n at date $t+1$ can't exceed what's accumulated from the previous stock $K^k_{n,t}$ and investment $I^k_{n,t}$ at date t:

$$K^k_{n,t+1} \leq \chi^k_{n,t} \left(I^k_{n,t}\right)^{\alpha^k} (K^k_{n,t})^{1-\alpha^k} + (1-\delta^k) K^k_{n,t}.$$

We assume that the parameters of preferences and technology ensure that the planner's objective (4) is bounded.

4.4 Equilibrium Relationships

Appendix Section B sets up the planner's problem as one of intertemporal constrained optimization. The solution delivers an allocation and associated shadow prices for each constraint. We interpret the appropriate shadow prices, for each country i at each date t, as a price index $p_{i,t}^j$ for absorption in sector j, a wage to labor $w_{i,t}$, and a rental rate $r_{i,t}^k$ for each type of capital. With this reinterpretation of the relevant shadow prices as competitive prices, we turn to the expressions that we take to the data.

4.4.1 Prices and Trade Shares

The cost $b_{i,t}^j$ of a bundle of inputs for producing in sector j, combining labor, capital, and intermediates is:

$$b_{i,t}^j = (w_{i,t})^{\beta_i^{L,j}} \prod_{k \in \Omega_K} \left(r_{i,t}^k\right)^{\beta_i^{K,jk}} \prod_{l \in \Omega} \left(p_{i,t}^l\right)^{\beta_i^{M,jl}}, \tag{5}$$

while the associated price index for sector j in country n, combining production costs in each country is:

$$p_{n,t}^j = \gamma \left[\sum_{i=1}^{\mathcal{N}} T_{i,t}^j \left(b_{i,t}^j d_{ni,t}^j \right)^{-\theta} \right]^{-1/\theta}. \tag{6}$$

The share of country n's absorption of sector j imported from country i is:

$$\pi_{ni,t}^j = T_{i,t}^j \left[\frac{b_{i,t}^j d_{ni,t}^j}{p_{n,t}^j / \gamma} \right]^{-\theta}. \tag{7}$$

4.4.2 Household Spending

Household spending on consumption of good $j \in \Omega_K^*$ is:

$$p_{n,t}^j C_{n,t}^j = \omega_n \phi_{n,t} \psi_{n,t}^j, \tag{8}$$

while household spending on capital $k \in \Omega_K$ is:

$$r_{n,t}^k K_{n,t}^{H,k} = \omega_n \phi_{n,t} \psi^k. \tag{9}$$

Summing these two expressions across all sectors and countries, our normalization of global demand shocks and restriction on the ψs implies that the value of world consumption is 1, which serves as our numéraire.[22]

[22] This choice of numéraire gives the cleanest analytic expressions in the derivations that follow. We report our numerical results in terms of world GDP, to make them easier to interpret and more in line with existing work.

4.4.3 Investment

Investment in sector k satisfies the Euler equation:

$$\frac{p_{n,t}^{k}}{\alpha^{k}\chi_{n,t}^{k}}\left(\frac{I_{n,t}^{k}}{K_{n,t}^{k}}\right)^{1-\alpha^{k}}=\rho r_{n,t+1}^{k}+\rho\left(\frac{\left(1-\alpha^{k}\right)p_{n,t+1}^{k}I_{n,t+1}^{k}}{\alpha^{k}K_{n,t+1}^{k}}+\frac{\left(1-\delta^{k}\right)p_{n,t+1}^{k}}{\alpha^{k}\chi_{n,t+1}^{k}}\left(\frac{I_{n,t+1}^{k}}{K_{n,t+1}^{k}}\right)^{1-\alpha^{k}}\right). \quad (10)$$

The left-hand side is the sacrifice in period t required to attain another unit of capital in period $t+1$. The right-hand side is the benefit of another unit of capital in period $t+1$, both to rent out that period and to carry over to the future. Our assumption of perfect foresight implies that date $t+1$ magnitudes are known at date t.

4.4.4 Market Clearing

We define the value of country n's spending on sector j as $X_{n,t}^{j}=p_{n,t}^{j}x_{n,t}^{j}$. Defining $Y_{i,t}^{j}$ as the value of country i's gross production in sector j, world goods-market clearing implies that:

$$Y_{i,t}^{j}=\sum_{n=1}^{\mathcal{N}}\pi_{ni,t}^{j}X_{n,t}^{j}. \quad (11)$$

We denote final spending on sector j in country n as $X_{n,t}^{F,j}=p_{n,t}^{j}C_{n,t}^{j}$ for $j\in\Omega_{K}^{*}$ and $X_{n,t}^{F,k}=p_{n,t}^{k}I_{n,t}^{k}$ for $k\in\Omega_{K}$. Total spending on sector l output is the sum of country n's final spending on sector l plus the use of sector l output as intermediates by each sector j:

$$X_{n,t}^{l}=X_{n,t}^{F,l}+\sum_{j\in\Omega}\beta^{M,jl}Y_{n,t}^{j}. \quad (12)$$

Clearing in the market for country i's labor implies that labor income equals labor demand across sectors:

$$w_{i,t}L_{i,t}=\sum_{j\in\Omega}\beta_{i}^{L,j}Y_{i,t}^{j}, \quad (13)$$

while clearing in the market for its capital of type $k\in\Omega_{K}$ implies, using (8) and (9), that:

$$r_{i,t}^{k}K_{i,t}^{k}=\sum_{j\in\Omega}\beta^{K,jk}Y_{i,t}^{j}+\frac{\psi^{k}}{1-\psi^{C}-\psi^{D}}\left(X_{i,t}^{F,N}+X_{i,t}^{F,S}\right). \quad (14)$$

In our model, world GDP is:

$$Y_{t}=\sum_{i=1}^{\mathcal{N}}\left[w_{i,t}L_{i,t}+r_{i,t}^{C}K_{i,t}^{C}+r_{i,t}^{D}\left(K_{i,t}^{D}-K_{i,t}^{H,D}\right)\right],$$

where labor income $w_{i,t}L_{i,t}$ is given below by (13) and capital incomes $r_{i,t}^{k}K_{i,t}^{k}$ by (14). Consistent with national accounting practices, we include rental payments by households on structures, but exclude rental payments by households on durables, in our measure of GDP.

We treat sectors $j \in \Omega_T = \{D, N\}$ as tradable so that $d^j_{ni,t}$ are finite. Construction is not traded and we treat services as nontraded, so that for sectors $l \in \Omega^*_T = \{C, S\}$ we treat $d^l_{ni,t}$ as infinite for $i \neq n$. To acknowledge that deficits in manufactures don't correspond to total deficits in the data we introduce an exogenous services deficit $D^S_{n,t}$ to make up the difference. Hence $X^C_{n,t} = Y^C_{n,t}$ and $X^S_{n,t} = Y^S_{n,t} + D^S_{n,t}$, where $\sum_{n=1}^{\mathcal{N}} D^S_{n,t} = 0$.

4.4.5 Hiding Services

We can reduce the dimensionality of the model by folding the services sector into each other sector $j \in \Omega^*_S$ (the complement of the services sector). We do so because we lack price data for services and do not model its trade. To perform this step we define $\tilde{\beta}^{M,jS}_i = \beta^{M,jS}_i/(1 - \beta^{M,SS}_i)$ and introduce the following compound input shares: (i) we add to $\beta^{L,j}_i$ a term to capture sector j's use of labor indirectly through services intermediates to get $\tilde{\beta}^{L,j}_i = \beta^{L,j}_i + \tilde{\beta}^{M,jS}_i \beta^{L,S}_i$, (ii) we add to $\beta^{K,jk}_i$ a term to capture sector j's use of capital of type k indirectly through services intermediates to get $\tilde{\beta}^{K,jk}_i = \beta^{K,jk}_i + \tilde{\beta}^{M,jS}_i \beta^{K,Sk}_i$, and (iii) we add to $\beta^{M,jl}_i$ a term to capture sector j's use of output from l indirectly through j's use of services intermediates to get $\tilde{\beta}^{M,jl}_i = \beta^{M,jl}_i + \tilde{\beta}^{M,jS}_i \beta^{M,Sl}_i$.

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

$$A^j_{i,t} = \left(\left(T^S_{i,t}\right)^{\tilde{\beta}^{M,jS}_i} T^j_{i,t} \right)^{1/\theta},$$

so that the corresponding cost of a bundle of inputs becomes:

$$c^j_{i,t} = w_{i,t}^{\tilde{\beta}^{L,j}_i} \left(\prod_{k \in \Omega_K} \left(r^k_{i,t}\right)^{\tilde{\beta}^{K,jk}_i} \right) \left(\prod_{l \in \Omega^*_S} \left(p^l_{i,t}\right)^{\tilde{\beta}^{M,jl}_i} \right). \tag{15}$$

The price index (6) becomes:

$$p^j_{n,t} = \gamma \left[\sum_{i=1}^{\mathcal{N}} \left(\frac{c^j_{i,t} d^j_{ni,t}}{A^j_{i,t}} \right)^{-\theta} \right]^{-1/\theta}, \tag{16}$$

for $j \in \Omega_T$, while for sector C we have $p^C_{n,t} = \gamma c^C_{n,t}/A^C_{n,t}$. The share (7) of country n's spending on sector $j \in \Omega_T$ devoted to goods from i becomes:

$$\pi^j_{ni,t} = \left[\frac{\gamma c^j_{i,t} d^j_{ni,t}}{A^j_{i,t} p^j_{n,t}} \right]^{-\theta}. \tag{17}$$

Turning to the goods and factor-market clearing conditions, we can re-write equation (12) as:

$$X_{i,t}^{l} = X_{i,t}^{F,l} + \sum_{j \in \Omega_S^*} \tilde{\beta}_i^{M,jl} Y_{i,t}^{j} + \tilde{\beta}_i^{M,Sl} \left(X_{i,t}^{F,S} - D_{i,t}^{S} \right), \tag{18}$$

while (13) becomes:

$$w_{i,t} L_{i,t} = \sum_{j \in \Omega_S^*} \tilde{\beta}_i^{L,j} Y_{i,t}^{j} + \tilde{\beta}_i^{L,S} \left(X_{i,t}^{F,S} - D_{i,t}^{S} \right), \tag{19}$$

and (14) becomes:

$$r_{i,t}^{k} K_{i,t}^{k} = \sum_{j \in \Omega_S^*} \tilde{\beta}_i^{K,jk} Y_{i,t}^{j} + \tilde{\beta}_i^{K,Sk} \left(X_{i,t}^{F,S} - D_{i,t}^{S} \right) + \frac{\psi^k}{1 - \psi^C - \psi^D} \left(X_{i,t}^{F,N} + X_{i,t}^{F,S} \right). \tag{20}$$

4.5 The Exogenous Variables

We divide the exogenous variables of our model into those we treat as time-invariant parameters Θ and those we treat as time-varying shocks Ψ_t:

$$\Theta = \{\rho, \theta, \alpha^k, \delta^k, \psi^k, \tilde{\beta}_i^{L,j}, \tilde{\beta}_i^{K,jk}, \tilde{\beta}_i^{M,jl}\} \quad \text{and} \quad \Psi_t = \{d_{ni,t}^{l}, A_{i,t}^{l}, \chi_{i,t}^{k}, \phi_{i,t}, \psi_{i,t}^{N}, L_{i,t}, D_{i,t}^{S}\},$$

for $j \in \Omega$, $k \in \Omega_K$, $l \in \Omega_S^*$, and $i = 1, ..., \mathcal{N}$. (Since $\psi_{i,t}^{S} = 1 - \psi^C - \psi^D - \psi_{i,t}^{N}$ the demand shock for services is redundant.) Equations (8), (10), (11), and (15) through (20) determine paths of the endogenous variables: wages $w_{i,t}$, rental rates $r_{i,t}^{k}$ for sectors $k \in \Omega_K$, prices $p_{i,t}^{j}$ and total spending $X_{i,t}^{j}$ for sectors $j \in \Omega_S^*$, and final spending $X_{i,t}^{F,j}$ for sectors $j \in \Omega$. The state variables are the capital stocks $K_{i,t}^{k}$, which evolve according to (2), with $I_{i,t}^{k} = X_{i,t}^{F,k}/p_{i,t}^{k}$.

4.6 A Stationary State

In a stationary state Ψ is constant and the capital stocks have settled down to constant levels K_i^k. In this case the Euler equations (10) and capital accumulation equations (2) determine, for each type of capital, the ratio of investment to the capital stock and the ratio of the rental rate to the price of that capital good. The stationary values of the other endogenous variables follow from (8), (11), and (15) through (20).

5 Shocks and Outcomes

A common solution technique is to linearize the model around this stationary state. We instead solve the model exactly, after expressing it in changes, as in Dekle, Eaton, and Kortum (2007, 2008). For any variable x we define its change as $\hat{x}_{t+1} = x_{t+1}/x_t$. Expressing the model in changes eliminates the need to identify L_i, χ_i^j, ϕ_i, ψ_i^N, A_i^j, d_{ni}^j, $K_{i,0}^k$, p_i^j, w_i, and r_i^k in levels. Observations of trade shares π_{ni}^j, expenditures X_n^j, and the value of services output Y_i^S in an initial period provide all the information we need about levels. We now show how our model in changes relates six sets of underlying shocks to six sets of equilibrium outcomes.

5.1 Shocks

In changes, our shocks in $t+1$ are $\hat{\Psi}_{t+1} = \{\hat{d}_{ni,t+1}^j, \hat{A}_{i,t+1}^j, \hat{\chi}_{i,t+1}^j, \hat{\phi}_{i,t+1}, \hat{\psi}_{i,t+1}^N, \hat{L}_{i,t+1}, D_{i,t+1}^S\}$. We group them into six sets driving the global economy: (i) trade cost shocks $\hat{d}_{ni,t+1}^j$ for $j \in \Omega_T$, (ii) productivity shocks $\hat{A}_{i,t+1}^j$ for $j \in \Omega_S^*$, (iii) investment efficiency shocks $\hat{\chi}_{i,t+1}^k$ for $k \in \Omega_K$, (iv) demand shocks $\hat{\phi}_{i,t+1}$ and $\hat{\psi}_{i,t+1}^N$, (v) labor supply shocks $\hat{L}_{i,t+1}$, and (vi) services deficit shocks D_{t+1}^S (in levels).

5.2 Outcomes

We connect our shocks to six sets of observable outcomes in two ways. In this section we show how our shocks drive these outcomes along an equilibrium path. In the following section we show how to invert these relationships to infer the time paths of our shocks from observables.

Consider cutting into the equilibrium path at a date t^I at which we observe X_{i,t^I}^j, π_{ni,t^I}^j, Y_{i,t^I}^S, and $\hat{K}_{i,t^I+1}^k$. Given a path of subsequent shocks $\{\hat{\Psi}_{t+1}\}_{t=t^I}^{\infty}$, we can solve the equilibrium forward for: (i) changes in the trade shares $\hat{\pi}_{ni,t+1}^j$, (ii) changes in prices $\hat{p}_{i,t+1}^j$, (iii) changes in consumption expenditures on nondurables $\hat{X}_{i,t+1}^{F,N}$ and on services $\hat{X}_{i,t+1}^{F,S}$, (iv) changes in investment spending $\hat{X}_{i,t+1}^{F,k}$, (v) changes in wages $\hat{w}_{i,t+1}$, and (vi) changes in rental rates $\hat{r}_{i,t+1}^k$.

We can relate the six sets of outcomes to the six sets of shocks through the following six sets of equations, iterating forward from t to $t+1$:

1. From (17), using (22), we can express changes in trade shares for sectors $j \in \Omega_T$ as:

$$\hat{\pi}_{ni,t+1}^j = \left(\frac{\hat{c}_{i,t+1}^j \hat{d}_{ni,t+1}^j}{\hat{A}_{i,t+1}^j \hat{p}_{n,t+1}^j} \right)^{-\theta}, \tag{21}$$

   where:

$$\hat{c}_{i,t+1}^j = \left(\hat{w}_{i,t+1}\right)^{\tilde{\beta}_i^{L,j}} \left(\prod_{k \in \Omega_K} \left(\hat{r}_{i,t+1}^k\right)^{\tilde{\beta}_i^{K,jk}} \right) \left(\prod_{l \in \Omega_S^*} \left(\hat{p}_{i,t+1}^l\right)^{\tilde{\beta}_i^{M,jl}} \right), \tag{22}$$

   is the change in the cost of the input bundle.

2. Similarly, from (16), using (22), changes in prices for sectors $j \in \Omega_S^*$ solve:

$$\hat{p}_{n,t+1}^j = \left[\sum_{i=1}^{\mathcal{N}} \pi_{ni,t}^j \left(\frac{\hat{c}_{i,t+1}^j \hat{d}_{ni,t+1}^j}{\hat{A}_{i,t+1}^j} \right)^{-\theta} \right]^{-1/\theta}, \tag{23}$$

where, for sector C, we set $\pi_{nn,t}^C = \hat{\pi}_{nn,t+1}^C = 1$ and $\pi_{ni,t}^C = \hat{\pi}_{ni,t+1}^C = 0$ for $n \neq i$.

3. From (8), changes in consumption spending on nondurables and on services for sectors $j \in \Omega_K^*$ satisfy:

$$\hat{X}_{i,t+1}^{F,j} = \hat{\phi}_{i,t+1} \hat{\psi}_{i,t+1}^j. \tag{24}$$

4. From (10), using (2) in changes, changes in investment spending on durables and construction solve the Euler equation:

$$\frac{1}{\rho} \frac{\hat{K}_{i,t+1}^k}{\hat{K}_{i,t+1}^k - (1-\delta^k)} = \alpha^k \frac{r_{i,t+1}^k K_{i,t+1}^k}{X_{i,t}^{F,k}} + \hat{X}_{i,t+1}^{F,k} \left[(1-\alpha^k) + \frac{1}{\hat{\chi}_{i,t+1}^k} \left(\frac{\hat{p}_{i,t+1}^k \hat{K}_{i,t+1}^k}{\hat{X}_{i,t+1}^{F,k}} \right)^{\alpha^k} \frac{(1-\delta^k)}{\hat{K}_{i,t+1}^k - (1-\delta^k)} \right], \tag{25}$$

for $k \in \Omega_K$. Payments to capital in $t+1$, $r_{i,t+1}^k K_{i,t+1}^k$, come from (27) below.

5. From (19) and (11), changes in wages, satisfy:

$$\hat{w}_{i,t+1} \hat{L}_{i,t+1} w_{i,t} L_{i,t} = \sum_{j \in \Omega_S^*} \tilde{\beta}_i^{L,j} Y_{i,t+1}^j + \tilde{\beta}_i^{L,S} \left(X_{i,t+1}^{F,S} - D_{i,t+1}^S \right). \tag{26}$$

6. From (20) and (11), changes in rental rates for sectors $k \in \Omega_K$ satisfy:

$$\hat{r}_{i,t+1}^k \hat{K}_{i,t+1}^k r_{i,t}^k K_{i,t}^k = \sum_{j \in \Omega_S^*} \tilde{\beta}_i^{K,jk} Y_{i,t+1}^j + \tilde{\beta}_i^{K,Sk} \left(X_{i,t+1}^{F,S} - D_{i,t+1}^S \right) + \frac{\psi^k}{1-\psi^C-\psi^D} \left(X_{i,t+1}^{F,N} + X_{i,t+1}^{F,S} \right). \tag{27}$$

Solving (26) and (27) requires that we relate country i's sector $j \in \Omega_S^*$ output to its absorption around the world according to (11) where total spending $X_{n,t+1}^l$, $l \in \Omega_S^*$, is given by the global-input output identity (18).

To update the change in capital stocks we manipulate (2) to get:

$$\hat{K}_{i,t+2}^k - (1-\delta^k) = \hat{\chi}_{i,t+1}^k \left(\frac{\hat{X}_{i,t+1}^{F,k}}{\hat{p}_{i,t+1}^k \hat{K}_{i,t+1}^k} \right)^{\alpha^k} \left(\hat{K}_{i,t+1}^k - (1-\delta^k) \right). \tag{28}$$

5.3 Connecting Outcomes to Shocks

Shocks have both direct effects and indirect effects through changes in prices and factor costs. If shocks are anticipated, they have an effect on prior outcomes, and, even if they are temporary, their effects linger in capital. We can use equations (21) through (27) to examine their direct impact.

To get insight into the implications of shocks irrespective of where they occur, consider first a type of shock hitting worldwide, eliminating any geographic dimension: (i) From (21), increases in trade costs $\hat{d}^j_{ni,t+1}$ (meaning $\hat{d}^j_{ni,t+1} > 1$) reduce import shares within sector j as countries divert sourcing from abroad to home. (Remember that $\hat{d}^j_{ii,t+1} = 1$.) (ii) From (23), increases in productivity $\hat{A}^j_{i,t+1}$ lower the sectoral price index for sector j output relative to input costs. (iii) From (24), increases in the demand for nondurable consumption $\hat{\psi}^N_{i,t+1}$ shift spending from (nontradable) services to (tradable) nondurable manufactures. (iv) From (25), increases in the efficiency of investment $\hat{\chi}^k_{i,t+1}$ raise investment spending in sector k. Increases in the demand for nondurable consumption $\hat{\psi}^N_{i,t+1}$ and in investment efficiency in durables $\hat{\chi}^D_{i,t+1}$ raise spending on tradables at the expense of nontradables. Overall trade goes up even if the share of trade within the sector doesn't change. (v) Increases in the labor force $\hat{L}_{i,t+1}$ show up in (26), generating an offsetting decline in wages.

By definition, shocks to aggregate demand $\hat{\phi}_{i,t+1}$ can't be worldwide, since they average to one. An increase in $\hat{\phi}_{i,t+1}$ for country i acts to increase i's spending on nontraded goods, which raises its factor prices and hence its absorption and its GDP relative to the rest of the world. Its imports rise and its exports fall.[23]

We can also consider the effect of other shocks when they occur in one country in isolation. As in the classic Dornbusch, Fischer, and Samuelson (1977) model, an increase in productivity $\hat{A}^j_{i,t+1}$ in a tradable sector j lowers country i's cost of producing varieties in that sector. The relative wage in country i rises as does the range of sector j varieties it produces and exports. An increase in country i's labor force $\hat{L}_{i,t+1}$ lowers its wage but also increases the range of varieties it produces and exports. An increase in investment efficiency $\hat{\chi}^D_{i,t+1}$ increases country i's production and imports of durables. In line with the Lerner symmetry theorem, an increase in country i's trade costs as an exporter $\hat{d}^j_{ni,t+1}$ or as an importer $\hat{d}^j_{in,t+1}$ (for all $n \neq i$) lowers both country i's imports and its exports.

[23] We base our description of the effects of country-specific shocks on exercises which perturb the stationary state of the model, as described in Appendix Section C. Agents learn of the shock one period in advance. We consider both temporary and permanent changes (in levels). A 25 percent permanent increase in the level of shock s in period $t+1$ means setting $\hat{s}_{t+1} = 1.25$ and $\hat{s}_\tau = 1$ for $\tau \neq t+1$. A 25 percent temporary increase means setting $\hat{s}_{t+1} = 1.25$, $\hat{s}_{t+2} = 1/1.25$ and $\hat{s}_\tau = 1$ for $\tau \neq t+1, t+2$. In the experiments we describe, temporary and permanent changes have qualitatively similar effects, so we don't discuss each separately.

An issue in the literature on real business cycles (see, e.g., Stockman and Tesar, 1995) has been the observed negative comovement of GDP and the trade balance. We find that an increase in durables productivity $\hat{A}^D_{i,t+1}$ in country i raises both its GDP and its trade balance. In contrast, an increase in demand $\hat{\phi}_{i,t+1}$ or in durables investment efficiency $\hat{\chi}^D_{i,t+1}$ raises GDP but lowers the trade balance, in line with the data. Similarly, a country-specific increase in $\hat{A}^D_{i,t+1}$ raises output of durables in the affected country while decreasing it elsewhere, generating negative comovement in durables output across countries. In contrast, a country-specific increase in $\hat{\chi}^D_{i,t+1}$ raises durables output everywhere, creating positive comovement.

In most cases we find the news effect of a shock, the period before it materializes, to be in the same direction but much smaller in magnitude than the effect on impact. Major exceptions are with country-specific increases in productivity $\hat{A}^D_{i,t+1}$ or investment efficiency in durables $\hat{\chi}^D_{i,t+1}$. Both production and absorption rise on impact, but contract the period before, as agents delay investment until the subsequent period when durables will be cheaper or contribute more to the capital stock.

6 Quantification

To quantify the model, we need to calibrate the parameters, solve for the paths of capital stocks, and back out the six sets of shocks. In this section we first describe these three steps. We then report the shocks that emerge from applying this procedure to quarterly data from the 21 countries appearing in Table 1, from 2000:Q1 to 2012:Q4.[24] We take (in levels) series corresponding to $X^{F,j}_{i,t}$, $X^j_{i,t}$, $Y^j_{i,t}$ for $j \in \Omega$ (and hence $D^S_{i,t}$) and $\pi^j_{ni,t}$ for $j \in \Omega_T$. We take (in changes) series corresponding to $\hat{L}_{i,t+1}$ and $\hat{p}^j_{i,t+1}$ for $j \in \Omega^*_S$.

6.1 Parameter Values

We now discuss our calibration of the parameters in Θ. We set the quarterly discount factor $\rho = 0.987$ to be consistent with a real interest rate of 5 percent per year. We set $\theta = 2$, a value between the smaller values typically used in the open-economy macro literature and the larger values used in Eaton and Kortum (2002). We choose $\alpha^C = 0.5$ and $\alpha^D = 0.55$. (A larger α^j means lower capital adjustment costs.) We choose $\delta^C = 0.008$ to correspond to an annual depreciation rate for structures of 4 percent, a value in between that used by Krusell, Ohanian, Rios-Rull, and Violante (2000) and the U.S. BEA's measured rate of depreciation in private structures in 2008.

[24]Data from China and France become available in 2006:Q1.

We choose $\delta^D = 0.026$ to correspond to an annual durables depreciation rate of 10 percent.[25]

We calibrate the preference parameters ψ^C and ψ^D by using the Euler equation (25) in steady state, which, together with (27), becomes:

$$\frac{1-\rho\left(1-\delta^k\alpha^k\right)}{\rho\alpha^k\delta^k}X_i^{F,k} = r_i^k K_i^k = \sum_{j\in\Omega_S^*}\tilde{\beta}_i^{K,jk}Y_i^j + \tilde{\beta}_i^{K,Sk}Y_i^{F,S} + \frac{\psi^k}{1-\psi^C-\psi^D}\left(X_i^{F,N}+X_i^{F,S}\right),$$

where the absence of a time subscript indicates a stationary value. We assume that the world as a whole is close enough to steady state to use data averaged over the observed period to calibrate these preference parameters. Denoting the time average of variable Z_t as $\bar{Z}$, we calculate ψ^k as:

$$\psi^k = \frac{1-\rho\left(1-\delta^k\alpha^k\right)}{\rho\alpha^k\delta^k}\sum_{i=1}^{\mathcal{N}}\bar{X}_i^{F,k} - \sum_{i=1}^{\mathcal{N}}\left(\sum_{j\in\Omega_S^*}\tilde{\beta}_i^{K,jk}\bar{Y}_i^j + \tilde{\beta}_i^{K,Sk}\bar{Y}_i^{F,S}\right), \tag{29}$$

where we exploit the result that, $\sum_{i=1}^{\mathcal{N}}\left(X_i^{F,N}+X_i^{F,S}\right) = 1-\psi^C-\psi^D$. This calculation yields $\psi^C = 0.33$, which is within one percent of the average annual expenditure share of housing in the 2008 U.S. consumer expenditure survey, and $\psi^D = 0.08$.

We calculate the input-output coefficients from the 2009 edition of the OECD's country tables.[26] To determine $\beta_i^{L,j}$ we divide compensation of employees in sector j by that sector's total output. We measure capital's share of output as value added less compensation of employees divided by total output in sector j. We assume that nonresidential structures represent 43 percent of the business sector's capital share, $\beta_i^{K,jC}/(\beta_i^{K,jC}+\beta_i^{K,jD}) = 0.43$, consistent with Greenwood, Hercowitz, and Krusell (1997).[27] To determine $\beta_i^{M,jl}$ we divide total spending in sector j on inputs from sector l by sector j's total output. We then use the definitions from Section 4.4.5 to get $\tilde{\beta}_i^{L,j}$, $\tilde{\beta}_i^{K,jk}$, and $\tilde{\beta}_i^{M,jl}$.

6.2 Paths of Capital

To extract the baseline shocks $\{\hat{\Psi}_{t+1}\}$ during the period of our analysis (2000:Q1 to 2012:Q4), we need to know the paths of the changes in the capital stocks $\hat{K}_{i,t+1}^k$ over that period. Computing the associated baseline paths of the $\hat{K}_{i,t+1}^k$ in turn requires assumptions about the $\{\hat{\Psi}_{t+1}\}$ beyond

[25] Our depreciation rate on durables is slightly lower than the 12.5 percent rate assumed in Krusell, Ohanian, Rios-Rull, and Violante (2000) for equipment. A higher rate would imply a reduced value for the share of consumer expenditures on durables ψ^D.

[26] We use the most recent input-output table available in this edition for each country. Appendix Table A.1 shows how we concord the 48 sectors used in these tables to form input-output tables for the four sectors $j \in \Omega$.

[27] The U.S. BEA's Fixed Asset Table 4.1 gives that the current-cost stock of nonresidential structures equaled 61 percent of all private nonresidential fixed assets in 2008. Our assumption follows if the gross return on nonresidential structures equals roughly 2/3 of the gross return on total nonresidential capital, which is realistic given the lower depreciation rate on structures.

the period of our data. Denoting the period at which our data end, 2012:Q4, as t^E we freeze the levels of all the shocks at their 2012:Q4 values.

This world with unchanging shocks converges to a stationary state in which all endogenous magnitudes are constant. We then solve for the $\hat{K}^k_{i,t+1}$ for $t \geq t^E$ that, using equations (21) through (28), lead the economy along a perfect foresight path to this stationary state.[28]

With $\hat{K}^k_{i,t^E+1}$ in hand, we iterate backwards and extract $\hat{K}^k_{i,t+1}$ for $t < t^E$ by incorporating the Euler equation (25) into the capital accumulation equation (28):

$$\frac{\hat{K}^k_{i,t}}{\hat{K}^k_{i,t} - (1-\delta^k)} = \rho \frac{\alpha^k}{X^{F,k}_{i,t-1}} r^k_{i,t} K^k_{i,t} + \rho \hat{X}^{F,k}_{i,t} \left(\left(1-\alpha^k\right) + \frac{1-\delta^k}{\hat{K}^k_{i,t+1} - (1-\delta^k)} \right). \tag{30}$$

Since our substitution of the Euler equation has eliminated $\hat{\chi}^k_{i,t+1}$, extracting the path of $\hat{K}^k_{i,t+1}$ requires no knowledge of any shocks. What is required are data on investment spending $X^{F,k}_{i,t}$ and the spending and production terms on the right-hand side of equation (27) to deliver $r^k_{i,t} K^k_{i,t}$.

Figure 3 shows the paths for $\hat{K}^C_{i,t+1}$ and $\hat{K}^D_{i,t+1}$ that this procedure gives us for the three largest countries, the United States, China, and Rest of World. There are two regimes. In the period after 2012:Q4 the capital stocks glide smoothly toward the stationary state in which $\hat{K}^k_i = 1$. In the period of our analysis the capital stocks fluctuate according to the data we feed into equation (30). The stock of durables is more volatile and converges fully by 2050, while structures, with their lower depreciation rate, need longer.[29]

6.3 Paths of Shocks

Given paths for changes in capital $\hat{K}^k_{i,t+1}$, our model delivers the following expressions for the shocks during the period of our data:

1. We use expression (21) as it applies to $n \neq i$ (relative to how it applies to $n = i$) to obtain trade cost shocks in sectors $j \in \Omega_T$:

$$\hat{d}^j_{ni,t+1} = \left(\frac{\hat{\pi}^j_{ni,t+1}}{\hat{\pi}^j_{ii,t+1}} \right)^{-1/\theta} \frac{\hat{p}^j_{n,t+1}}{\hat{p}^j_{i,t+1}}. \tag{31}$$

2. We use (24), together with the condition that $\psi^N_{i,t} + \psi^S_{i,t} = 1 - \psi^C - \psi^D$ to back out the

[28] Appendix Section C describes the algorithm we use to calculate the $\hat{K}^k_{i,t^E+1}$.

[29] We cut the simulation off at 2050 to save on computing time. Extending the simulation out long enough for structures also to converge to their stationary state delivers values of $\hat{K}^k_{i,t^E+1}$, what matters for our analysis, that are indiscernibly different.

aggregate and nondurables demand shocks:

$$\hat{\phi}_{i,t+1} = \frac{X_{i,t+1}^{F,N} + X_{i,t+1}^{F,S}}{X_{i,t}^{F,N} + X_{i,t}^{F,S}} \text{ and } \hat{\psi}_{i,t+1}^{N} = \frac{\hat{X}_{i,t+1}^{F,N}}{\hat{\phi}_{i,t+1}}. \tag{32}$$

3. We take the changes in labor $\hat{L}_{i,t}$ directly from the data.

4. We take services trade deficits $D_{i,t+1}^{S}$ directly from the data.

5. We back out investment efficiency shocks $\hat{\chi}_{i,t+1}^{k}$ using the law of motion for capital in changes (28):

$$\hat{\chi}_{i,t+1}^{k} = \left(\frac{\hat{X}_{i,t+1}^{F,k}}{\hat{p}_{i,t+1}^{k}\hat{K}_{i,t+1}^{k}}\right)^{-\alpha^k} \frac{\hat{K}_{i,t+2}^{k} - (1-\delta^k)}{\hat{K}_{i,t+1}^{k} - (1-\delta^k)}. \tag{33}$$

6. We back out productivity shocks $\hat{A}_{i,t+1}^{j}$ for sectors $j \in \Omega_T$ using expression (21) as it applies to $n = i$:

$$\hat{A}_{i,t+1}^{j} = \frac{1}{\hat{p}_{i,t+1}^{j}} \left(\hat{\pi}_{ii,t+1}^{j}\right)^{1/\theta} \hat{c}_{i,t+1}^{j}, \tag{34}$$

and for sector C we use $\hat{A}_{i,t+1}^{C} = \hat{c}_{i,t+1}^{C}/\hat{p}_{i,t+1}^{C}$. The changes in factor prices needed to evaluate $\hat{c}_{i,t+1}^{j}$ in these productivity expressions come from (26) and (27).

This procedure delivers our baseline set of shocks $\{\hat{\Psi}_{t+1}\}$, with all values frozen as described above for $t \geq t^E$.[30] By construction, the solution to the model with the baseline shocks replicates our data for the period of 2000:Q1 to 2012:Q4.

6.4 Values of Shocks

Tables 2 to 4 summarize our findings about the baseline shocks. We report the average change in the shocks for each country during the quarters leading up to 2008:Q3, during the period we identify as the global recession, 2008:Q3 to 2009:Q2, and during the period we identify as the trade recovery, 2009:Q2 to 2011:Q1. All figures are annualized.

We start in Table 2, which summarizes the behavior of trade frictions. Since there are 420 trade friction shocks $\hat{d}_{ni}^{j}$ in each tradable sector, one for each ordered pair of separate countries,

[30] To evaluate the robustness of this procedure, we have also backed out the baseline shocks under alternative assumptions about the behavior of shocks in the period after our data. For example, one such exercise introduced a set of future demand shocks that implied steady state manufacturing deficits close to zero. This alternative assumption had little quantitative and no qualitative effect on our results.

we report only a trade-weighted average for each country (as both exporter and importer).[31] The world as a whole experienced a mild decline in its trade frictions prior to the recession, as shown by the values 0.99 and 0.98 for $\hat{d}^D_{ni}$ and $\hat{d}^N_{ni}$. This decline continued during the recession. Several countries go against this trend, exhibiting a substantial increase in trade frictions in the recession, particularly for durables. At the same time, some countries appear to have experienced large declines in trade frictions. (The higher variation in changes in trade frictions during the recession relative to other periods could reflect its brevity.) The decline in trade barriers accelerated during the recovery. Only Greece missed this trend.

Table 2 also reports each country's services deficit shocks relative to its GDP. Services deficits decline for 16 of our 21 countries in the recession, reflecting in part the fact that most of them are oil importers, and oil prices fell in this period. By construction, there is never a services deficit for the world.

Table 3 shows that most countries experienced declines in construction productivity in the recession, with the world average dropping to 0.92 from a previously flat trajectory with shocks averaging 1.00. These productivity losses were reversed during the recovery. In contrast, overall productivity growth in both durable and nondurable manufacturing during the recession hardly differed from other periods.

Table 3 also shows changes in employment. World employment, calculated as the GDP-weighted average across countries, increased by 1 percent in the pre-recession period but fell by 2 percent during the recession, with no overall reversal in the recovery. The countries with the largest declines during the recession were Spain and the United States.

Table 4 shows that there was only a mild worldwide decline in investment efficiency in construction during the recession, although the large increases in China and Japan offset small declines in most countries. The recovery period looks similar.

What most dramatically separates the recession from surrounding periods is the decline in investment efficiency in durables $\hat{\chi}^D_{i,t+1}$, also shown in Table 4.[32] In the pre-recession period, these

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

$$\hat{d}^j_i = \left[\sum_{n \neq i} \frac{X^j_{ni}}{E^j_i + M^j_i}\left(\hat{d}^j_{ni}\right)^{-\theta} + \sum_{k \neq i} \frac{X^j_{ik}}{E^j_i + M^j_i}\left(\hat{d}^j_{ik}\right)^{-\theta}\right]^{-1/\theta},$$

where $E^j_i = \sum_{n \neq i} X^j_{ni}$ and $M^j_i = \sum_{k \neq i} X^j_{ik}$ 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.

[32] We calculate the global average change in the investment efficiency shocks in sector k as:

$$\hat{\chi}^k_{t+1} = \sum_i \frac{X^{F,k}_{i,t}}{X^{F,k}_t} \hat{\chi}^k_{i,t+1},$$

shocks are tightly centered around 1. The world as a whole experienced a decline in durables investment efficiency of 23 percent during the recession. This decline was widespread, with the only increase occurring in China, at a rate slightly below its pre-recession average. Efficiency in durables investment generally recovered after the recession, but at a much slower pace. Denmark and Greece experienced substantial further declines in durables investment efficiency during the recovery.

Declines in nondurables demand largely match the declines in durable investment efficiency, with the steepest drops in Denmark, Italy, Romania, Spain, and the United States. As we show in the next section, however, since nondurables is a smaller sector than durables, the shocks to nondurables demand had less overall effect.

Finally, Table 4 reports the aggregate demand shocks. China and Japan exhibit the largest increases and Poland and Romania the largest decreases. Note that the United States also experienced a positive aggregate demand shock.[33] By construction, this shock has no global component.

6.5 Forces at Work in the Recession and Recovery

As described in Section 3, a major feature of the global recession was the widespread collapse in trade and in manufacturing production, particularly in durables. This collapse was reversed in the recovery. Construction activity also fell in the recession, but continued to fall during the recovery. The magnitude of the changes varied substantially by country. Another striking feature of the recession was the big realignment of relative GDPs.

How do our shocks explain these outcomes? Globally, the biggest shocks in the recession were the drops in investment efficiency in durables and in the final demand for nondurables, each of which plummeted by 23 percent. Declines in investment efficiency $\hat{\chi}^D_{i,t+1}$ and in the demand for nondurable consumption $\hat{\psi}^N_{i,t+1}$ lowered spending in these sectors. As spending shifted into nontraded sectors trade and manufacturing production fell. Trade frictions limited the geographic scope of the shocks. Where the shocks were more pronounced, so were the reductions in imports and in manufacturing production.

Table 4 suggests that shocks to aggregate demand $\hat{\phi}_{i,t+1}$, which are normalized to one around the world in any period, were much more dispersed during the global recession than before. The variance in quarter-to-quarter aggregate demand shocks $\hat{\phi}_{i,t+1}$ from 2000:Q1 to 2012:Q4, the dashed line in Figure 2(d), reinforces this impression. Note how the spike in the variance of the

where $X^{F,k}_t = \sum_i X^{F,k}_{i,t}$ is total world investment spending in sector k.

[33] Aggregate demand shocks are largely picking up changes in relative GDPs. During the recession the Japanese yen appreciated substantially against the U.S. dollar while the dollar appreciated modestly against the euro.

shocks coincides with the spike in the variance in changes in shares of world GDP (the solid line). Equation (32) shows the tight connection between final spending on nondurables and on services, a large share of total spending, and aggregate demand shocks $\hat{\phi}_{i,t+1}$.

Other shocks played a minor role during the recession. If anything, trade frictions $\hat{d}^{j}_{ni,t+1}$ decreased, and they continued to fall during the recovery. While productivity in construction $\hat{A}^{C}_{i,t+1}$ was procyclical, productivity in manufactures, $\hat{A}^{D}_{i,t+1}$ and $\hat{A}^{N}_{i,t+1}$, did very little globally, reflecting little change in output prices relative to input prices or in home shares within tradable goods sectors.[34]

We can quantify the contributions of individual shocks on the dynamics of the recession and recovery more precisely by examining what would have happened if they had operated in isolation. We now turn to a set of counterfactuals in which only subsets of shocks would have been at work over the period.

7 Counterfactuals

Having backed out the shocks that account fully for the changes that occurred from 2008:Q3 to 2012:Q4, we can ask how to assign responsibility for the collapse of trade during the global recession and for the subsequent recovery. To do so we consider how the world would have evolved in a counterfactual in which only one set of shocks is active, shutting down other shocks by fixing them at their 2008:Q2 level.

Within the period of our counterfactuals, we focus separately on the global recession, 2008:Q3 to 2009:Q2, and the recovery, 2009:Q2 to 2011:Q1.[35] If a counterfactual with a particular set of shocks delivers an evolution similar to what's in the data, we attribute what happened to these shocks. If the evolution implied by a counterfactual is quite different from the data, we conclude that these shocks were not relevant.

7.1 Computing a Counterfactual

To compute a counterfactual, we need to take a stand on how agents foresee the future. Since we back out baseline shocks under an assumption of perfect foresight, any counterfactual is a surprise. We assume that the surprise occurs in 2008:Q3, on the eve of the trade collapse, with agents acting as if they have perfect foresight of the counterfactual shocks at that point but not

[34] Our finding that shocks to the efficiency of investment outperform productivity shocks in explaining fluctuations squares with the closed-economy literature discussed in Section 2.3.

[35] In reporting changes over multiple quarters, as with the shocks, 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. We report all counterfactual outcomes relative to global GDP in that counterfactual.

before.[36] A consequence of this assumption is that, in a counterfactual, the Euler equation (25) holds for changes from 2008:Q3 to 2008:Q4 and onward, but does not hold for the initial change from 2008:Q2 to 2008:Q3.[37]

7.2 Global Trade

Figure 4 summarizes our main findings. It plots the path of global trade from 2000:Q2 to 2012:Q4 in the data as well as in counterfactuals with the following sets of shocks acting in isolation: (i) nondurables demand, (ii) aggregate demand, (iii) productivity (combining construction, nondurables, and durables), (iv) investment efficiency in durables, (v) investment efficiency in construction, (vi) trade frictions (combining nondurables and durables), and (vii) services deficits. Negative shocks to investment efficiency in durables are overwhelmingly the driver of the trade collapse. Lower nondurables demand and higher trade frictions also contribute to the decline but play a modest role. Other shocks contribute little or nothing.[38]

To be more quantitative, the first row of Table 5 reports the contributions of different sets of shocks to the cumulative decline in world trade over the recession. Shocks to investment efficiency in durables account for about two thirds of the total decline in world trade of 20 percent. Declines in demand for nondurable manufactures contribute 18 percent and increases in trade frictions contribute 14 percent to the decline. (The effects need not and do not add up exactly.)

The recovery in trade, as evident in Figure 4, is not just a reversal of these forces. A rise in investment efficiency in durables is a major component of the recovery but declining trade frictions play an even larger role (See Appendix Table A.2 for details).

7.3 Country-Level Results by Type of Shock

To what extent do our findings about the contributions of these forces at the world level across time carry over to explaining variation across countries? Table 5 reports, for each of our 21 countries, the change in trade from 2008:Q3 to 2009:Q2 under different sets of shocks.

The decline in investment efficiency in durables delivered a big hit to every country's trade, with demand for nondurables playing a more modest role. Trade frictions were important for a few countries. In China and India trade frictions and investment efficiency in durables contribute about equally to the (relatively modest) trade declines there.

[36] We have also solved counterfactuals under the alternative assumption that the surprise occurs in 2008:Q4. Some country-level dynamics differ in this case, but our conclusions about the relative contributions of shocks to the collapse of global trade do not change.

[37] Appendix Section C describes the numerical algorithm used to compute counterfactuals.

[38] The story for manufacturing production (illustrated in Appendix Figure A.4) is similar, except trade frictions play no role.

Figure 5 illustrates how various sets of shocks explain the decline in trade in the cross section. The figure plots the change in trade accounted for by various sets of shocks (on the y-axis) against a country's actual change in trade (on the x-axis). Hence the horizontal line at one corresponds to no change in the counterfactual and the 45-degree line to the actual change. Note that only shocks to investment efficiency in durables investment strongly covary with the declines in trade.

Figure 6 shows the analogous results for manufacturing production during the recession. Shocks to investment efficiency in durables were primarily responsible for the declines everywhere. Combined shocks to aggregate and nondurable demand also played important roles in the declines in Greece, Italy, Japan, Romania, Spain, and the United States. As shown in Appendix Table A.3, positive productivity shocks (across durables and nondurables) drove China's and India's substantial rise in manufacturing production. The main message, though, is that shocks to investment efficiency in durables were the main driver of the decline in both trade and in manufacturing production across the world during the global recession.

Changes in GDP are a different story, as shown in Figure 7 and in Appendix Table A.4. Aggregate demand shocks are the primary mover here, except for China and India, where, again, productivity (not pictured) is the primary driver of rapid GDP growth. Shocks to investment efficiency in construction contributed to the declines in Mexico and Poland and to the moderate increases in China and Japan.

We can combine these results to look at what happened to the ratio of trade to GDP by country. While shocks to durable investment efficiency were clearly the most important factor explaining the collapse in global trade, demand shocks, through their effect on the denominator, are also important for explaining cross-country variation in the declines in the ratio of trade to country-level GDP. Figure 8 shows the outcome of a counterfactual with shocks to investment efficiency, aggregate demand, and demand for nondurables. Together investment efficiency in durables and demand shocks explain most of the decline and cross-country variation in the ratio of trade to GDP.

To summarize, not only was the drop in the efficiency of investment in durables the major factor behind the collapse in global trade and manufacturing production, it was the major factor for individual countries as well. Relative GDPs, on the other hand, were driven primarily by demand shocks and secondarily by investment efficiency in construction. Together, the investment efficiency and demand shocks do a good job of explaining realized changes in the ratio of trade to GDP during the recession. Shocks to trade frictions, productivities, and services deficits do little.

Appendix Table A.2 reports the behavior of trade in these counterfactuals during the recovery from 2009:Q2 to 2011:Q1. Trade did indeed rise for every country except Greece, where we attribute the decline to increased trade frictions. For the rest, trade increased due primarily to decreased trade frictions and, to a lesser extent, a rebound in investment efficiency. Increases in the demand for nondurables also contributed to the recovery. Continued declines in investment efficiency in structures slowed the recoveries in Greece and, to a lesser extent, in Denmark, Romania, Spain, and the United Kingdom. Productivity declines in durables slowed recovery in several countries as well, while China's and India's trade rose in response to positive productivity shocks.

7.4 Cross-Border Transmission of Shocks

We now examine the geographic location of shocks rather than the type of shock. We first consider what would have happened if only shocks emanating from the United States were at work. We then consider whether the recession in Germany was primarily the result of local or of foreign shocks.

7.4.1 The United States

As the world's largest economy and as the country considered the epicenter of the financial crisis that set off the global recession, to what extent was the collapse in global trade and manufacturing production the consequence of shocks in the United States? Consider a counterfactual in which only the United States experiences shocks, with shocks elsewhere set equal to one (or services deficits fixed at their pre-recession levels).[39] U.S. shocks alone reduce global trade by 3.6 percent, as opposed to the actual decline of 20 percent, and reduce global manufacturing production by 2.9 percent, as opposed to the actual decline of 13 percent. As seen in Table 1, the United States contributes about 12 percent of world trade and about 14 percent of world manufacturing production. Hence, in either case, U.S. shocks by themselves reduce global trade and production by about 50 percent more than their respective U.S. shares, reflecting how the world trading system amplifies the effect of shocks.

Figure 9 shows the implications of U.S. shocks for individual countries. The decline in U.S. demand for manufactures, both from the decline in investment efficiency in durables and from the decline in demand for nondurables, dramatically reduces U.S. imports and manufacturing production. U.S. exports actually increase substantially since we've eliminated the decline in demand for manufactures elsewhere. Manufacturing production and exports decline in other

[39] We include the actual shocks to trade frictions between the United States and other countries, while setting trade friction shocks between pairs not including the United States equal to one. In order to obey adding-up constraints we need to scale deficits and demand shocks around the world to satisfy $\sum_i D^S_{i,t+1} = 0$ and $\sum_i (X^N_{i,t} + X^S_{i,t})\hat{\phi}_{i,t+1} = 1 - \psi^C - \psi^D$.

countries, most dramatically for Canada and Mexico. For these two countries U.S. shocks account for most of the actual decline in exports. The decline in U.S. imports reduces manufacturing production in Canada so much that Canadian imports fall as well.[40] The effect on imports of other countries is slightly positive as exports are diverted away from the United States and Canada toward other destinations.

The opposite experiment in which only non-U.S. shocks are at work is mostly the mirror image. Declines in the rest of the world are close to their actual ones, whereas, except for exports, the U.S. is largely unscathed.

7.4.2 Germany

The U.S. experiment may suggest that countries suffered primarily from home-grown shocks during the recession. The equivalent experiment for Germany, however, shows how a country much more exposed to world trade can suffer a significant decline in activity due solely to shocks from abroad.

Figure 10 shows the result of a counterfactual in which only shocks *not* involving Germany are at work. Note that there is little change from what actually happened, meaning that most of what happened in Germany can be explained by shocks from elsewhere. German imports, which remain at their pre-recession level, are the exception. Removing German shocks only slightly mitigates the effect of the recession on manufacturing production in Germany, Austria, and Poland, and on the exports of Austria and Poland.

8 Conclusion

We find that a decline in the efficiency of investment in durable manufacturing capital stocks drove the stunning collapse in trade and in manufacturing production that accompanied the global recession. This shock leads to an endogenous reduction in final spending on tradable sectors. 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) or negative productivity shocks, led to the trade collapse.

While one shock stands out as most salient for the global trade collapse, others matter over various periods for some sets of countries and not for others. For example, our results suggest an analysis focused on China's experience in the recession might conclude productivity played a particularly large role, while an analysis focused on Japan might conclude the same about

[40] For Canada, the decline is due not only to a reduction in U.S. demand for manufactures. Increased trade frictions with the United States also play a role.

aggregate demand. One benefit of developing a tractable dynamic framework for quantitative analysis of a large number of countries is the ability to use their interactions to distinguish bilateral from multilateral shocks and paint a richer picture of the common and idiosyncratic characteristics of global fluctuations. Another benefit is the ability to quantify the extent to which trade can be a major conduit for propogating the collapse in manufacturing around the world.

We think that our analysis opens up opportunities to model macroeconomic fluctuations and international trade, identifying 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 services such as agriculture and, particularly critical for macroeconomic fluctuations, oil. Also straightforward is adapting it to incorporate additional factors of production and unemployment.[41]

Other extensions are more challenging. 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 rules out such phenomena as pricing to market. In assuming perfect foresight, it rules out uncertainty or a richer treatment of the response to unexpected news. Incorporating asset market incompleteness, imperfect competition, and uncertainty 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, making a transparent but stark set of assumptions about the shocks beyond the horizon of our data. In providing this anatomy, therefore, the methodology does not provide a window into the future. To use the framework to look forward requires a better understanding of 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.

[41] Tombe (2014) 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.

References

Alessandria, G., J. Kaboski, and V. Midrigan (2010a): "The Great Trade Collapse of 2008-09: An Inventory Adjustment?," *IMF Economic Review*, 58(2), 254–294.

——— (2010b): "Inventories, Lumpy Trade, and Large Devaluations," *American Economic Review*, 100(5), 2304–2339.

Alvarez, F., and R. E. Lucas (2007): "General equilibrium analysis of the Eaton-Kortum model of international trade," *Journal of Monetary Economics*, 54(6), 1726–1768.

——— (2009): "Capital Accumulation and International Trade," *Working Paper*.

Amiti, M., and D. Weinstein (2011): "Exports and Financial Shocks," *The Quarterly Journal of Economics*, 126(4), 1841–1877.

Baldwin, R. (2009): *The Collapse of Global Trade, Murky Protectionism, and the Crisis: Recommendations for the G20*. Vox EU Ebook.

Behrens, K., G. Corcos, and G. Mion (2013): "Trade Crisis? What Trade Crisis?," *The Review of Economics and Statistics*, 95(2), 702–709.

Bems, R., R. Johnson, and K.-M. Yi (2010): "The Role of Vertical Linkages in the Propagation of the Global Downturn of 2008," *IMF Economic Review*, 58(2), 295–326.

Bems, R., R. C. Johnson, and K.-M. Yi (2013): "The Great Trade Collapse," *Annual Review of Economics*, 5, 375–400.

Bhagwati, J. (2009): "Comments in 'Collapse in World Trade: A Symposium of Views'," *The International Economy*, Spring, 28–38.

Boileau, M. (1999): "Trade in Capital Goods and the Volatility of Net Exports and the Terms of Trade," *Journal of International Economics*, 48(2), 347–365.

——— (2002): "Trade in Capital Goods and Investment-specific Technical Change," *Journal of Economic Dynamics & Control*, 26(6), 963–984.

Bricongne, J.-C., L. Fontagne, G. Gaulier, D. Taglioni, and V. Vicard (2011): "Firms and the Global Crisis: French Exports in the Turmoil," *Journal of International Economics*, 87(1), 134–146.

Brock, W. (2009): "Comments in 'Collapse in World Trade: A Symposium of Views'," *The International Economy*, Spring, 28–38.

Caliendo, L., and F. Parro (2015): "Estimates of the Trade and Welfare Effects of NAFTA," *The Review of Economic Studies*, 82(1), 1–44.

Chari, V., P. J. Kehoe, and E. R. McGrattan (2007): "Business Cycle Accounting," *Econometrica*, 75(3), 781–836.

Charles, K., E. Hurst, and M. Notowidigdo (2013): "Manufacturing Decline, Housing Booms, and Non-Employment," *Working Paper*.

Chor, D., and K. Manova (2011): "Off the Cliff and Back: Credit Conditions and International Trade during the Global Financial Crisis," *Journal of International Economics*, 87(1), 117–133.

Dekle, R., J. Eaton, and S. Kortum (2007): "Unbalanced Trade," *American Economic*

Review: Papers and Proceedings, 97(2), 351–355.

——— (2008): "Global Rebalancing with Gravity: Measuring the Burden of Adjustment," *IMF Staff Papers*, 55(3), 511–540.

Dornbusch, R., S. Fischer, and P. Samuelson (1977): "Comparative Advantage, Trade, and Payments in a Ricardian Model with a Continuum of Goods," *American Economic Review*, 67(5), 823–839.

Eaton, J., and S. Kortum (2002): "Technology, Geography, and Trade," *Econometrica*, 70(5), 1741–1780.

Eaton, J., S. Kortum, and B. Neiman (2013): "On Deficits and Unemployment," *Revue économique*, 64(3), 405–420.

Eichengreen, B. (2009): "Comments in 'Collapse in World Trade: A Symposium of Views'," *The International Economy*, Spring, 28–38.

Engel, C., and J. Wang (2011): "International Trade in Durable Goods: Understanding Volatility, Cyclicality, and Elasticities," *Journal of International Economics*, 83(1), 37–52.

Feldstein, M., and C. Horioka (1980): "Domestic Saving and International Capital Flows," *The Economic Journal*, 90(358), 314–29.

Fisher, J. D. (2006): "The Dynamic Effects of Neutral and Investment-Specific Technology Shocks," *Journal of Political Economy*, 114(3), 413–51.

Fitzgerald, D. (2012): "Trade Costs, Asset Market Frictions and Risk Sharing," *American Economic Review*, 6(102), 2700–2733.

Gawande, K., B. Hoekman, and Y. Cui (2011): "Determinants of Trade Policy Responses to the 2008 Financial Crisis," *Working Paper*.

Gopinath, G., O. Itskhoki, and B. Neiman (2012): "Trade Prices and the Global Trade Collapse of 2008-2009," *IMF Economic Review*, 60(3), 303–328.

Greenwood, J., Z. Hercowitz, and G. Huffman (1988): "Investment, Capacity Utilization, and the Real Business Cycle," *American Economic Review*, 78(3), 402–417.

Greenwood, J., Z. Hercowitz, and P. Krusell (1997): "Long-Run Implications of Investment-Specific Technological Change," *American Economic Review*, 87(3), 342–62.

Hoffmann, F., and T. Lemieux (2014): "Unemployment in the Great Recession: A Comparison of Germany, Canada, and the United States," *Working Paper*.

Jacob, P., and G. Peersman (2013): "Dissecting the Dynamics of the U.S. Trade Balance in an Estimated Equilibrium Model," *Journal of International Economics*, 90(2), 302–315.

Jurado, K. (2015): "Advance Information and Distorted Beliefs in Macroeconomic and Financial Fluctuations," *Working Paper*.

Justiniano, A., G. Primiceri, and A. Tambalotti (2010): "Investment Shocks and Business Cycles," *Journal of Monetary Economics*, 57(2), 132–145.

——— (2011): "Investment Shocks and the Relative Price of Investment," *Review of Economic Dynamics*, 14(1), 101–121.

Karabarbounis, L., and B. Neiman (2014): "The Global Decline of the Labor Share," *Quar-*

terly Journal of Economics, 129(1), 61–103.

——— (2015): "Capital Depreciation and Labor Shares Around the World: Measurement and Implications," *Working Paper*.

Kee, H. L., C. Neagu, and N. Alessandro (2013): "Is Protectionism on the Rise? Assessing National Trade Policies during the Crisis of 2008," *Review of Economics and Statistics*, 95(1), 342–346.

Kehoe, T., K. Ruhl, and J. Steinberg (2014): "Global Imbalances and Structural Change in the United States," *Working Paper*.

Krusell, P., L. E. Ohanian, J.-V. Rios-Rull, and G. L. Violante (2000): "Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis," *Econometrica*, 68(5), 1029–1053.

Kydland, F., and E. Prescott (1982): "Time to Build and Aggregate Fluctuations," *Econometrica*, 50(6), 1345–1370.

Lagakos, D., and M. Waugh (2013): "Selection, Agriculture, and Cross-Country Productivity Differences," *American Economic Review*, 103(2), 948–980.

Leibovici, F., and M. Waugh (2012): "International Trade and Intertemporal Substitution," *Working Paper*.

Levchenko, A. A., L. T. Lewis, and L. L. Tesar (2010): "The Collapse of International Trade During the 2008-2009 Crisis: In Search of the Smoking Gun," *IMF Economic Review*, 58(2), 214–253.

Lucas, R. E., and E. C. Prescott (1971): "Investment Under Uncertainty," *Econometrica*, 39(5), 659–681.

McKinnon, R. (2009): "Comments in 'Collapse in World Trade: A Symposium of Views'," *The International Economy*, Spring, 28–38.

Obstfeld, M., and K. Rogoff (2001): "The Six Major Puzzles in International Macroeconomics: Is there a Common Cause?," in *NBER Macroeconomics Annual 2000*. MIT: Cambridge, MA.

Schmitt-Grohe, S., and M. Uribe (2012): "What's News in Business Cycles," *Econometrica*, 80(6), 2733–2764.

Shikher, S. (2011): "Capital, technology, and specialization in the neoclassical model," *Journal of International Economics*, 83(2), 229–242.

Stockman, A., and L. Tesar (1995): "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements," *American Economic Review*, 85(1), 168–185.

Tombe, T. (2014): "The Missing Food Problem," *American Economic Journal: Macroeconomics*, forthcoming.

Yi, K.-M. (2009): "The Collapse of Global Trade: The Role of Vertical Specialization," in *The Collapse of Global Trade, Murky Protectionism, and the Crisis: Recommendations for the G20*, ed. by R. Baldwin, and S. Evenett, vol. 20, pp. 45–48. VoxEU.org.

	Country	Code	Share of Global GDP (percent)	Share of Global Trade (percent)	Trade / GDP (percent)	Production / GDP (percent)
(1)	Austria	AUT	0.7	1.5	39.5	57.8
(2)	Canada	CAN	2.6	3.0	19.9	40.0
(3)	China	CHN	7.5	10.3	24.0	153.1
(4)	Czech Republic	CZE	0.4	1.3	56.7	95.9
(5)	Denmark	DNK	0.6	0.9	28.0	37.6
(6)	Finland	FIN	0.5	0.8	29.2	71.2
(7)	France	FRA	4.7	5.3	19.7	42.8
(8)	Germany	DEU	6.0	11.1	32.4	68.2
(9)	Greece	GRC	0.6	0.4	13.4	31.5
(10)	India	IND	2.1	1.6	13.3	56.1
(11)	Italy	ITA	3.8	4.4	20.1	69.6
(12)	Japan	JPN	7.4	5.3	12.5	71.7
(13)	Mexico	MEX	1.9	2.4	21.4	55.2
(14)	Poland	POL	0.9	1.6	29.6	65.6
(15)	Romania	ROU	0.3	0.5	27.4	48.9
(16)	South Korea	KOR	1.6	3.2	36.0	138.2
(17)	Spain	ESP	2.6	2.7	17.7	50.1
(18)	Sweden	SWE	0.8	1.4	30.5	57.7
(19)	United Kingdom	GBR	4.5	4.2	16.6	34.4
(20)	United States	USA	23.9	12.3	9.0	37.1
(21)	Rest of World	ROW	26.5	25.7	17.0	61.6

Table 1: Summary Statistics for 20 Countries and Rest of World, 2008:Q3

Notes: Trade and production data are just for manufactures. Trade is defined as the average of exports and imports. Trade data do not include flows between countries within Rest of World. See Appendix Section A for details.

	$\hat{d}_i^D$			$\hat{d}_i^N$			$\Delta \frac{D_i^S}{Y_i^F}$		
	Prior Period	Global Recession	Recov Period	Prior Period	Global Recession	Recov Period	Prior Period	Global Recession	Recov Period
World	**0.99**	**0.99**	**0.95**	**0.98**	**0.97**	**0.97**	**0.00**	**0.00**	**0.00**
Austria	1.00	1.11	0.93	0.98	0.96	1.03	0.00	-0.02	0.01
Canada	1.00	1.06	0.94	0.99	1.04	0.99	0.00	0.05	0.00
China	0.99	1.03	0.94	1.00	1.00	0.93	0.01	-0.02	0.03
Czech Republic	0.94	0.96	0.91	0.97	0.95	0.94	0.01	-0.03	0.01
Denmark	0.98	1.05	0.73	0.97	0.89	0.95	0.00	0.03	0.00
Finland	1.00	1.12	1.00	0.99	1.03	0.95	0.00	-0.01	0.00
France	1.02	0.97	0.98	0.99	0.97	0.98	0.00	-0.01	0.01
Germany	0.98	0.99	0.98	0.97	0.98	0.99	0.00	-0.03	0.00
Greece	1.02	0.96	1.03	1.00	1.02	1.01	0.01	-0.02	0.00
India	0.96	1.10	0.94	0.96	1.04	0.97	0.00	-0.01	0.01
Italy	0.99	1.00	0.98	0.99	0.97	0.97	0.00	-0.02	0.00
Japan	1.02	0.93	0.95	0.97	1.00	1.00	0.00	-0.04	0.01
Mexico	0.98	0.94	0.88	0.99	0.96	0.99	0.00	0.01	0.00
Poland	0.95	0.90	0.97	0.96	0.89	0.98	0.00	-0.02	0.00
Romania	0.95	0.91	0.89	0.98	0.91	0.94	0.00	-0.01	-0.01
South Korea	0.99	0.92	0.98	1.00	0.92	0.95	0.01	-0.10	0.04
Spain	1.00	1.04	0.93	0.98	0.95	0.97	0.00	-0.03	0.01
Sweden	1.00	1.01	0.95	0.98	0.98	1.00	0.00	-0.01	0.01
United Kingdom	1.00	0.99	0.90	0.98	0.87	0.96	0.00	0.00	0.00
United States	0.99	1.00	0.94	0.98	0.98	0.98	0.00	-0.03	0.00
Rest of World	0.99	0.99	0.96	0.98	0.98	0.97	-0.01	0.06	-0.02

Table 2: Trade Frictions and Services Deficit Shocks

Notes: Global Recession is 2008:Q3 to 2009:Q2. Prior Period begins in 2000:Q1 with exceptions documented in Appendix Section A. Recovery Period is 2009:Q2 to 2011:Q1. Shocks are annualized. Trade friction shocks are calculated as a trade-weighted average of the bilateral shocks (see Footnote 31). The services trade deficit shock is the change in the deficit divided by GDP at the beginning of the quarter, averaged over the period.

	$\hat{A}_i^C$			$\hat{A}_i^D$			$\hat{A}_i^N$			$\hat{L}_i$		
	Prior Period	Global Recession	Recov Period	Prior Period	Global Recession	Recov Period	Prior Period	Global Recession	Recov Period	Prior Period	Global Recession	Recov Period
World	**1.00**	**0.92**	**1.05**	**1.02**	**1.02**	**1.02**	**1.01**	**1.03**	**1.02**	**1.01**	**0.98**	**1.00**
Austria	1.01	0.93	1.00	1.03	1.12	0.92	1.00	0.97	1.05	1.01	0.99	1.01
Canada	0.99	0.78	1.08	1.03	0.98	1.01	1.02	0.96	1.03	1.02	0.98	1.01
China	1.04	0.83	1.07	1.07	1.11	1.02	1.09	1.11	1.03	1.00	1.00	1.00
Czech Republic	1.00	1.09	0.93	1.00	0.92	0.93	1.01	0.96	0.96	1.01	0.99	0.99
Denmark	1.00	0.98	1.08	0.99	1.05	0.64	0.99	0.87	0.95	1.01	0.98	0.98
Finland	1.01	0.85	1.13	1.02	0.99	1.01	1.00	0.97	0.99	1.01	0.98	0.99
France	0.97	0.98	1.03	1.02	0.97	1.00	1.02	1.04	1.00	1.01	0.99	1.00
Germany	1.00	0.95	1.04	1.00	0.95	1.02	0.99	0.97	1.01	1.01	1.01	1.00
Greece	1.03	0.97	0.99	1.03	0.99	1.01	1.03	1.01	0.98	1.02	0.99	0.97
India	1.03	0.93	1.08	1.04	1.14	1.07	1.06	1.05	1.08	1.02	1.00	1.00
Italy	1.00	0.90	1.00	1.00	1.00	0.99	1.00	0.98	0.99	1.01	0.98	0.99
Japan	1.01	0.89	0.96	0.99	1.01	1.00	0.98	1.01	1.00	1.00	0.99	0.99
Mexico	1.02	0.96	1.05	1.01	0.92	0.94	1.03	0.93	1.04	1.02	1.01	1.01
Poland	0.98	1.35	0.97	1.02	1.00	1.03	1.03	0.99	1.03	1.01	1.02	0.98
Romania	0.99	0.87	1.03	1.02	0.92	0.93	1.04	0.88	0.97	1.01	0.97	0.99
South Korea	0.99	0.97	1.03	1.00	1.03	1.00	1.04	1.02	1.00	1.01	0.99	1.01
Spain	0.99	0.97	1.01	1.01	1.06	0.96	1.01	0.99	0.99	1.04	0.92	0.98
Sweden	0.99	0.88	1.03	1.01	0.93	1.03	1.00	0.99	1.05	1.01	0.98	1.00
United Kingdom	0.99	0.90	1.07	1.01	0.98	0.93	1.00	0.87	0.98	1.01	0.99	1.00
United States	0.99	0.98	1.04	1.01	1.02	1.00	0.99	1.18	0.96	1.01	0.96	0.99
Rest of World	1.00	0.90	1.06	1.03	0.97	1.05	1.03	0.96	1.05	1.01	0.99	1.01

Table 3: Productivity and Labor Supply Shocks

Notes: Global Recession is 2008:Q3 to 2009:Q2. Prior Period begins in 2000:Q1 with exceptions documented in Appendix Section A. Recovery Period is 2009:Q2 to 2011:Q1. Shocks are annualized. Productivity shocks for World are aggregated across countries analogous to trade frictions in Table 2.

	$\hat{\chi}_i^C$ Prior Period	$\hat{\chi}_i^C$ Global Recession	$\hat{\chi}_i^C$ Recov Period	$\hat{\chi}_i^D$ Prior Period	$\hat{\chi}_i^D$ Global Recession	$\hat{\chi}_i^D$ Recov Period	$\hat{\psi}_i^N$ Prior Period	$\hat{\psi}_i^N$ Global Recession	$\hat{\psi}_i^N$ Recov Period	$\hat{\phi}_i$ Prior Period	$\hat{\phi}_i$ Global Recession	$\hat{\phi}_i$ Recov Period
World	**1.01**	**0.98**	**0.98**	**0.99**	**0.77**	**1.08**	**0.99**	**0.77**	**1.10**	**1.00**	**1.00**	**1.00**
Austria	1.02	0.96	0.96	1.01	0.87	1.01	1.00	0.80	1.24	1.00	0.97	0.96
Canada	1.04	1.10	1.01	0.95	0.69	1.07	0.96	0.97	0.92	1.03	0.89	1.08
China	1.08	1.24	1.05	1.04	1.04	1.10	1.01	1.04	1.08	1.13	1.16	1.09
Czech Republic	1.09	0.70	1.02	1.02	0.56	1.11	0.94	0.78	1.09	1.09	0.88	0.96
Denmark	1.02	0.86	0.91	1.00	0.65	0.82	0.98	0.64	0.94	1.02	0.90	0.98
Finland	1.03	0.90	0.91	1.03	0.67	1.07	1.02	0.73	0.96	1.02	0.97	0.95
France	1.06	0.90	0.93	1.00	0.72	1.02	0.99	0.75	1.07	1.01	0.94	0.96
Germany	0.98	0.97	0.95	1.01	0.74	1.04	1.00	0.81	1.12	0.99	0.96	0.95
Greece	1.00	0.96	0.73	1.03	0.74	0.90	0.98	0.79	1.08	1.05	0.94	0.88
India	1.03	1.03	1.04	1.03	0.85	1.11	1.02	1.04	0.95	1.03	0.93	1.18
Italy	1.03	0.94	0.94	1.01	0.63	1.06	0.99	0.68	1.10	1.01	1.01	0.93
Japan	0.93	1.23	1.05	0.96	0.88	1.03	1.02	0.73	1.21	0.93	1.25	1.00
Mexico	1.01	0.75	0.98	0.96	0.58	1.03	1.00	0.95	1.08	1.00	0.74	1.08
Poland	1.10	0.53	1.12	1.01	0.52	1.05	0.99	0.94	1.16	1.06	0.68	1.03
Romania	1.20	1.04	0.92	1.09	0.45	1.08	0.97	0.66	1.11	1.14	0.68	0.96
South Korea	1.01	0.87	0.99	1.04	0.63	1.23	1.04	0.75	1.05	0.99	0.85	1.07
Spain	1.10	0.98	0.85	0.97	0.41	1.09	0.96	0.69	1.14	1.05	0.92	0.95
Sweden	1.02	0.81	1.08	0.99	0.53	1.19	1.01	0.96	1.05	1.00	0.82	1.08
United Kingdom	1.02	0.85	0.87	0.98	0.75	1.00	0.98	0.74	0.93	1.00	0.79	0.98
United States	0.97	0.97	0.87	0.95	0.79	1.03	1.00	0.71	1.11	0.98	1.06	0.96
Rest of World	1.03	0.91	0.99	1.03	0.72	1.11	0.99	0.72	1.13	1.04	0.98	1.04

Table 4: Investment Efficiency and Demand Shocks

Notes: Global Recession is 2008:Q3 to 2009:Q2. Prior Period begins in 2000:Q1 with exceptions documented in Appendix Section A. Recovery Period is 2009:Q2 to 2011:Q1. Shocks are annualized. Shocks to investment efficiency for the World are calculated as an investment-weighted average of the country shocks (see Footnote 32). Shocks to aggregate and nondurables demand for the World are calculated similarly, using overall consumption spending and nondurable consumption spending as weights.

		Change $\left(\frac{2009{:}Q2}{2008{:}Q3}\right)$ in Trade in Various Counterfactuals								
	Trade / World GDP in 2008:Q3 (percent)	**All Shocks (i.e. Data)**	**Trade Friction Shocks** $\left(\hat{d}^j_{ni}\right)$	**Prod. Shocks** $\left(\hat{A}^j_i\right)$	**Inv. Efficy. in Structures Shocks** $\left(\hat{\chi}^C_i\right)$	**Inv. Efficy. in Durables Shocks** $\left(\hat{\chi}^D_i\right)$	**Nondurables Demand Shocks** $\left(\hat{\psi}^N_i\right)$	**Aggregate Demand Shocks** $\left(\hat{\phi}_i\right)$	**Services Deficits Shocks** $\left(D^S_i\right)$	**Labor Supply Shocks** $\left(\hat{L}_i\right)$
World	**17.5**	**0.80**	**0.97**	**1.00**	**0.99**	**0.87**	**0.96**	**1.00**	**1.00**	**1.00**
Austria	0.3	0.79	0.90	1.04	0.99	0.87	0.96	0.99	0.99	0.99
Canada	0.5	0.75	0.91	0.99	1.02	0.87	0.99	1.03	1.01	1.01
China	1.8	0.85	0.91	1.11	0.98	0.93	0.97	0.98	0.99	1.00
Czech Republic	0.2	0.75	1.02	0.91	1.00	0.81	0.97	1.00	0.99	0.99
Denmark	0.2	0.81	1.01	0.96	0.99	0.86	0.95	1.01	1.00	0.99
Finland	0.1	0.68	0.86	0.97	1.00	0.85	0.97	1.01	1.00	1.00
France	0.9	0.83	1.03	0.98	1.00	0.86	0.95	1.00	0.99	1.00
Germany	1.9	0.78	0.99	0.96	0.99	0.86	0.96	1.00	0.99	1.00
Greece	0.1	0.83	1.02	1.00	1.00	0.89	0.96	0.98	1.00	1.00
India	0.3	0.83	0.91	1.06	1.00	0.92	0.98	1.01	0.99	1.00
Italy	0.8	0.77	0.98	0.98	0.99	0.85	0.94	0.99	0.99	0.99
Japan	0.9	0.77	0.95	1.01	0.98	0.89	0.96	0.97	0.98	0.99
Mexico	0.4	0.77	1.01	0.97	1.00	0.81	0.99	1.04	1.00	1.00
Poland	0.3	0.76	0.97	0.99	0.98	0.80	0.97	1.03	0.99	0.99
Romania	0.1	0.72	1.06	0.94	0.99	0.75	0.94	1.01	0.99	0.98
South Korea	0.6	0.83	0.99	1.03	0.99	0.87	0.97	1.01	0.98	0.99
Spain	0.5	0.76	0.97	1.01	1.00	0.83	0.95	0.99	1.00	0.98
Sweden	0.3	0.72	0.95	0.94	0.99	0.82	0.98	1.03	0.99	0.99
United Kingdom	0.7	0.81	1.01	0.97	0.99	0.86	0.95	1.02	0.99	0.99
United States	2.2	0.81	0.98	1.02	1.00	0.87	0.97	1.01	1.00	1.00
Rest of World	4.5	0.79	0.97	0.99	1.00	0.87	0.96	1.00	1.00	1.00

Table 5: Trade during the Global Recession

Notes: Each column reports the outcome of counterfactuals that include individual shock paths with all other shocks suppressed. The reported effects capture the annualized rate of growth of trade during the three quarter recession for each transition path. All values are relative to global GDP.

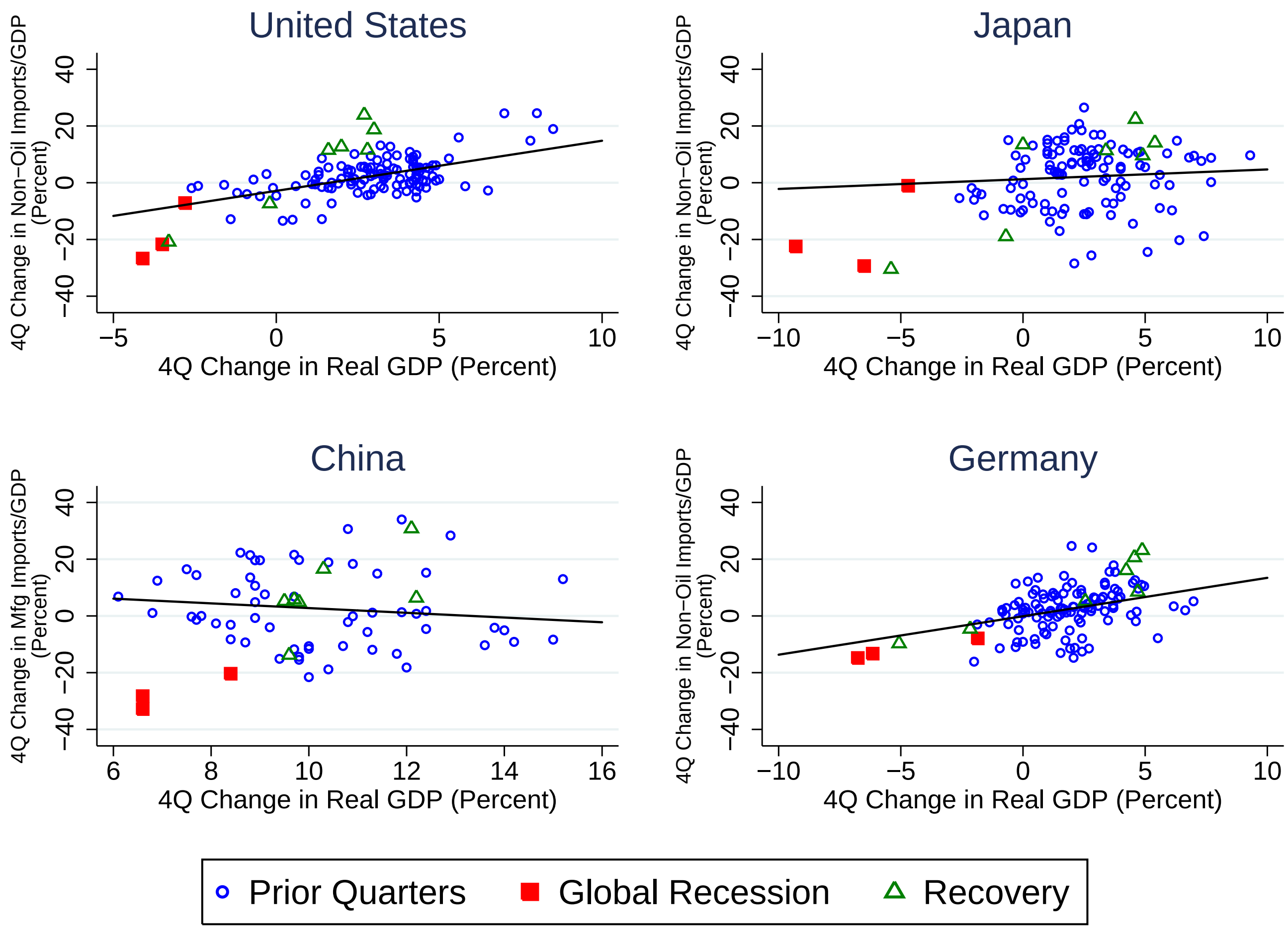
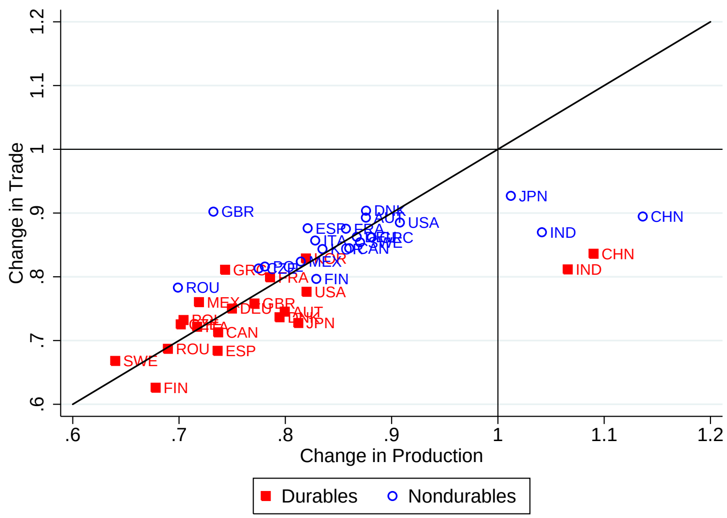
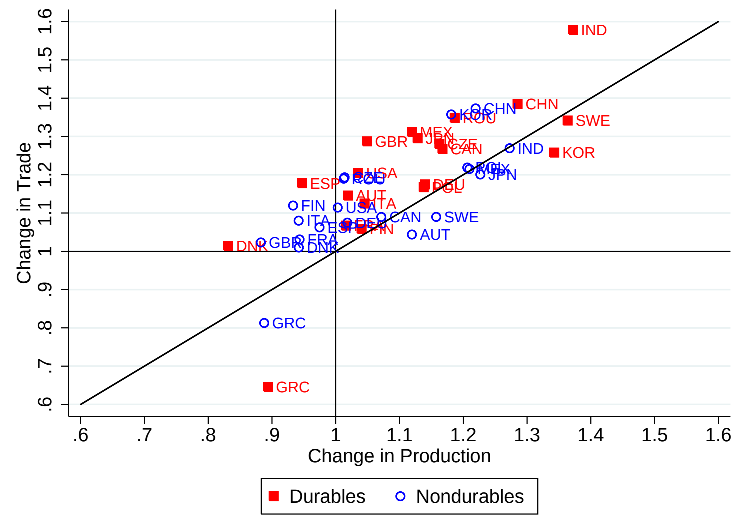


Figure 1: Cyclical Properties of Trade in the Four Largest Economies

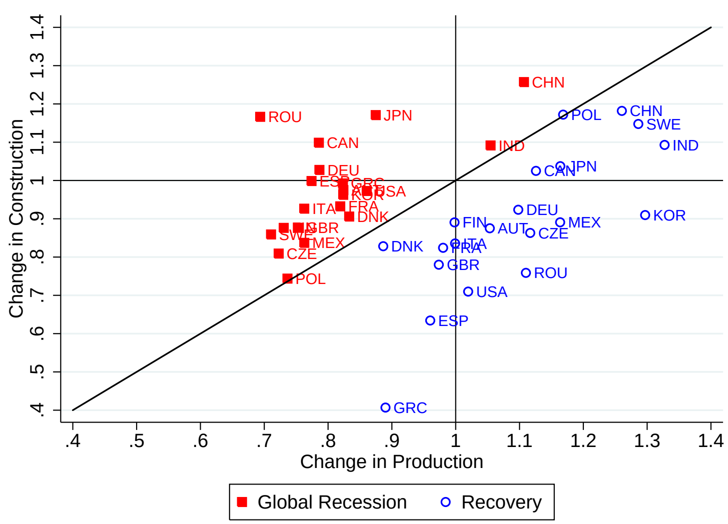
Notes: Global Recession includes the three quarters from 2008:Q3 to 2009:Q2 and Recovery includes the seven quarters from 2009:Q2 to 2011:Q1. The beginning quarter for the United States and Germany is 1979:Q1, for Japan 1981:Q1, and for China 1993:Q1. Data limitations force us to report manufacturing imports relative to GDP for China. See Appendix Section A for details.



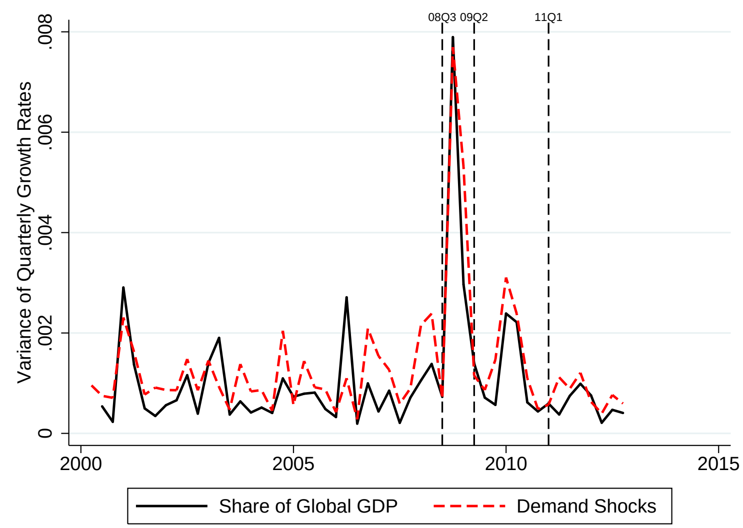
(a) Changes in Trade and Production during the Global Recession



(b) Changes in Trade and Production during the Recovery



(c) Changes in Construction and Production during both Periods



(d) Variance of GDP Growth and Aggregate Demand Shocks

Figure 2: Trade, Production, Construction, and GDP in the Global Recession and Recovery

Notes: Observations in Panels (a)-(c) give the ratio of the value at the end of period divided by that at the beginning of the period, so a value of 1 implies no change. Panel (d) plots the variance of quarterly growth of GDP shares and of shocks to aggregate demand. The dotted vertical lines indicate the dates of the "Global Recession" and "Recovery". All values are relative to global GDP.

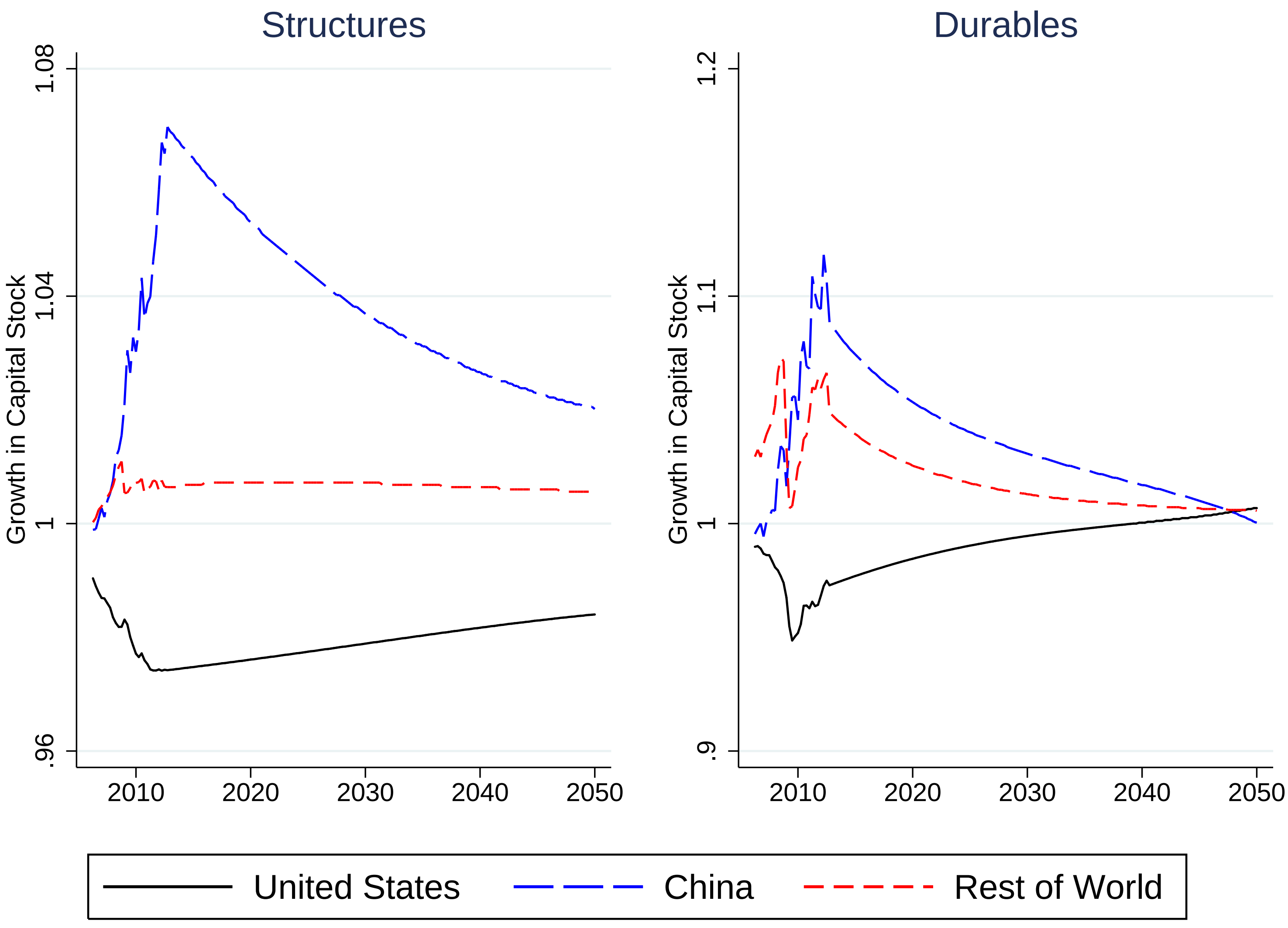


Figure 3: Simulated Transition of Capital Stocks Toward Steady State

Notes: The figures plot, for the three largest countries, the evolution of annualized growth rates in structures and durable capital stocks implied by our model. The figures include the observed period for which we have data as well as the subsequent imputed transition toward steady state. The growth rates are annualized.

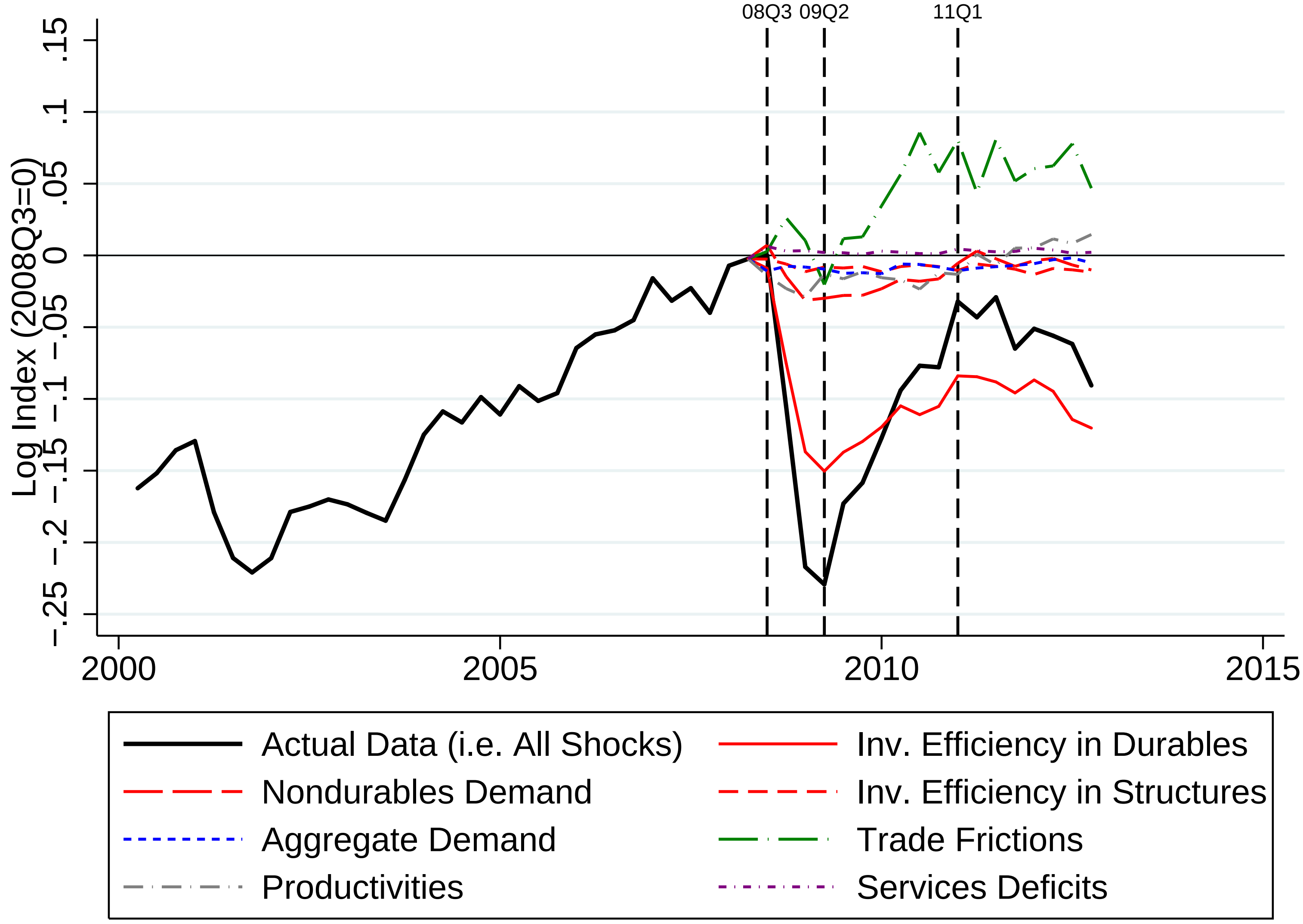


Figure 4: Actual and Counterfactual Evolution of Global Trade

Notes: Lines beginning in 2008:Q3 represent counterfactual outcomes with the paths of indicated shocks at their calibrated values and all other shocks unchanged. All values are relative to global GDP.

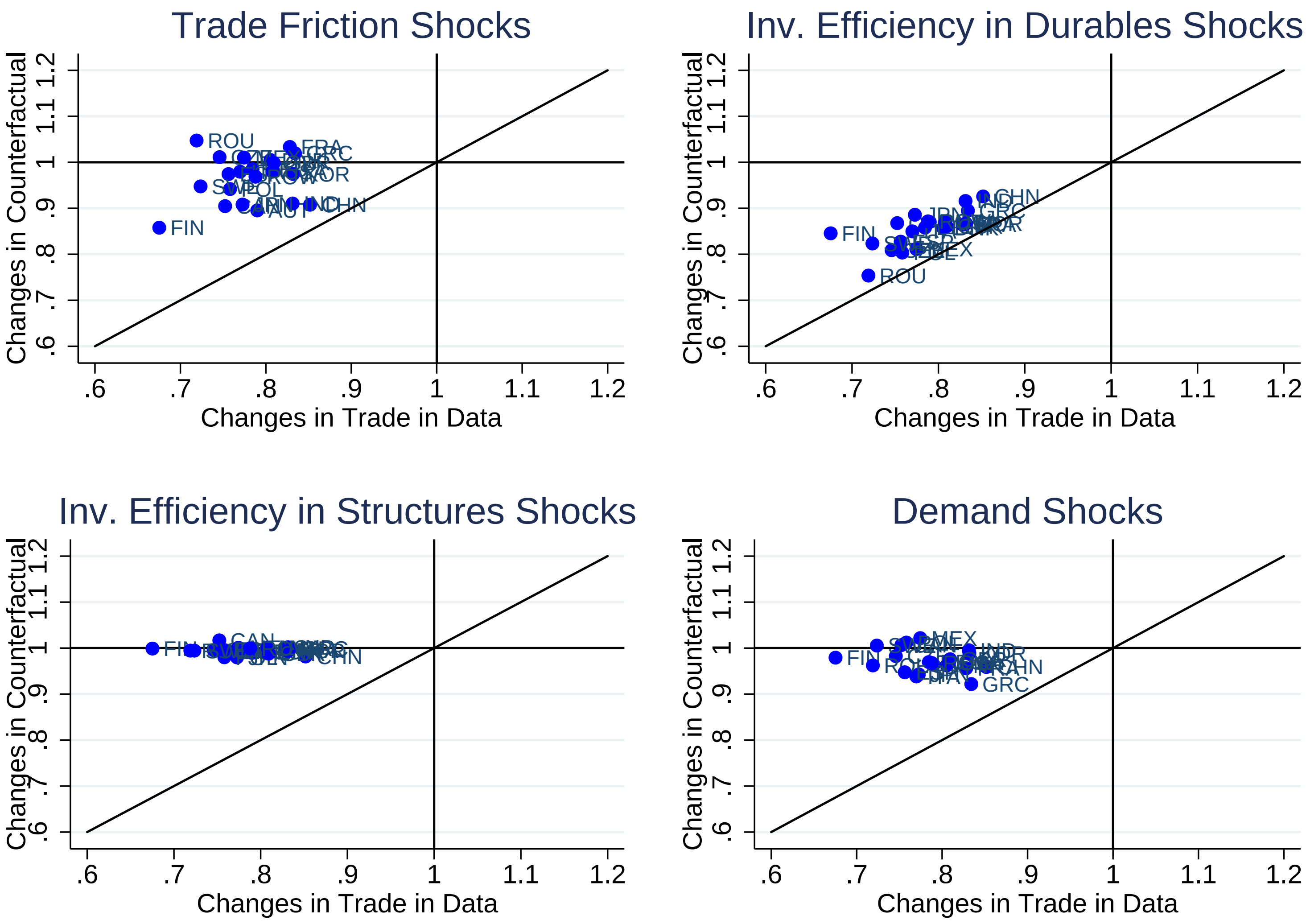


Figure 5: Cross-Sectional Explanatory Power of Various Shocks for Trade during the Global Recession

Notes: The figures plot, against the actual changes in a country's trade during the three quarter recession, the changes that occur over that period in a counterfactual exposed only to the path of the indicated shocks. All values are relative to global GDP.

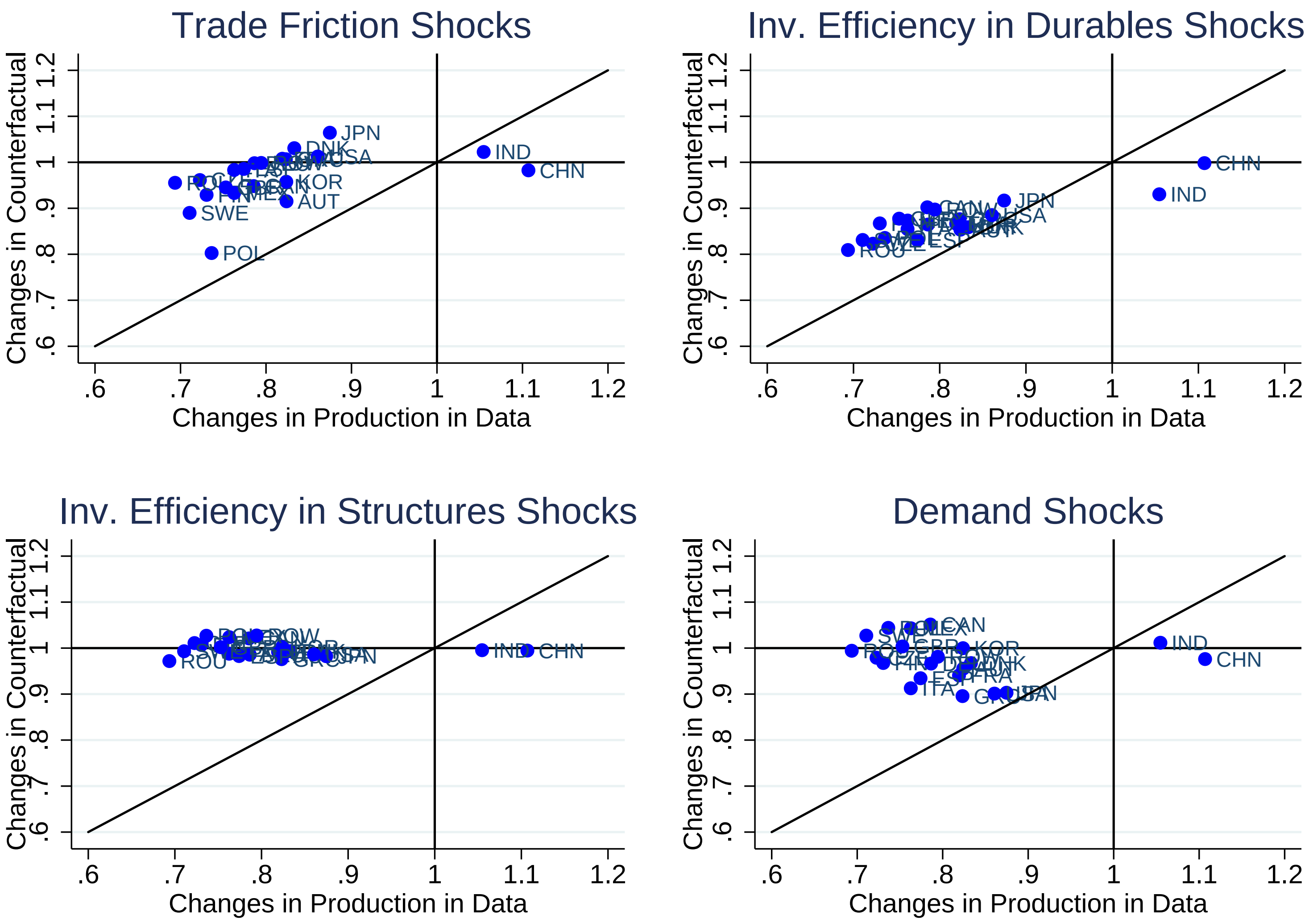


Figure 6: Cross-Sectional Explanatory Power of Various Shocks for Production during the Global Recession

Notes: The figures plot, against the actual changes in a country's production during the three quarter recession, the changes that occur over that period in a counterfactual exposed only to the path of the indicated shocks. All values are relative to global GDP.

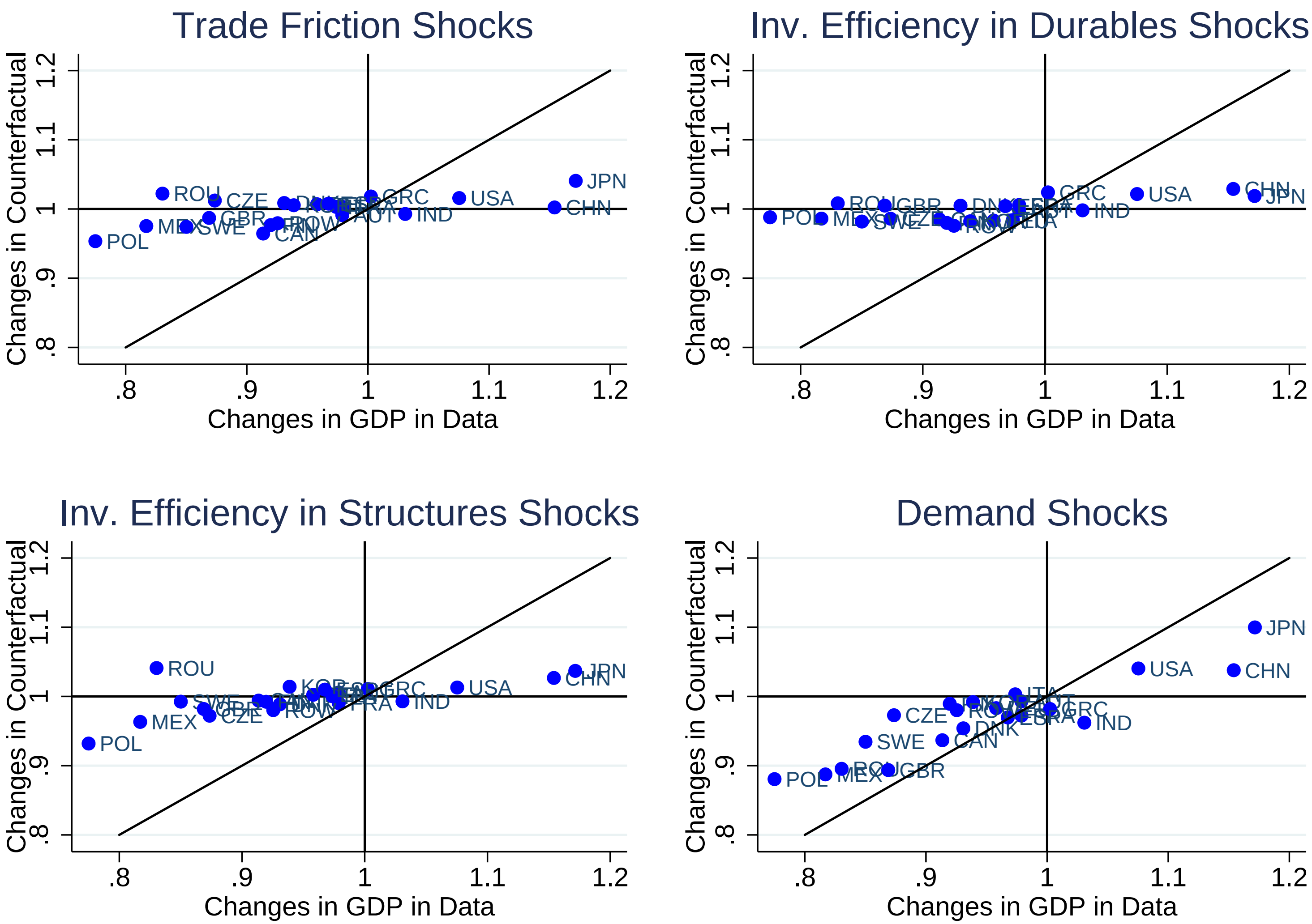


Figure 7: Cross-Sectional Explanatory Power of Various Shocks for GDP during the Global Recession

Notes: The figures plot, against the actual changes in a country's GDP during the three quarter recession, the changes that occur over that period in a counterfactual exposed only to the path of the indicated shocks. All values are relative to global GDP.

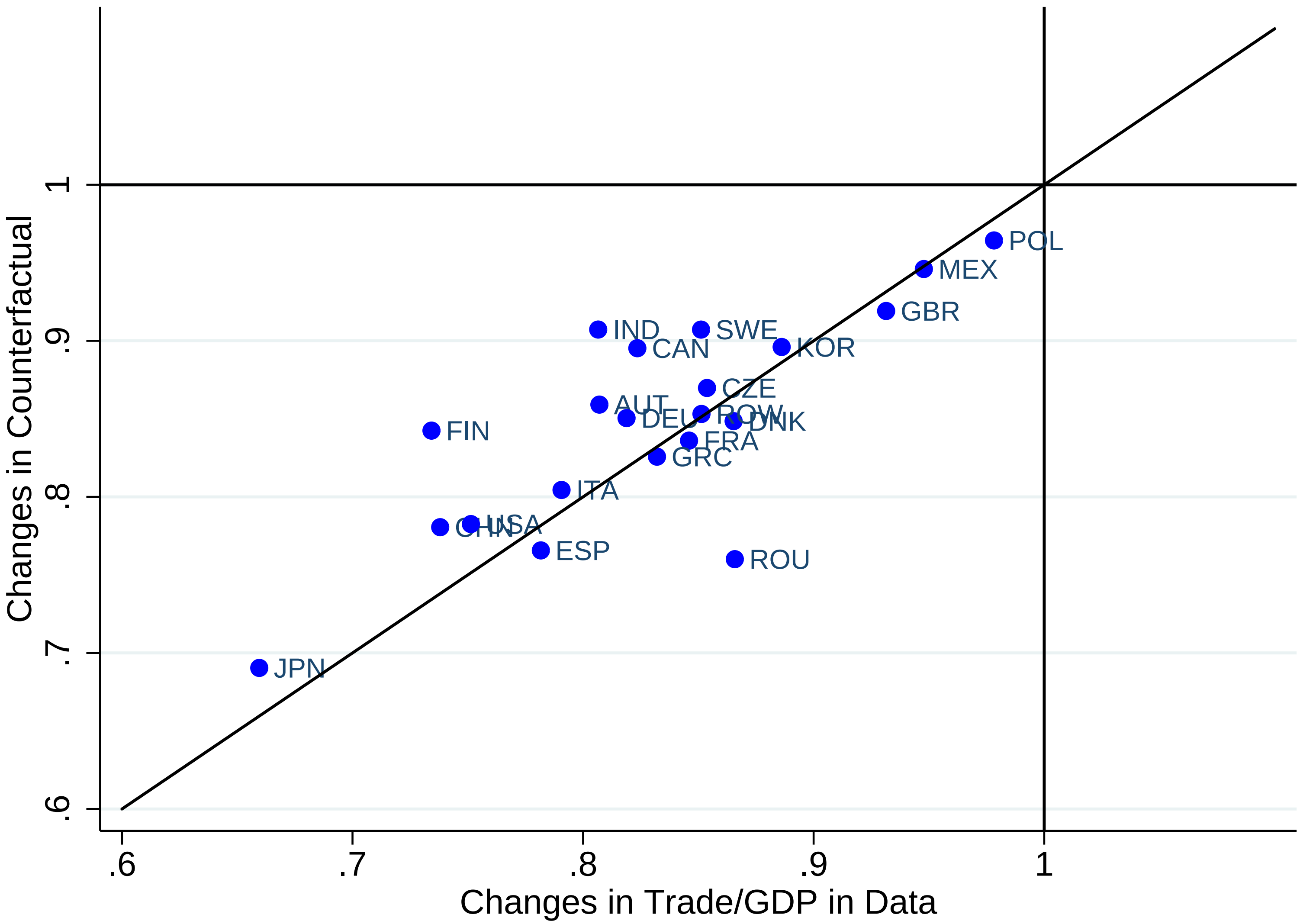


Figure 8: Explanatory Power of Investment Efficiency and Demand Shocks for Trade/GDP during the Global Recession

Notes: The figures plot, against the actual changes a country's Trade/GDP during the three quarter recession, the changes that occur over that period in a counterfactual exposed only to the path of shocks to investment efficiencies and to demand.

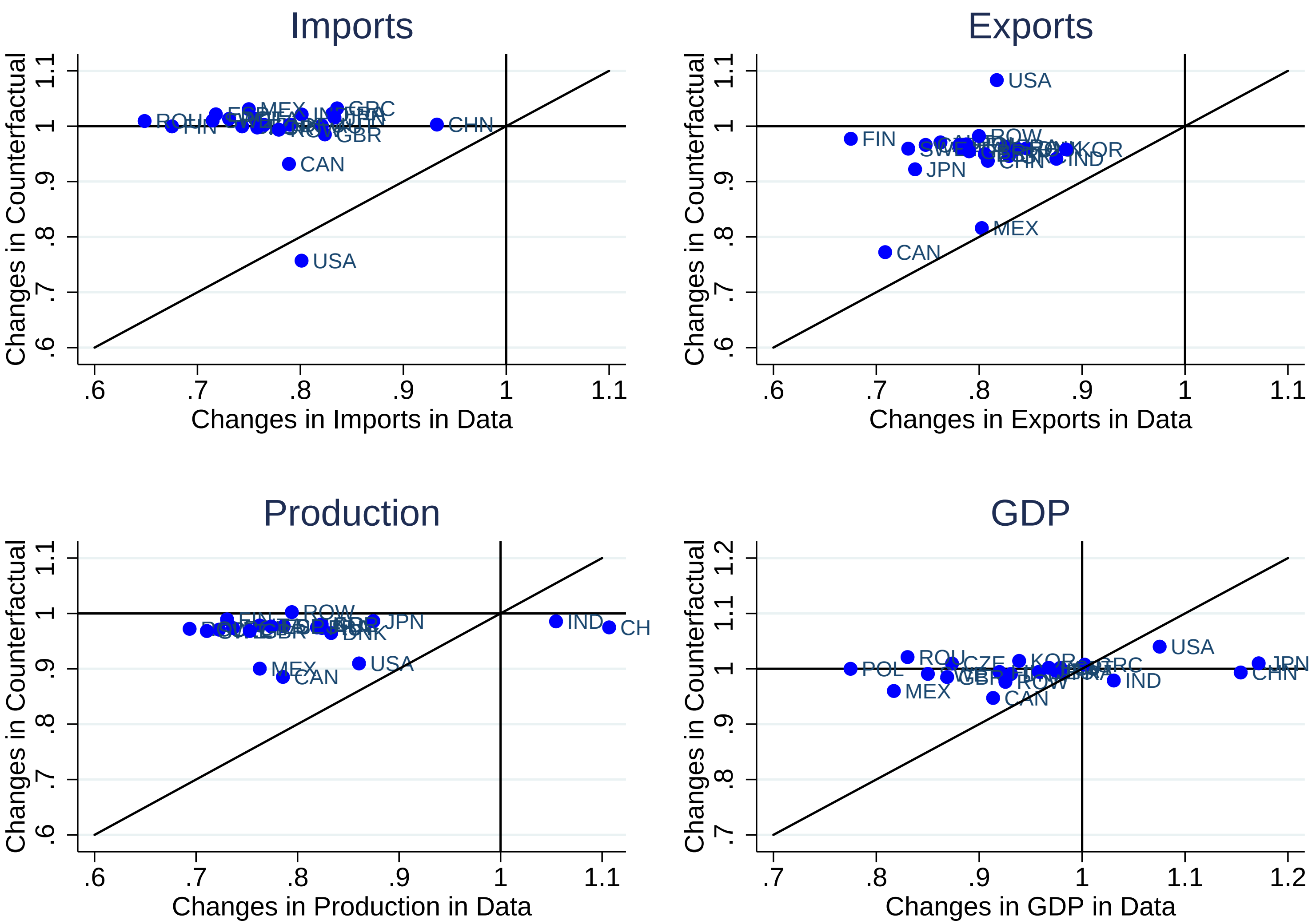


Figure 9: Counterfactual Response to U.S. Shocks during the Global Recession

Notes: The figures plot, against the actual changes in a country's imports, exports, production, and GDP during the three quarter recession, the changes that occur over that period in a counterfactual exposed only to U.S. shocks. That is, we plot the counterfactual response when labor, trade frictions, productivity, investment efficiency, demand, and services deficit shocks for the United States occur as they did in the data, but where no other shocks occur.

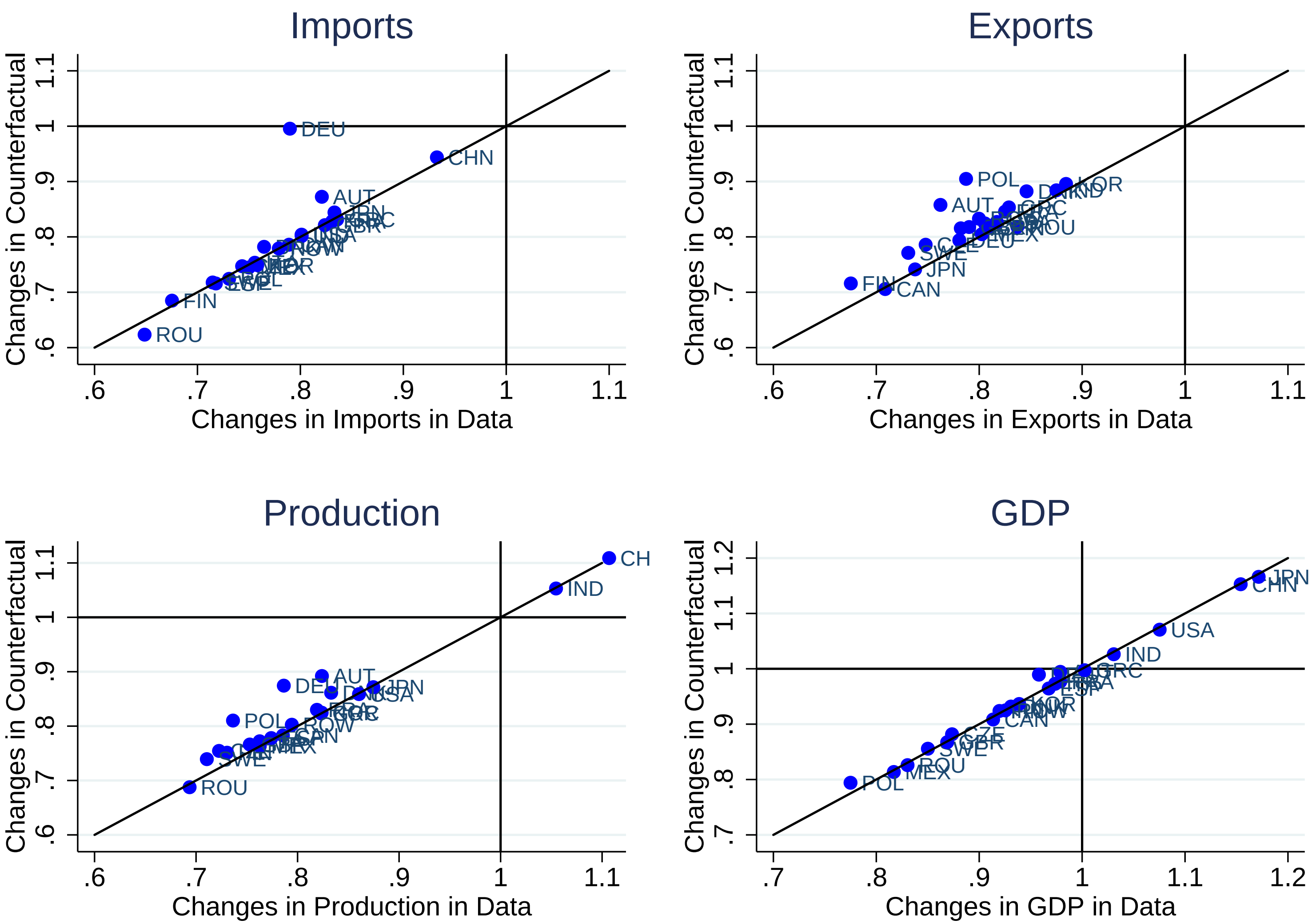


Figure 10: Counterfactual Response to Shocks other than Germany's during the Global Recession

Notes: The figures plot, against the actual changes in a country's imports, exports, production, and GDP during the three quarter recession, the changes that occur over that period in a counterfactual exposed only to shocks other than Germany's. That is, we plot the counterfactual response when labor, trade frictions, productivity, investment efficiency, demand, and services deficit shocks occur as they did in the data for all countries other than Germany.