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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 GDPs in terms of different sets of shocks. Applying the model to 21 countries, we investigate the 29 percent drop in world trade during 2008-2009. A shift in final spending away from tradable sectors, largely caused by declines in durables investment efficiency, accounts for most of the collapse in trade relative to GDP. Shocks to trade frictions, productivity, and demand play minor roles.

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1 Introduction

International trade in manufactures 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, as shown in Figure 1, 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-sector general equilibrium model of international trade into a multi-country real business cycle model. We divide economic activity into the manufacture of durables, the manufacture of nondurables, construction, and everything else (called "services"). Only the outputs of the first two sectors are tradable. Output of the durable manufacturing sector goes into stocks of equipment while construction activity creates structures. The framework incorporates economic geography, an input-output structure, and capital accumulation. With saving and investment chosen optimally in each country, trade imbalances emerge endogenously. 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 six types of country-specific shocks: (i) to the cost of trade in each manufacturing sector between each pair of trading partners, (ii) to productivity in each sector, (iii) to the efficiency of investment in each type of capital, (iv) to aggregate demand, (v) to the demand for nontradable manufactures, and (vi) 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 recession through the end

[1] We measure the drop from the third quarter of 2008 to the second quarter of 2009. The data are trade in manufactures and GDP, both in current U.S. dollars. Appendix Figure A.1 plots trade in goods and services relative to GDP for the four largest economies in the world: the United States, Japan, China, and Germany. In 2007 trade in manufactures constituted 68.6 percent of the total trade of the 20 countries in our study while in 2009 manufactures constituted 66.7 percent of their trade. Hence trade in manufactures was both the bulk of trade and the largest participant in the trade collapse. We focus on trade in manufactures because we lack comprehensive data on bilateral trade in services, while the small amount of trade in other merchandise, such as oil, is subject to idiosyncratic forces outside the scope of our analysis.

[2] Shocks (i) to (iii) are to technology, shocks (iv) and (v) are to preferences, and shocks (vi) are to endowments. Since we don't model trade in services, to respect accounting identities we introduce exogenous services deficits, which we treat as transfers, as our seventh type of shock. While services deficits are exogenous, overall deficits emerge as equilibrium outcomes. Services deficits turn out to play only a very small role in our quantitative analysis.

of the subsequent recovery. We assemble quarterly data on nominal and real GDP as well as on prices, production, and bilateral trade by sector 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 from 2000 to 2012.

Our model embeds a gravity equation for trade in each manufacturing sector, which allows us to extract shocks to trade costs using movements in bilateral trade shares and prices. We apply the dual to extract shocks to total factor productivity in each sector using output and input prices and, for the two traded sectors, the import share. We extract shocks to the efficiency of investment in each type of capital to reconcile data on investment spending with the model's implication for the dynamics of the capital stock. Our assumption of complete markets allows us to back out shocks to demand from shifts in consumption spending across countries and in the composition of consumption spending within countries. Since we treat labor as exogenous, we take the labor shock directly from data on changes in employment.

If we feed in all the shocks, the dynamic solution of our model will reproduce exactly the quarterly data on GDP, prices, production, and trade in each country. Instead, we introduce various subsets of these shocks and run dynamic general equilibrium counterfactuals to address two questions:[3] What type of shocks drove what happened? Where did these shocks originate? We look not only at trade, but also at manufacturing production and GDP around the world. Several results stand out.

Declines in the efficiency of investment in durable manufactures, an intensively traded sector, were the major driver of the overall collapse in trade, as well as the decline 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 quite flat in the eight years before. These declines shifted final spending away from durables toward the nontraded sectors. A counterfactual with these shocks on their own generates almost two-thirds of the collapse in global trade relative to GDP.

Moreover, cross-country differences in these shocks were the primary determinant of cross-country variation in the declines 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 durables trade and the largest

[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 closed-economy business-cycle accounting.

increase in durables production. At the other extreme, Romania and Spain had the steepest declines in durables investment efficiency and among the steepest declines in durables trade. Our results complement the literature, discussed below, pointing to the importance of investment efficiency shocks in quantitative business cycle models.

Other types of shocks made more modest contributions to the trade collapse. Declines in the demand for nondurable manufactures (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, led them to source a larger share of their traded goods domestically.

Productivity in nontraded sectors generally declined, but for tradable sectors productivity often rose. Productivity shocks therefore had little impact on global trade. Increases in a country's aggregate demand raise 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.[4]

The global nature of the trade collapse 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 directly 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 production slowdown. Its trading relationships with the rest of the world meant that shocks elsewhere played a significant role in its downturn.

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 for nondurables. By 2012, however, global trade had leveled off below its pre-recession peak.

Finally, we ask how our shocks account for fluctuations in real GDP. Shocks to productivity in nontraded sectors and shocks to labor supply had the greatest impact. Hence we attribute the decline in real GDP during the global recession primarily to a different set of shocks (productivity and labor supply) than those most responsible for the decline in trade and in manufacturing

[4] We report all nominal values in terms of nominal global GDP. We use the term *relative GDP* (or simply *GDP* if there is no ambiguity) to mean a country's nominal GDP translated into U.S. dollars relative to the dollar value of global GDP. To distinguish this concept from that of real GDP, we use the term *real GDP* when referring to this second concept.

production (investment efficiency).

Our paper proceeds as follows. Section 2 reviews the 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 observable outcomes to 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 which identify the role of different types of shocks in the global recession. Section 8 concludes.

2 Related Literature

Our work bridges several 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.

2.1 The Trade Collapse

Baldwin (2009) serves 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, including Amiti and Weinstein (2011) and Chor and Manova (2011), blame the trade collapse on tightening trade credit. Others, including Brock (2009), cite increased protectionism.

Another literature has attributed the collapse in trade to the differential impact of the recession on different sectors of the economy.[5] A third hypothesis put forth in Eichengreen (2009) and Yi (2009) is that international vertical supply chains disintegrated.

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

[5] See, for example, Levchenko, Lewis, and Tesar (2010) for a detailed analysis of the United States, Behrens, Corcos, and Mion (2013) for Belgium, Bricongne, Fontagne, Gaulier, Taglioni, and Vicard (2011) for France, and Bems, Johnson, and Yi (2010) for an analysis of multi-country trade and production data.

did not. Our bottom line largely supports their conclusion. We attribute 64 percent 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 11 percent of the decline in global trade relative to GDP. 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 work relates to a large open-economy macroeconomics literature that studies the behavior of trade, predominantly using dynamic two-country models. Stockman and Tesar (1995) highlight the importance of shocks to intertemporal preferences while Boileau (1999) and Engel and Wang (2011) explain the greater volatility of trade by recognizing that a large share of what is traded consists of durable intermediates rather than final goods.[6] Alessandria, Kaboski, and Midrigan (2010a,b) develop dynamic two-country models in which inventories play a central role. Leibovici and Waugh (2012) emphasize the time-to-ship friction for explaining trade dynamics, while investment shocks play a critical role in Boileau (2002), Erceg, Guerrieri, and Gust (2008), and Jacob and Peersman (2013).[7]

Our methodology builds 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. Their analysis is limited to two countries, so is not amenable to realistic quantification. Dekle, Eaton, and Kortum (2007, 2008) and Eaton, Kortum, Neiman, and Romalis (2011) develop multi-country models that can be confronted with the rich data on bilateral trade, but their models are static and treat deficits and shocks to the demand for tradables as exogenous.

Alvarez and Lucas (2009) and Fitzgerald (2012) also embed multi-country models with trade barriers into explicitly dynamic frameworks. Alvarez and Lucas study transition dynamics and steady state responses to tariff changes in a model with balanced trade. Fitzgerald tests for asset-market completeness and, among rich counties, is unable to reject it. We push our frame-

[6]Kose and Yi (2001), Ambler, Cardia, and Zimmermann (2004), Huang and Liu (2007), Arkolakis and Ramanarayanan (2009), and Johnson (2014) address the role of trade in intermediates for business cycle transmission and for the correlation of consumption across countries.

[7]Greenwood, Hercowitz, and Huffman (1988) introduce shocks to investment efficiency. A large subsequent literature in closed-economy macroeconomics identifies such shocks as a major driver of aggregates, particularly of investment, over the business cycle. See, for instance, Fisher (2006), Justiniano, Primiceri, and Tambalotti (2010, 2011), Schmitt-Grohe and Uribe (2012), and Jurado (2015).

work 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.

The real business cycle literature has sought to uncover the ergodic processes driving business 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) in their study of the joint dynamics of traded sector employment and the U.S. trade deficit.

3 A First Look at the Data

Along with the collapse of trade, other features of the global recession were a decline in construction and a drop in manufacturing production. The long-dashed line in Figure 1 shows that construction didn't start its persistent slide until 2009:Q2. By contrast, trade and manufacturing production both fell sharply after 2008:Q3 and rebounded after 2009:Q2. For the purposes of studying the trade collapse we thus identify the period 2008:Q3 to 2009:Q2 as the global recession.

During these quarters global manufacturing production (plotted with the short-dashed line in Figure 1) fell by 13 percent while global trade in manufactures (plotted with the sold line) declined by an even larger 20 percent. To what extent was the sharper decline in trade due to compositional effects between countries or between durable and nondurable manufacturing within countries?

To perform the first component of this decomposition, we divide the world into the 21 countries listed in Table 1.[8] We can account for nearly half (49 percent) of the decline in manufacturing trade relative to manufacturing production by relatively greater declines in production in (mostly smaller) countries with higher ratios of trade to production.[9]

[8]The data shown in the table are for 2008:Q3, the base period before the global trade collapse. Not including Rest of World, the other 20 countries comprise nearly three-fourths of global GDP. Appendix Section A describes the data used here and throughout the paper.

[9]We decompose the global decline in the ratio of trade to production in manufactures into within and between country effects as follows. Let T_n^M be trade in manufactures and Y_n^M production of manufactures in country $n = 1, ..., \mathcal{N}$. The decomposition is:

$$\Delta\left(\frac{T^M}{Y^M}\right) = \underbrace{\sum_{n=1}^{\mathcal{N}} \overline{Y_n^M / Y^M} \times \Delta\left(\frac{T_n^M}{Y_n^M}\right)}_{\text{Within-Country}} + \underbrace{\sum_{n=1}^{\mathcal{N}} \overline{T_n^M / Y_n^M} \times \Delta\left(\frac{Y_n^M}{Y^M}\right)}_{\text{Between-Country}},$$

As for the second component, Engel and Wang (2011) and Levchenko, Lewis, and Tesar (2010) point out that durables, which were particularly hard hit during the recession, are more intensively traded. During the recession, the ratio of trade to production was 31 percent for durables compared with 22 percent for nondurables, and the share of durables in total production declined by 2.2 percentage points during the recession.[10] Combining this sectoral reallocation with the country reallocation discussed above, we find that compositional effects account for 60 percent of the decline in global trade relative to global production.

In Figure 2(a), we separately plot each country's change in durables trade and production (in solid squares) and nondurables trade and production (in hollow circles). (Here and in what follows we report changes as the value at the end of the period divided by the value at the beginning of the period. Hence no change delivers 1.) Several points stand out. First, the declines in trade and manufacturing production were widespread. Second, the declines in trade and production for durables were almost always more pronounced than for nondurables. Third, where production falls more trade falls 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.

Several authors have examined the role of construction in the global recession.[11] Figure 2(c) plots changes in construction against manufacturing production both in the recession and recovery. Where construction declined at all, it never fell more than production. 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.

Finally, Figure 2(d) compares changes in countries' real GDPs with changes in their relative GDPs during the recession and recovery. During the recession real GDP declined in most countries by from three to six percent. China, India, and Poland are the only countries where real GDP grew. Changes in relative GDP were more extreme, with China, Japan, and the United States displaying the largest increases.[12] Not only did real global activity decline in the recession, there was also a major cross-country realignment in incomes.

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where x (with no subscript) denotes the global total of x_n, Δx_n denotes its value in 2009:Q2 less its value in 2008:Q3, and $\overline{x}_n$ denotes the average of its value in these two quarters.

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

[11] Charles, Hurst, and Notowidigdo (2013) look at U.S. manufacturing and construction employment while Hoffmann and Lemieux (2014) compare construction employment in Canada, Germany, and the United States.

[12] These changes in relative GDPs, of course, in part reflect the appreciations of the Chinese renminbi, the Japanese yen, and the U.S. dollar in this period.

4 The Model

We now turn from the data 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.

4.1 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).[13] The economy has $n = 1, ..., \mathcal{N}$ countries each with four sectors: construction (C), durable manufactures (D), nondurable manufactures (N), and services (S).[14] We let $\Omega = \{C, D, N, S\}$ denote the set of all sectors.

In addition to its labor endowment $L_{n,t}$, at any date t country n has an endowment $K^k_{n,t}$ 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.

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 $z \in [0, 1]$.[15] Country n's efficiency $a^j_{n,t}(z)$ at making good z in sector j is the realization of a random variable $a^j_{n,t}$ with distribution:

$$F^j_{n,t}(a) = \Pr\left[a^j_{n,t} \leq a\right] = \exp\left[-\left(\frac{a}{\gamma A^j_{n,t}}\right)^{-\theta}\right], \tag{1}$$

drawn independently for each z across countries n. Here, $A^j_{n,t} > 0$ is a parameter that reflects

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

[14] 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.

[15] Our analysis would emerge largely unscathed if we modelled output of each sector in each country as homogeneous but differentiated according to source, as in Armington. Our approach does not require specifying production technology as requiring inputs classified by both sector and provenance.

country n's overall productivity in sector j. The parameter θ is an inverse measure of the dispersion of efficiencies.[16]

Production of good z 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 returns to scale. The output elasticities in country n and sector j for labor, capital of type k, and intermediates from sector j' are given by $\beta_n^{L,j}$, $\beta_n^{K,jk}$, and $\beta_n^{M,jj'}$ for $j, j' \in \Omega$, $k \in \Omega_K$.

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 $d_{ni,t}^j \geq 1$ units, with $d_{nn,t}^j = 1$. (For the nontraded construction and services sectors we treat $d_{ni,t}^j$ as infinite for $i \neq n$.)

4.1.2 Capital Stock Dynamics

Capital of type k accumulates in country n according to:

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

where $I_{n,t}^k$ is investment, $\chi_{n,t}^k$ governs the efficiency of investment, $0 < \alpha^k \leq 1$ governs adjustment costs, and δ^k is the depreciation rate. In introducing shocks to the efficiency of investment we follow recent developments in the business cycle literature described in Section 2.2. 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 $\psi_{n,t}^j \geq 0$, 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

[16] To simplify the expressions that follow, we introduce:

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

where Γ denotes the gamma function and where we assume that $\theta > \sigma - 1$. As long as this inequality 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 intertemporal preferences for country n at date t, which we call 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 n. We restrict aggregate demand shocks to have no global component, setting $\sum_{n=1}^{\mathcal{N}} \omega_n \phi_{n,t} = 1$. 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 n, $K_{n,0}^k$.

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 n at date t, $L_{n,t}^j(z)$, can't exceed the labor endowment $L_{n,t}$:

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

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

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

3. In each country n at each date t the output $y_{n,t}^j(z)$ of good z in sector j can't exceed what's

implied by inputs and technology:

$$y^j_{n,t}(z) \leq a^j_{n,t}(z) \left(\frac{L^j_{n,t}(z)}{\beta^{L,j}_n}\right)^{\beta^{L,j}_n} \prod_{k\in\Omega_K} \left(\frac{K^{jk}_{n,t}(z)}{\beta^{K,jk}_n}\right)^{\beta^{K,jk}_n} \prod_{j'\in\Omega} \left(\frac{M^{jj'}_{n,t}(z)}{\beta^{M,jj'}_n}\right)^{\beta^{M,jj'}_n},$$

where $M^{jj'}_{n,t}(z)$ are intermediates from sector j' used to make good z in sector j.

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

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

where $x^j_{mn,t}(z)$ is country m's absorption of good z in sector j from country n (and $d^j_{mn,t}$ 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. What its households consume and what it uses as intermediates can't exceed country n's absorption from sector $h \in \Omega^*_K$:

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

8. What its firms invest and what it uses as intermediates can't exceed country n's absorption from sector $k \in \Omega_K$:

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

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:

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

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, together with the distributional assumption (1), delivers simple expressions for sectoral allocations and the shadow prices on the associated constraints. We interpret the appropriate shadow prices, for each country n at each date t, as a price index $p^j_{n,t}$ for absorption in sector j, a wage to labor $w_{n,t}$, and a rental rate $r^k_{n,t}$ 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 $c^j_{n,t}$ of a bundle of inputs in country n for producing in sector j, combining labor, capital, and intermediates, is:

$$c^j_{n,t} = (w_{n,t})^{\beta^{L,j}_n} \prod_{k \in \Omega_K} \left(r^k_{n,t}\right)^{\beta^{K,jk}_n} \prod_{j' \in \Omega} \left(p^{j'}_{n,t}\right)^{\beta^{M,jj'}_n}, \tag{5}$$

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

$$p^j_{n,t} = \left[\sum_{i=1}^{\mathcal{N}} \left(\frac{c^j_{i,t} d^j_{ni,t}}{A^j_{i,t}}\right)^{-\theta}\right]^{-1/\theta}. \tag{6}$$

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

$$\pi^j_{ni,t} = \left(\frac{c^j_{i,t} d^j_{ni,t}}{A^j_{i,t} p^j_{n,t}}\right)^{-\theta}. \tag{7}$$

4.4.2 Household Spending

Household spending on consumption of good $h \in \Omega^*_K$ is:

$$p^h_{n,t} C^h_{n,t} = \omega_n \phi_{n,t} \psi^h_{n,t}, \tag{8}$$

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

$$r^k_{n,t} K^{H,k}_{n,t} = \omega_n \phi_{n,t} \psi^k. \tag{9}$$

Summing these two expressions across all sectors and countries, our restriction on global aggregate demand shocks together with our normalization of the ψ's implies that the value of world consumption is 1, which serves as our numéraire.[17]

4.4.3 Investment

Investment in sector k satisfies the Euler equation:

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

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.[18]

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 $Y_{n,t}^j$ as the value of country n's gross production in sector j, world goods-market clearing implies that:

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

[17]This choice of numéraire gives the cleanest analytic expressions in the derivations that follow. To make our numerical results in line with our presentation of the data, we report them relative to global GDP. In our model, global GDP is:

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

where labor income $w_{n,t}L_{n,t}$ is given below by (13) and capital incomes $r_{n,t}^k K_{n,t}^k$ 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.

[18]The Euler equation appears more familiar when written in terms of preferences. Defining the function:

$$u_{n,t}(C_{n,t}^S) = \phi_{n,t}\psi_{n,t}^S \ln C_{n,t}^S,$$

the first-order condition for $C_{n,t}^S$ is:

$$\omega_n u_{n,t}'(C_{n,t}^S) = p_{n,t}^S.$$

Inserting the first-order conditions for $C_{n,t}^S$ and $C_{n,t+1}^S$ into (10) and imposing a standard capital accumulation equation, $\alpha^k = \chi_{n,t}^k = \chi_{n,t+1}^k = 1$, gives:

$$u_{n,t}'(C_{n,t}^S)\frac{p_{n,t}^k}{p_{n,t}^S} = \rho u_{n,t+1}'(C_{n,t+1}^S)\frac{p_{n,t+1}^k}{p_{n,t+1}^S}\left(\frac{r_{n,t+1}^k}{p_{n,t+1}^k} + 1 - \delta^k\right).$$

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

$$X_{n,t}^{j} = X_{n,t}^{F,j} + \sum_{j' \in \Omega} \beta^{M,j'j} Y_{n,t}^{j'}. \tag{12}$$

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

$$w_{n,t} L_{n,t} = \sum_{j \in \Omega} \beta_n^{L,j} Y_{n,t}^{j}, \tag{13}$$

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

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

We treat sectors $l \in \Omega_T = \{D, N\}$ as tradable so that $d_{ni,t}^{l}$ are finite. Construction is not traded and we treat services as nontraded, so that for sectors $j \in \Omega_T^* = \{C, S\}$ we treat $d_{ni,t}^{j}$ 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 $D_{n,t}^{S}$ to make up the difference. Hence $X_{n,t}^{C} = Y_{n,t}^{C}$ and $X_{n,t}^{S} = Y_{n,t}^{S} + D_{n,t}^{S}$, where $\sum_{n=1}^{\mathcal{N}} D_{n,t}^{S} = 0$.

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:

$$\Theta = \{\rho, \theta, \alpha^k, \delta^k, \psi^k, \beta_n^{L,j}, \beta_n^{K,jk}, \beta_n^{M,jj'}\} \quad \text{and} \quad \Psi_t = \{d_{ni,t}^{l}, A_{n,t}^{j}, \chi_{n,t}^{k}, \phi_{n,t}, \psi_{n,t}^{N}, L_{n,t}, D_{n,t}^{S}\},$$

for $j, j' \in \Omega$, $k \in \Omega_K$, $l \in \Omega_T$, and $n = 1, ..., \mathcal{N}$. (Since $\psi_{n,t}^{S} = 1 - \psi^C - \psi^D - \psi_{n,t}^{N}$, the demand shock for services is redundant.) Equations (5) through (14) determine paths of the endogenous variables, which include wages $w_{n,t}$, rental rates $r_{n,t}^{k}$ for sectors $k \in \Omega_K$, trade share $\pi_{ni,t}^{l}$ for sectors $l \in \Omega_T$, prices $p_{n,t}^{j}$, total spending $X_{n,t}^{j}$, final spending $X_{n,t}^{F,j}$, and output $Y_{n,t}^{j}$ for sectors $j \in \Omega$. The state variables are the capital stocks $K_{n,t}^{k}$, which evolve according to (2), with $I_{n,t}^{k} = X_{n,t}^{F,k} / p_{n,t}^{k}$.

4.6 A Stationary State

In a stationary state Ψ is constant and the capital stocks have settled down to constant levels K_n^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:

$$\frac{I_n^k}{K_n^k} = \left(\frac{\delta^k}{\chi_n^k}\right)^{1/\alpha^k}$$

and the ratio of the rental income to investment spending:

$$\frac{r_n^k K_n^k}{X_n^{F,k}} = \frac{1-\rho+\rho\delta^k\alpha^k}{\rho\delta^k\alpha^k}, \tag{15}$$

where the absence of a time subscript indicates a stationary value. The stationary values of the other endogenous variables follow from (5) through (14).

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).[19] 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_n, χ_n^j, ϕ_n, ψ_n^N, A_n^j, d_{ni}^l, $K_{n,0}^k$, p_n^j, w_n, and r_n^k in levels.

5.1 Shocks

In changes, our shocks in $t+1$ are $\hat{\Psi}_{t+1} = \{\hat{d}_{ni,t+1}^l, \hat{A}_{n,t+1}^j, \hat{\chi}_{n,t+1}^k, \hat{\phi}_{n,t+1}, \hat{\psi}_{n,t+1}^N, \hat{L}_{n,t+1}, D_{n,t+1}^S\}$ consisting of: (i) trade cost shocks $\hat{d}_{ni,t+1}^l$ for $l \in \Omega_T$, (ii) productivity shocks $\hat{A}_{n,t+1}^j$ for $j \in \Omega$, (iii) investment efficiency shocks $\hat{\chi}_{n,t+1}^k$ for $k \in \Omega_K$, (iv) aggregate demand shocks $\hat{\phi}_{n,t+1}$, (v) nondurable demand shocks $\hat{\psi}_{n,t+1}^N$, (vi) labor supply shocks $\hat{L}_{n,t+1}$, and (vii) services deficit shocks $D_{n,t+1}^S$ (in levels).

5.2 Outcomes

In this section we show how, given initial values for $X_{n,t}^j$, $\pi_{ni,t}^l$, $Y_{n,t}^S$, and $\hat{K}_{n,t+1}^k$, we can use $\hat{\Psi}_{t+1}$ to solve for a set of outcomes the next period, including $X_{n,t+1}^j$, $\pi_{ni,t+1}^l$, $Y_{n,t+1}^S$, and $\hat{K}_{n,t+2}^k$. Hence, knowing $\hat{\Psi}_{t+2}$, we can iterate forward another period, and so on.

[19] Prior to our work, this "changes" approach has been used only in static settings. Caliendo, Dvorkin, and Parro (2015) have recently applied it to a perfect-foresight model of trade and labor-market dynamics.

The initial values of $X^j_{n,t}$, $\pi^l_{ni,t}$, $Y^S_{n,t}$, and $\hat{K}^k_{n,t+1}$ are themselves, of course, equilibrium outcomes. In Section 6.2 below we describe how, starting at some initial period t, we use data on $X^j_{n,t}$, $\pi^l_{ni,t}$, $Y^S_{n,t}$, along with assumptions about the future evolution of $\left\{\hat{\Psi}_{t+s}\right\}_{s=1}^{\infty}$, to solve for $\hat{K}^k_{n,t+1}$ under perfect foresight. But for now we take $\hat{K}^k_{n,t+1}$ as given.

We now turn to the key equations that relate outcomes to shocks:

1. From (7), using (5), we can express changes in trade shares for sectors $l \in \Omega_T$ as:

$$\hat{\pi}^l_{ni,t+1} = \left(\frac{\hat{c}^l_{i,t+1}\hat{d}^l_{ni,t+1}}{\hat{A}^l_{i,t+1}\hat{p}^l_{n,t+1}}\right)^{-\theta}, \tag{16}$$

   where:

$$\hat{c}^l_{n,t+1} = \left(\hat{w}_{n,t+1}\right)^{\beta^{L,l}_n} \prod_{k\in\Omega_K}\left(\hat{r}^k_{n,t+1}\right)^{\beta^{K,lk}_n} \prod_{j\in\Omega}\left(\hat{p}^j_{n,t+1}\right)^{\beta^{M,lj}_n}, \tag{17}$$

   is the change in the cost of the input bundle.

2. Similarly, from (6), using (17), changes in prices for sectors $j \in \Omega$ solve:

$$\hat{p}^j_{n,t+1} = \left[\sum_{i=1}^{\mathcal{N}} \pi^j_{ni,t}\left(\frac{\hat{c}^j_{i,t+1}\hat{d}^j_{ni,t+1}}{\hat{A}^j_{i,t+1}}\right)^{-\theta}\right]^{-1/\theta}, \tag{18}$$

   where, for $j \in \Omega^*_T$, $\pi^j_{nn,t} = 1$ and $\pi^j_{ni,t} = 0$ for $i \neq n$.

3. From (8), changes in nondurables consumption spending satisfy:

$$\hat{X}^{F,N}_{n,t+1} = \hat{\phi}_{n,t+1}\hat{\psi}^N_{n,t+1}. \tag{19}$$

4. From (8), changes in services consumption spending satisfy:

$$\hat{X}^{F,S}_{n,t+1} = \hat{\phi}_{n,t+1}\hat{\psi}^S_{n,t+1}. \tag{20}$$

5. From (10), using (2) in changes, changes in investment spending on durables and construction $\hat{X}^{F,k}_{n,t+1}$ solve the Euler equation:

$$\begin{aligned}\frac{1}{\rho}\frac{\hat{K}^k_{n,t+1}}{\hat{K}^k_{n,t+1}-(1-\delta^k)} &= \alpha^k\frac{r^k_{n,t+1}K^k_{n,t+1}}{X^{F,k}_{n,t}} + \\ &\hat{X}^{F,k}_{n,t+1}\left[\left(1-\alpha^k\right)+\frac{1}{\hat{\chi}^k_{n,t+1}}\left(\frac{\hat{p}^k_{n,t+1}\hat{K}^k_{n,t+1}}{\hat{X}^{F,k}_{n,t+1}}\right)^{\alpha^k}\frac{\left(1-\delta^k\right)}{\hat{K}^k_{n,t+1}-\left(1-\delta^k\right)}\right],\end{aligned} \tag{21}$$

for $k \in \Omega_K$. Payments to capital in $t+1$, $r^k_{n,t+1}K^k_{n,t+1}$, come from (23) below.

6. From (13), changes in wages satisfy:

$$\hat{w}_{n,t+1}\hat{L}_{n,t+1}w_{n,t}L_{n,t} = \sum_{j\in\Omega} \beta_n^{L,j} Y^j_{n,t+1}. \tag{22}$$

7. From (14), changes in rental rates for sectors $k \in \Omega_K$ satisfy:

$$\hat{r}^k_{n,t+1}\hat{K}^k_{n,t+1}r^k_{n,t}K^k_{n,t} = \sum_{j\in\Omega} \beta_n^{K,jk} Y^j_{n,t+1} + \frac{\psi^k}{1-\psi^C-\psi^D}\left(X^{F,N}_{n,t+1} + X^{F,S}_{n,t+1}\right). \tag{23}$$

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

$$\hat{K}^k_{n,t+2} - (1-\delta^k) = \hat{\chi}^k_{n,t+1}\left(\frac{\hat{X}^{F,k}_{n,t+1}}{\hat{p}^k_{n,t+1}\hat{K}^k_{n,t+1}}\right)^{\alpha^k}\left(\hat{K}^k_{n,t+1} - (1-\delta^k)\right). \tag{24}$$

Given $X^j_{n,t}$, $\pi^l_{ni,t}$, $Y^S_{n,t}$, $\hat{K}^k_{n,t+1}$, and $\hat{\Psi}_{t+1}$, we can use equations (16) through (24) , along with (11) and (12), to solve for: (i) changes in the trade shares $\hat{\pi}^l_{ni,t+1}$, (ii) changes in prices $\hat{p}^j_{n,t+1}$, (iii) changes in final nondurable spending $\hat{X}^{F,N}_{n,t+1}$, (iv) changes in final services spending $\hat{X}^{F,S}_{n,t+1}$, (v) changes in investment spending $\hat{X}^{F,k}_{n,t+1}$, (vi) changes in wages $\hat{w}_{n,t+1}$, (vii) changes in rental rates $\hat{r}^k_{n,t+1}$, (viii) changes in output $\hat{Y}^j_{n,t+1}$, (ix) changes in absorption $\hat{X}^j_{n,t+1}$, and (x) subsequent changes in capital stocks $\hat{K}^k_{n,t+2}$. Setting $\pi^l_{ni,t+1} = \hat{\pi}^l_{ni,t+1}\pi^l_{ni,t}$, $X^j_{n,t+1} = \hat{X}^j_{n,t+1}X^j_{n,t}$, and $Y^S_{n,t+1} = \hat{Y}^S_{n,t+1}Y^S_{n,t}$ and using $\hat{K}^k_{n,t+2}$ gives us what we need to iterate forward another period. Having reached some period $s > t$, all we need to know about values of $\hat{\Psi}_{s'+1}$ for $s' > s$ is embodied in the initial conditions $X^j_{n,t}$, $\pi^l_{ni,t}$, $Y^S_{n,t}$, and $\hat{K}^k_{n,t+1}$.

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 (16) through (23) 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 (16), increases in trade costs $\hat{d}^j_{ni,t+1}$ (meaning $\hat{d}^j_{ni,t+1} > 1$ for $n \neq i$) reduce import shares within sector j as countries divert sourcing from abroad to home. (ii) From (18), increases in productivity $\hat{A}^j_{n,t+1}$ lower the sectoral price index for sector j output relative to input costs. (iii) From (22), increases in the efficiency of investment $\hat{\chi}^k_{n,t+1}$ raise investment spending in sector k. (iv) From (19), increases in demand for nondurable consumption $\hat{\psi}^N_{n,t+1}$ shift spending from (nontradable) services to (tradable) nondurable manufactures. (v) Increases in labor supply $\hat{L}_{n,t+1}$ show up in (22), generating an offsetting decline in wages.

Increases in demand for nondurable consumption $\hat{\psi}^N_{n,t+1}$ and in investment efficiency in durables $\hat{\chi}^D_{n,t+1}$ 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.

Since we restrict the $\phi_{n,t}$'s to average to one, shocks to aggregate demand $\hat{\phi}_{n,t+1}$ can't be worldwide. An increase in $\hat{\phi}_{n,t+1}$ for country n acts to increase n'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.[20]

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 $\hat{A}^j_{n,t+1}$ in a tradable sector j lowers country n's cost of producing varieties in that sector. The relative wage in country n rises as does the range of sector j varieties it produces and exports. An increase in country n's labor supply $\hat{L}_{n,t+1}$ lowers its wage but also increases the range of varieties it produces and exports. An increase in investment efficiency $\hat{\chi}^D_{n,t+1}$ increases country n's production and imports of durables. In line with the Lerner symmetry theorem, an increase in country n's trade costs as an importer $\hat{d}^j_{ni,t+1}$ or as an exporter $\hat{d}^j_{in,t+1}$ (for all $i \neq n$) lowers both country n's imports and its exports.

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. An increase in durables productivity $\hat{A}^D_{n,t+1}$ in country n raises both its GDP and its trade balance. In contrast, an increase in aggregate demand $\hat{\phi}_{n,t+1}$ or in durables investment efficiency $\hat{\chi}^D_{n,t+1}$ raises GDP but lowers the trade balance, in line with the data.

A country-specific increase in $\hat{A}^D_{n,t+1}$ 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 $\hat{\chi}^D_{n,t+1}$ 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

[20] 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.

the same direction but much smaller in magnitude than the effect on impact. Major exceptions are with country-specific increases in productivity $\hat{A}^D_{n,t+1}$ and in investment efficiency in durables $\hat{\chi}^D_{n,t+1}$. 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 seven shocks. We apply the procedure to quarterly data from the 21 countries appearing in Table 1, from 2000:Q1 to 2012:Q4.[21] We take (in levels) series corresponding to $X^j_{n,t}$ and $Y^j_{n,t}$ for $j \in \Omega$ (and hence $X^{F,j}_{n,t}$ and $D^S_{n,t}$) as well as $\pi^l_{ni,t}$ for $l \in \Omega_T$. We take (in changes) series corresponding to $\hat{L}_{n,t+1}$ and $\hat{p}^j_{n,t+1}$.

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 the trade elasticity $\theta = 2$ to be between the smaller values typically used in the open-economy macro literature, such as in Backus, Kehoe, and Kydland (1995), and the larger values used in the trade literature, such as in Eaton and Kortum (2002).[22] We choose $\alpha^C = 0.5$ and $\alpha^D = 0.55$. (A larger α^j means lower capital adjustment costs.) We choose $\delta^C = 0.011$ 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. We choose $\delta^D = 0.026$ to correspond to an annual durables depreciation rate of 10 percent.

To calibrate preference parameters ψ^C and ψ^D we assume that the world as a whole is close to a stationary state. For each country, the stationary state relationship (15), together with (23), becomes:

$$\frac{1-\rho\left(1-\delta^k\alpha^k\right)}{\rho\alpha^k\delta^k}X^{F,k}_n = r^k_n K^k_n = \sum_{j\in\Omega}\beta^{K,jk}_n Y^j_n + \frac{\psi^k}{1-\psi^C-\psi^D}\left(X^{F,N}_n + X^{F,S}_n\right).$$

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

[22] The response to a trade friction shock of a given size depends crucially on the value of the trade elasticity θ. Our counterfactuals, however, are based on shocks to trade costs that are extracted given θ. Thus we will extract larger shocks to trade costs if we impose a smaller value of θ. As a consequence, our main results for the recession are, for the most part, insensitive to θ. As discussed below, we report alternative results for the case of $\theta = 0.5$ in the Appendix.

Denoting the time average of variable Z_t as $\bar{Z}$, we calculate ψ^k by summing the equation above across countries:

$$\psi^k = \frac{1-\rho\left(1-\delta^k\alpha^k\right)}{\rho\alpha^k\delta^k}\sum_{n=1}^{\mathcal{N}}\bar{X}_n^{F,k} - \sum_{n=1}^{\mathcal{N}}\sum_{j\in\Omega}\beta_n^{K,jk}\bar{Y}_n^j, \tag{25}$$

where we exploit the result that $\sum_{n=1}^{\mathcal{N}}\left(X_n^{F,N}+X_n^{F,S}\right) = 1-\psi^C-\psi^D$. 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 using the most recent available table for each country in the 2009 edition of the OECD's input-output tables.[23] To calculate $\beta_n^{L,j}$ 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, $\beta_n^{K,jC}/(\beta_n^{K,jC}+\beta_n^{K,jD}) = 0.43$, consistent with Greenwood, Hercowitz, and Krusell (1997). To determine $\beta_n^{M,jj'}$ we divide total spending in sector j on inputs from sector j' by sector j's total output.

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 $\hat{K}_{n,t+1}^k$ over that period. Computing the associated baseline paths of the $\hat{K}_{n,t+1}^k$ in turn requires assumptions about the $\{\hat{\Psi}_{t+1}\}$ beyond the period of our data. We denote the period at which our data end, 2012:Q4, as t^E and freeze the levels of all subsequent shocks at their 2012:Q4 values.

This world with unchanging shocks converges to the stationary state described in Section 4.6 in which all endogenous magnitudes are constant. Appendix Section C describes our algorithm for computing the $\hat{K}_{n,t^E+1}^k$ that, using equations (16) through (24), lead the economy along a perfect foresight path to this stationary state, given X_{n,t^E}^j, π_{ni,t^E}^l, and Y_{n,t^E}^S.

With $\hat{K}_{n,t^E+1}^k$ in hand, we iterate backwards and extract $\hat{K}_{n,t+1}^k$ for $t < t^E$ by incorporating the Euler equation (22) into the capital accumulation equation (24):

$$\frac{\hat{K}_{n,t}^k}{\hat{K}_{n,t}^k-(1-\delta^k)} = \rho\frac{\alpha^k}{X_{n,t-1}^{F,k}}r_{n,t}^k K_{n,t}^k + \rho\hat{X}_{n,t}^{F,k}\left(\left(1-\alpha^k\right)+\frac{1-\delta^k}{\hat{K}_{n,t+1}^k-(1-\delta^k)}\right). \tag{26}$$

Since our substitution of the Euler equation has eliminated $\hat{\chi}_{n,t+1}^k$, extracting the path of $\hat{K}_{n,t+1}^k$ requires no knowledge of any shocks. What is required are data on investment spending $X_{n,t}^{F,k}$ and

[23] Appendix Table A.1 shows how the 48 sectors used in these tables correspond to our four sectors $j \in \Omega$.

the spending and production terms on the right-hand side of equation (23) to deliver $r^k_{n,t} K^k_{n,t}$.

Figure 3 shows the paths for $\hat{K}^C_{n,t+1}$ and $\hat{K}^D_{n,t+1}$ 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 $\hat{K}^k_n = 1$. In the period of our analysis the capital stocks fluctuate according to the data that we feed into equation (26). The stock of durables is more volatile and converges fully by 2050, while structures, with their lower depreciation rate, need longer.[24]

6.3 Paths of Shocks

Given paths for changes in capital $\hat{K}^k_{n,t+1}$, equations (16) through (24) deliver the following equations to back out the shocks during the period of our data:

1. Expression (16), as it applies to $n \neq i$ relative to how it applies to $n = i$, gives us trade cost shocks in sectors $l \in \Omega_T$:[25]

$$\hat{d}^l_{ni,t+1} = \left(\frac{\hat{\pi}^l_{ni,t+1}}{\hat{\pi}^l_{ii,t+1}} \right)^{-1/\theta} \frac{\hat{p}^l_{n,t+1}}{\hat{p}^l_{i,t+1}}. \tag{27}$$

2. Expression (16), as it applies to $n = i$, gives us productivity shocks $\hat{A}^j_{n,t+1}$ for sectors $j \in \Omega$:

$$\hat{A}^j_{n,t+1} = \frac{1}{\hat{p}^j_{n,t+1}} \left(\hat{\pi}^j_{nn,t+1} \right)^{1/\theta} \hat{c}^j_{n,t+1}, \tag{28}$$

   where, for $j \in \Omega^*_T$, $\hat{\pi}^j_{nn,t+1} = 1$.[26] The changes in factor prices needed to evaluate $\hat{c}^j_{n,t+1}$ come from (22) and (23).

3. We back out investment efficiency shocks $\hat{\chi}^k_{n,t+1}$ using the law of motion for capital in changes (24):

$$\hat{\chi}^k_{n,t+1} = \left(\frac{\hat{X}^{F,k}_{n,t+1}}{\hat{p}^k_{n,t+1} \hat{K}^k_{n,t+1}} \right)^{-\alpha^k} \frac{\hat{K}^k_{n,t+2} - (1 - \delta^k)}{\hat{K}^k_{n,t+1} - (1 - \delta^k)}. \tag{29}$$

4. We use (19) and (20), together with the condition that $\psi^N_{n,t} + \psi^S_{n,t} = 1 - \psi^C - \psi^D$, to back

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

[25] Taking the product $\hat{d}^l_{ni,t+1} \hat{d}^l_{in,t+1}$ cancels the price terms, leaving the index of two-way trade costs proposed by Head and Ries (2001). By exploiting data on price changes in (27), we uncover asymmetries in trade costs.

[26] Expression (28) corresponds to the dual measure (based on input and output prices) of total factor productivity, adjusting for selection in the sector j goods actually produced by country n, as in Costinot, Donaldson, and Komunjer (2011).

out the aggregate demand shocks:

$$\hat{\phi}_{n,t+1} = \frac{X^{F,N}_{n,t+1} + X^{F,S}_{n,t+1}}{X^{F,N}_{n,t} + X^{F,S}_{n,t}}. \tag{30}$$

5. We use (30) together with data on final spending on nondurables to back out the nondurable demand shocks:

$$\hat{\psi}^{N}_{n,t+1} = \frac{\hat{X}^{F,N}_{n,t+1}}{\hat{\phi}_{n,t+1}}. \tag{31}$$

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

7. We take services trade deficits $D^{S}_{n,t+1}$ directly from the data.

This procedure delivers our baseline set of shocks $\{\hat{\Psi}_{t+1}\}$, with all values frozen as described above for $t \geq t^E$.[27] 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 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 $\hat{d}^{l}_{ni}$ in each tradable sector, one for each ordered pair of separate countries, we report only a trade-weighted average for each country (as both exporter and importer).[28] The world as a whole experienced a mild decline in its trade frictions prior to the recession, as shown by the values 0.991 and 0.980 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

[27] We have backed out baseline shocks under alternative assumptions about their behavior in the period after our data. One such exercise introduces a set of future demand shocks that significantly reduce the size of deficits in the stationary state. We find little quantitative and no qualitative effect on our results.

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

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

where X^{j}_{ni} is the value of country n's imports from country i, $M^{j}_{n} = \sum_{i \neq n} X^{j}_{ni}$ is country n's total imports, and $E^{j}_{n} = \sum_{i \neq n} X^{j}_{in}$ is country n's exports, all for sector j. We aggregate across countries, in a similar manner, to create the global average.

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 partly reflects its brevity.) The decline in overall trade barriers accelerated during the recovery. Only Greece missed this trend.

Table 2 also reports each country's services deficit and labor shocks. Services deficits decline for 17 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. World employment, calculated as the GDP-weighted average across countries, increased by 1 percent in the pre-recession period but fell by nearly 2 percent during the recession, with no overall reversal in the recovery. The countries with the largest negative labor shocks during the recession were Spain and the United States.

Table 3 shows that most countries experienced declines in construction productivity in the recession, with the world average dropping to 0.934 from a previously flat trajectory. These productivity losses were reversed during the recovery. Services productivity followed a similar pattern, but with slower growth in the recovery. In contrast, productivity in both manufacturing sectors grew faster during the recession in many countries.[29]

Table 4 shows that there was only a mild worldwide decline in investment efficiency in construction during the recession. The increases in China and Japan largely 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, $\hat{\chi}^D_{n,t+1} < 1$, also shown in Table 4.[30] In the pre-recession period, these shocks are tightly centered around 1. The world as a whole experienced a decline in durables investment efficiency of 22.8 percent during the recession. This decline was widespread, with the only increase occurring in China, at a rate slightly below its pre-recession average. For most countries these declines in efficiency in durables investment were only partially reversed in the recovery, with Denmark and Greece experiencing substantial further drops.

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.

[29] As discussed in Appendix Section A.5, we can use Domar (1961) weights to aggregate our sectoral productivities into an economy-wide productivity shock. Appendix Figure A.2 compares our aggregate measure for the United States with the quarterly TFP series for the U.S. business sector in Fernald et al. (2012). The two series align quite well and have a correlation of 0.78.

[30] We calculate the global $\hat{\chi}^j$ shock as investment-spending weighted averages of the country shocks.

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.[31] 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 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 22.8 percent. Declines in investment efficiency $\hat{\chi}^{D}_{n,t+1}$ and in the demand for nondurable consumption $\hat{\psi}^{N}_{n,t+1}$ 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 $\hat{\phi}_{n,t+1}$, whose average around the world is constrained to equal one in any period, were much more dispersed during the global recession than before. Equation (30) shows the tight connection between final spending on nondurables and on services, a large share of total spending, and aggregate demand shocks $\hat{\phi}_{n,t+1}$. As shown below, these shocks accounted for the large swings in relative GDPs during the recession, plotted on the vertical axis of Figure 2(d).

If anything, trade frictions $\hat{d}^{j}_{ni,t+1}$ decreased, and they continued to fall during the recovery. While productivity in construction $\hat{A}^{C}_{n,t+1}$ and services $\hat{A}^{S}_{n,t+1}$ was procyclical, productivity in manufactures, $\hat{A}^{D}_{n,t+1}$ and $\hat{A}^{N}_{n,t+1}$, was not.

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

[31] Aggregate demand shocks are largely picking up changes in relative GDPs, driven largely by swings in exchange rates. During the recession the Japanese yen appreciated substantially against the U.S. dollar while the dollar appreciated modestly against the euro.

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.[32] If a counterfactual with a particular type of shock 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 major players.

7.1 Computation

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 before.[33] A consequence of this assumption is that, in a counterfactual, the Euler equation (22) 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. See Appendix Section C for a description of the numerical algorithm.

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 types of shocks acting in isolation: (i) nondurables demand, (ii) aggregate demand, (iii) productivity in all sectors, (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.[34]

To be more quantitative, the first row of Table 5 reports the contributions of each different type of shock to the cumulative decline in world trade over the recession. Shocks to investment

[32] 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 nominal outcomes relative to global GDP in that counterfactual.

[33] We have also solved counterfactuals under the assumption that the surprise occurs in 2008:Q4. Some country-level dynamics differ, but our conclusions about the drivers of the global trade collapse do not change.

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

efficiency in durables account for 64 percent (i.e., 13.2 percentage points) of the 20.5 percent decline in world trade. Declines in demand for nondurable manufactures contribute 18 percent and increases in trade frictions contribute 11 percent to the decline.[35] (The contributions from each type of shock need not and do not exactly sum to one.)

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.5 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 generated by different types 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]

Figure 5 illustrates how different 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 in most countries. 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.2, 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

[35] Using a trade elasticity of $\theta = 0.5$, these results remain largely unchanged. Durables investment efficiency shocks and nondurables demand shocks in this case explain 65 percent and 17 percent of the decline, respectively. The biggest difference with the baseline case is that with the lower value of θ, the contribution of trade frictions to the trade collapse increases from 11 to 16 percent. Further results for the case of $\theta = 0.5$ can be found in Appendix Figures A.5 to A.7 and Appendix Tables A.12 to A.14.

[36] The less than 2 percent decline in U.S. trade in the trade friction counterfactual masks a much larger decline in imports combined with no change in exports. Appendix Section D elaborates on our counterfactual results for the U.S. and on how our findings relate to the trade wedge analysis in Levchenko, Lewis, and Tesar (2010).

in manufacturing production relative to global GDP across the world during the global recession.

Changes in relative GDP are a different story, as shown in Figure 7 and in Appendix Table A.3. Aggregate demand shocks are the primary mover here, except for China and India, where, again, productivity (not pictured) is the source of their relative 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.

Another outcome of interest is the decline of each country's trade relative to its own GDP. Figure 8 shows what happens to these ratios with shocks only to investment efficiency, to demand for nondurables, and to aggregate demand. Together these shocks generate most of the decline and the cross-country variation in the ratio of trade to GDP, leaving little room for trade frictions or productivity.

Which sets of shocks drove the declines in real GDP during the recession? Productivity shocks, emanating overwhelmingly from nontradables, drive outcomes for real GDP at the country and world level, generating over 70 percent of the decline in global real GDP on their own. The decline in labor contributes about 10 percent to the decline.[37] Figure 9 shows that the combination of shocks to productivity and to labor explain most of the cross-country differences in real GDP during the recession.[38]

To summarize our results for the recession, 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. Shocks to trade frictions, productivities, and services deficits do little. Shocks to productivity and, to some extent, labor drove changes in real GDP.

During the recovery (2009:Q2 to 2011:Q1) trade bounced back everywhere except for Greece. Appendix Table A.5 reports how our counterfactuals account for what happened. Decreased trade frictions and, to a lesser extent, a rebound in durables investment efficiency were major factors, with increases in the demand for nondurables also contributing.[39]

[37]Labor was particularly important for the real GDP declines in Spain and the United States.

[38]Appendix Table A.4 reports the behavior of real GDP in our main counterfactuals during the global recession.

[39]Productivity and trade frictions were the most critical shocks generating real GDP growth during the recovery (See Appendix Table A.8). That declining trade frictions would have a perceptible role in driving growth in real GDP is surprising. An explanation is that, as shown in Appendix Table A.17, the share of purchases from home producers fell substantially during the recovery. Applying the Arkolakis, Costinot, and Rodriguez-Clare (2011) formula with $\theta = 2$ to these drops implies large gains from trade. (With $\theta = 0.5$ the gains are even larger.)

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 shocks emanating only from the United States were at work. We then consider whether outcomes in Germany were 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 (and services deficits fixed at their pre-recession levels).[40] U.S. shocks alone reduce global trade by 3.6 percent, as opposed to the actual decline of 20.5 percent, and reduce global manufacturing production by 2.9 percent, as opposed to the actual decline of 13.0 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 10 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 countries, most dramatically in 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. 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.

[40] 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 $\sum_i (X^N_{i,t} + X^S_{i,t})\hat{\phi}_{i,t+1} = 1 - \psi^C - \psi^D$.

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 11 shows the result of a counterfactual in which only shocks *not* involving Germany are at work. Note that there are only moderate changes from what actually happened, meaning that much 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 partly mitigates the effect of the recession on manufacturing production in Germany, Austria, and Poland, on German GDP, 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. These shocks reduced final spending on tradable sectors. Our results thus support the view that changes in the composition of demand, rather than higher trade barriers or negative productivity shocks, led to the trade collapse.

Our model offers a way to analyze jointly the macroeconomic experiences of many countries connected by trade. The framework allows us to identify where shocks originate and how they spread from country to country, providing a richer picture of the common and idiosyncratic characteristics of global fluctuations. It also suggests some promising avenues for future research, both in terms of expanding the scope of this analysis and in terms of furthering the methodology.[41]

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.[42]

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 propagat-

[41] For example, Eaton, Kortum, and Neiman (2015) use the framework to run counterfactuals with greatly reduced trade frictions to assess quantitatively the hypothesis in Obstfeld and Rogoff (2001) that trade costs are the key drivers of major puzzles in international macroeconomics, such as the Feldstein and Horioka (1980) puzzle. Reyes-Heroles (2015) uses a closely related framework to uncover the role of reduced trade barriers in driving huge increases in trade imbalances.

[42] Tombe (2014) and Lagakos and Waugh (2013) have integrated world food trade into a static general equilibrium framework. Farrokhi (2015) provides a quantitative general equilibrium model of world trade in crude and refined oil. Eaton, Kortum, and Neiman (2013) introduce unemployment in a simple way.

ing 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 the world economy over the past decade, making a transparent but stark set of assumptions about 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.

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	Country	Code	**Share of Global GDP** (percent)	**Share of Global Trade** (percent)	**Trade / GDP** (percent)	**Production / GDP** (percent)	**Construction / GDP** (percent)
(1)	Austria	AUT	0.7	1.5	39.5	57.8	16.0
(2)	Canada	CAN	2.6	3.0	19.9	40.0	57.6
(3)	China	CHN	7.5	10.3	24.0	153.1	18.1
(4)	Czech Republic	CZE	0.4	1.3	56.7	95.9	63.5
(5)	Denmark	DNK	0.6	0.9	28.0	37.6	83.1
(6)	Finland	FIN	0.5	0.8	29.2	71.2	44.7
(7)	France	FRA	4.7	5.3	19.7	42.8	54.0
(8)	Germany	DEU	6.0	11.1	32.4	68.2	48.1
(9)	Greece	GRC	0.6	0.4	13.4	31.5	55.4
(10)	India	IND	2.1	1.6	13.3	56.1	28.8
(11)	Italy	ITA	3.8	4.4	20.1	69.6	31.6
(12)	Japan	JPN	7.4	5.3	12.5	71.7	19.6
(13)	Mexico	MEX	1.9	2.4	21.4	55.2	55.9
(14)	Poland	POL	0.9	1.6	29.6	65.6	53.8
(15)	Romania	ROU	0.3	0.5	27.4	48.9	66.4
(16)	South Korea	KOR	1.6	3.2	36.0	138.2	28.4
(17)	Spain	ESP	2.6	2.7	17.7	50.1	39.8
(18)	Sweden	SWE	0.8	1.4	30.5	57.7	53.5
(19)	United Kingdom	GBR	4.5	4.2	16.6	34.4	58.2
(20)	United States	USA	23.9	12.3	9.0	37.1	32.0
(21)	Rest of World	ROW	26.5	25.7	17.0	61.6	30.4

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

Notes: Trade and production data are 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.

		$\hat{d}_n^D$			$\hat{d}_n^N$			$\Delta \frac{D_n^S}{Y_n^F}$			$\hat{L}_n$	
	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	**0.991**	**0.992**	**0.948**	**0.980**	**0.973**	**0.972**	**0.000**	**0.000**	**0.000**	**1.010**	**0.983**	**0.999**
Austria	0.999	1.114	0.933	0.976	0.959	1.029	0.000	-0.018	0.006	1.012	0.994	1.007
Canada	1.005	1.060	0.944	0.987	1.042	0.988	-0.002	0.048	-0.002	1.019	0.982	1.010
China	0.990	1.028	0.935	0.999	1.002	0.933	0.014	-0.017	0.032	1.004	1.001	1.002
Czech Republic	0.942	0.959	0.908	0.968	0.950	0.941	0.007	-0.033	0.011	1.007	0.994	0.991
Denmark	0.981	1.052	0.732	0.971	0.892	0.951	0.001	0.032	-0.004	1.008	0.981	0.976
Finland	0.996	1.124	1.004	0.991	1.033	0.951	0.000	-0.005	0.001	1.011	0.975	0.993
France	1.019	0.970	0.984	0.992	0.968	0.983	0.003	-0.014	0.008	1.008	0.992	0.999
Germany	0.984	0.993	0.977	0.974	0.977	0.985	0.000	-0.025	0.003	1.007	1.010	1.004
Greece	1.024	0.963	1.033	0.998	1.017	1.011	0.008	-0.020	0.003	1.015	0.987	0.973
India	0.959	1.100	0.936	0.958	1.044	0.966	-0.001	-0.014	0.015	1.018	1.001	1.003
Italy	0.994	1.004	0.982	0.985	0.972	0.968	0.003	-0.017	0.004	1.014	0.984	0.994
Japan	1.016	0.927	0.951	0.970	0.996	0.996	0.003	-0.041	0.012	0.999	0.988	0.994
Mexico	0.979	0.941	0.881	0.991	0.964	0.987	0.001	0.006	-0.002	1.020	1.009	1.015
Poland	0.953	0.903	0.974	0.964	0.886	0.980	0.004	-0.017	-0.003	1.009	1.018	0.982
Romania	0.952	0.911	0.894	0.975	0.915	0.937	0.005	-0.015	-0.015	1.007	0.974	0.991
South Korea	0.994	0.916	0.977	0.996	0.917	0.949	0.011	-0.101	0.040	1.014	0.995	1.011
Spain	0.995	1.039	0.926	0.977	0.954	0.971	0.003	-0.028	0.006	1.037	0.920	0.977
Sweden	0.995	1.006	0.950	0.979	0.982	0.998	-0.004	-0.008	0.008	1.012	0.984	1.000
United Kingdom	0.999	0.990	0.897	0.984	0.868	0.958	0.000	-0.003	-0.002	1.009	0.985	0.998
United States	0.991	1.004	0.939	0.983	0.985	0.982	0.002	-0.026	0.002	1.010	0.960	0.990
Rest of World	0.989	0.991	0.963	0.979	0.983	0.973	-0.007	0.062	-0.023	1.012	0.994	1.007

Table 2: Trade Frictions, Services Deficits, 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. Trade friction shocks are calculated as a trade-weighted average of the bilateral shocks (see Footnote 28). The services trade deficit shocks are the changes in the deficits divided by GDP at the beginning of the quarter, averaged over the period.

	$\hat{A}_n^C$			$\hat{A}_n^D$			$\hat{A}_n^N$			$\hat{A}_n^S$		
	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	**0.995**	**0.934**	**1.043**	**1.011**	**1.030**	**1.009**	**1.006**	**1.057**	**1.007**	**1.012**	**0.962**	**1.019**
Austria	1.008	0.940	0.988	1.023	1.141	0.916	0.995	0.998	1.041	1.010	0.951	1.026
Canada	0.989	0.778	1.078	1.031	0.979	1.002	1.014	0.958	1.027	1.009	1.000	1.013
China	1.033	0.845	1.059	1.064	1.124	1.013	1.074	1.131	1.014	1.020	0.955	1.026
Czech Republic	0.995	1.125	0.917	0.992	0.937	0.918	1.006	0.984	0.943	1.014	0.943	1.035
Denmark	0.996	1.003	1.063	0.982	1.061	0.631	0.983	0.892	0.940	1.013	0.963	1.025
Finland	1.004	0.879	1.121	1.011	1.018	1.002	0.998	1.018	0.976	1.010	0.915	1.019
France	0.967	0.995	1.018	1.010	0.983	0.989	1.006	1.056	0.989	1.017	0.967	1.025
Germany	0.997	0.979	1.028	0.995	0.979	1.004	0.985	1.013	0.991	1.008	0.925	1.036
Greece	1.021	0.983	1.004	1.016	0.999	1.024	1.009	1.031	0.997	1.030	0.969	0.974
India	1.007	0.909	1.059	1.013	1.111	1.042	1.026	1.013	1.044	1.063	1.060	1.056
Italy	0.995	0.920	0.986	1.000	1.021	0.981	1.000	1.016	0.978	1.002	0.942	1.028
Japan	1.006	0.917	0.952	0.990	1.031	0.993	0.978	1.040	0.989	1.016	0.924	1.032
Mexico	1.012	0.970	1.037	1.008	0.932	0.926	1.016	0.945	1.015	1.025	0.969	1.056
Poland	0.969	1.359	0.963	1.013	1.011	1.019	1.019	1.004	1.012	1.024	0.983	1.035
Romania	0.951	0.864	1.008	0.971	0.907	0.899	0.981	0.872	0.940	1.114	1.024	1.072
South Korea	0.989	0.979	1.027	1.000	1.043	0.996	1.040	1.051	0.994	1.008	0.947	1.020
Spain	0.984	0.967	1.010	1.005	1.057	0.954	1.003	0.996	0.978	1.012	0.998	1.021
Sweden	0.988	0.885	1.021	1.004	0.948	1.022	0.991	1.008	1.038	1.016	0.965	1.027
United Kingdom	0.990	0.901	1.071	1.007	0.980	0.927	0.998	0.873	0.978	1.008	0.991	1.007
United States	0.979	0.995	1.029	1.003	1.039	0.988	0.978	1.205	0.940	1.018	0.955	1.036
Rest of World	1.002	0.918	1.067	1.024	0.981	1.050	1.025	0.982	1.059	1.003	0.963	0.987

Table 3: Productivity 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.

	$\hat{\chi}_n^C$			$\hat{\chi}_n^D$			$\hat{\psi}_n^N$			$\hat{\phi}_n$		
	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	**1.007**	**0.984**	**0.976**	**0.993**	**0.772**	**1.076**	**0.995**	**0.772**	**1.104**	**1.000**	**1.000**	**1.000**
Austria	1.021	0.958	0.963	1.015	0.869	1.005	1.003	0.803	1.236	1.003	0.969	0.963
Canada	1.040	1.103	1.012	0.949	0.693	1.067	0.957	0.974	0.917	1.027	0.894	1.081
China	1.077	1.244	1.048	1.043	1.042	1.098	1.012	1.041	1.078	1.132	1.162	1.094
Czech Republic	1.088	0.697	1.017	1.023	0.563	1.115	0.936	0.779	1.091	1.093	0.876	0.955
Denmark	1.018	0.863	0.909	1.000	0.646	0.816	0.982	0.636	0.939	1.017	0.902	0.978
Finland	1.032	0.902	0.908	1.032	0.666	1.070	1.018	0.730	0.961	1.020	0.975	0.949
France	1.062	0.900	0.926	1.002	0.724	1.017	0.990	0.750	1.071	1.011	0.945	0.960
Germany	0.984	0.966	0.954	1.013	0.741	1.040	0.998	0.809	1.121	0.995	0.958	0.945
Greece	1.003	0.962	0.729	1.030	0.742	0.902	0.984	0.793	1.084	1.054	0.944	0.885
India	1.033	1.035	1.045	1.029	0.848	1.105	1.022	1.045	0.954	1.028	0.933	1.177
Italy	1.031	0.939	0.945	1.007	0.634	1.060	0.985	0.675	1.099	1.013	1.009	0.928
Japan	0.926	1.228	1.052	0.959	0.884	1.028	1.020	0.726	1.212	0.926	1.255	1.004
Mexico	1.005	0.747	0.977	0.963	0.581	1.026	1.001	0.954	1.081	1.000	0.742	1.080
Poland	1.097	0.533	1.120	1.013	0.519	1.052	0.992	0.945	1.164	1.063	0.675	1.034
Romania	1.202	1.044	0.918	1.088	0.454	1.078	0.965	0.662	1.109	1.138	0.684	0.959
South Korea	1.009	0.870	0.993	1.038	0.628	1.231	1.035	0.750	1.052	0.994	0.852	1.069
Spain	1.096	0.983	0.854	0.968	0.414	1.095	0.959	0.690	1.137	1.048	0.915	0.951
Sweden	1.020	0.814	1.075	0.994	0.533	1.185	1.014	0.955	1.049	1.003	0.821	1.083
United Kingdom	1.020	0.854	0.874	0.982	0.747	0.997	0.983	0.736	0.927	0.998	0.787	0.980
United States	0.974	0.970	0.868	0.953	0.787	1.029	0.997	0.709	1.109	0.982	1.061	0.956
Rest of World	1.031	0.911	0.991	1.030	0.723	1.107	0.990	0.721	1.127	1.036	0.977	1.042

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 30). 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** $\left(\hat{A}^j_n\right)$	**Inv. Efficy. in Structures Shocks** $\left(\hat{\chi}^C_n\right)$	**Inv. Efficy. in Durables Shocks** $\left(\hat{\chi}^D_n\right)$	**Nondurables Demand Shocks** $\left(\hat{\psi}^N_n\right)$	**Aggregate Demand Shocks** $\left(\hat{\phi}_n\right)$	**Services Deficits Shocks** $\left(D^S_n\right)$	**Labor Supply Shocks** $\left(\hat{L}_n\right)$
World	**17.5**	**0.795**	**0.977**	**1.001**	**0.994**	**0.868**	**0.964**	**0.999**	**0.996**	**0.996**
Austria	0.3	0.790	0.901	1.040	0.990	0.870	0.963	0.992	0.991	0.993
Canada	0.5	0.752	0.910	0.991	1.016	0.868	0.988	1.029	1.011	1.006
China	1.8	0.852	0.915	1.103	0.981	0.926	0.971	0.976	0.992	0.994
Czech Republic	0.2	0.746	1.020	0.908	0.996	0.809	0.968	1.003	0.989	0.990
Denmark	0.2	0.805	1.010	0.960	0.992	0.857	0.948	1.010	1.004	0.991
Finland	0.1	0.675	0.863	0.974	0.999	0.846	0.972	1.007	0.999	0.996
France	0.9	0.828	1.033	0.979	0.996	0.864	0.955	1.000	0.995	0.996
Germany	1.9	0.784	0.990	0.960	0.992	0.858	0.965	0.999	0.991	0.998
Greece	0.1	0.834	1.020	1.000	1.000	0.895	0.956	0.977	1.002	1.000
India	0.3	0.831	0.913	1.063	1.002	0.916	0.981	1.012	0.992	1.004
Italy	0.8	0.770	0.986	0.983	0.995	0.850	0.948	0.991	0.996	0.994
Japan	0.9	0.773	0.971	0.997	0.971	0.886	0.953	0.954	0.975	0.981
Mexico	0.4	0.774	1.014	0.975	0.998	0.811	0.987	1.033	1.000	1.002
Poland	0.3	0.758	0.998	0.993	0.982	0.804	0.975	1.027	0.994	0.998
Romania	0.1	0.719	1.072	0.955	0.999	0.754	0.953	1.000	0.995	0.991
South Korea	0.6	0.832	0.997	1.027	0.994	0.867	0.971	1.007	0.980	0.994
Spain	0.5	0.756	0.975	1.010	0.995	0.827	0.952	0.993	0.997	0.986
Sweden	0.3	0.724	0.946	0.943	0.993	0.824	0.974	1.023	0.994	0.991
United Kingdom	0.7	0.809	1.029	0.978	0.995	0.861	0.959	1.015	0.996	0.995
United States	2.2	0.808	0.984	1.013	0.998	0.869	0.963	1.002	0.999	0.995
Rest of World	4.5	0.788	0.977	0.992	0.999	0.872	0.962	1.002	1.002	1.000

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 changes of trade during the three quarter recession for each transition path. All values are relative to global GDP.

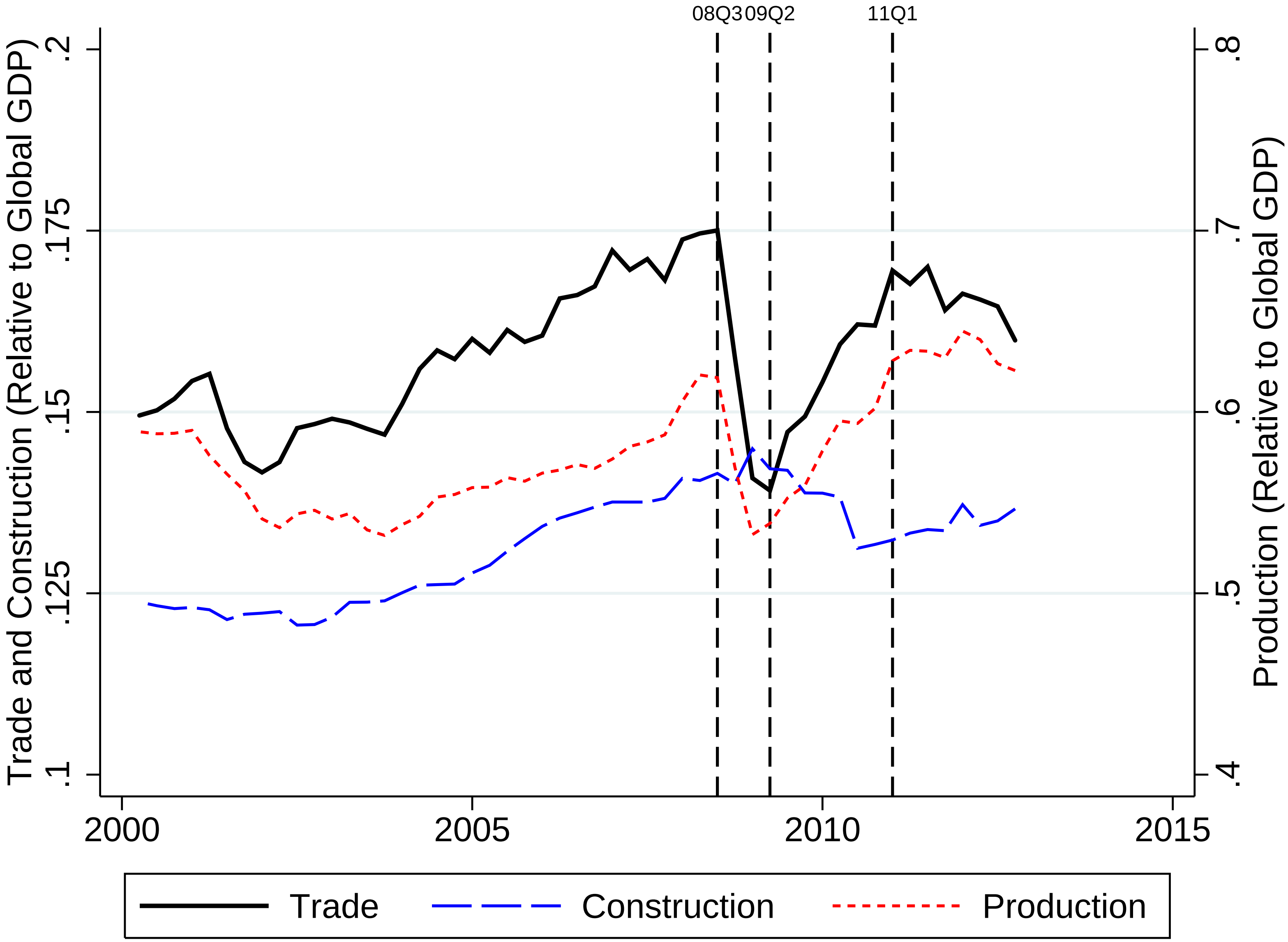
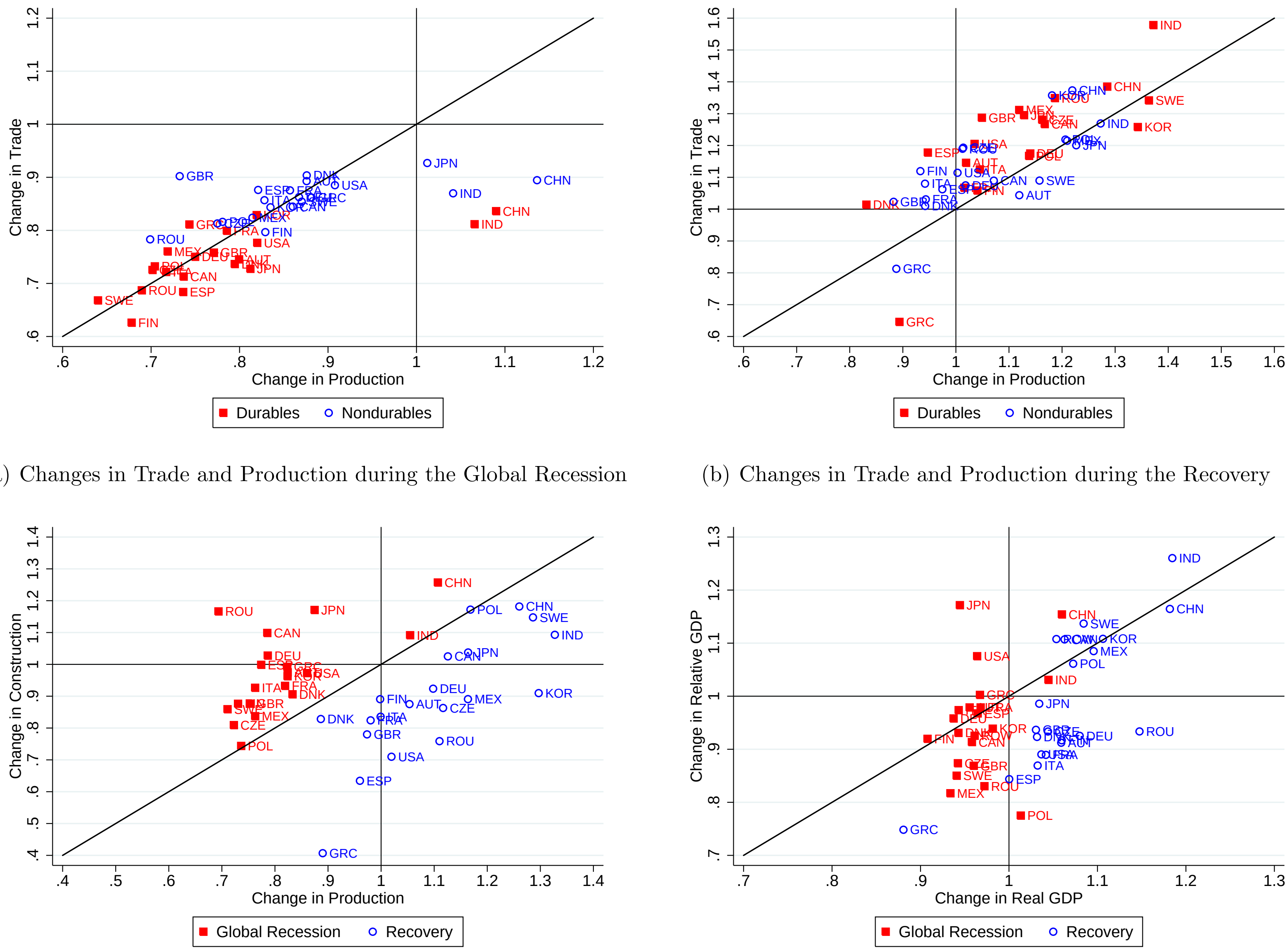


Figure 1: Global Trade, Production, and Construction as a Share of GDP

Notes: See Appendix Section A for details on dataset and discussion of how we construct the lines prior to 2006, when our constant panel of countries starts. Trade and production are for the manufacturing sector.



(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) Changes in Relative and Real GDP

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

Notes: Observations in Panels (a)-(d) 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. All values other than for real GDP are relative to global GDP. Trade and production are for the manufacturing sector.

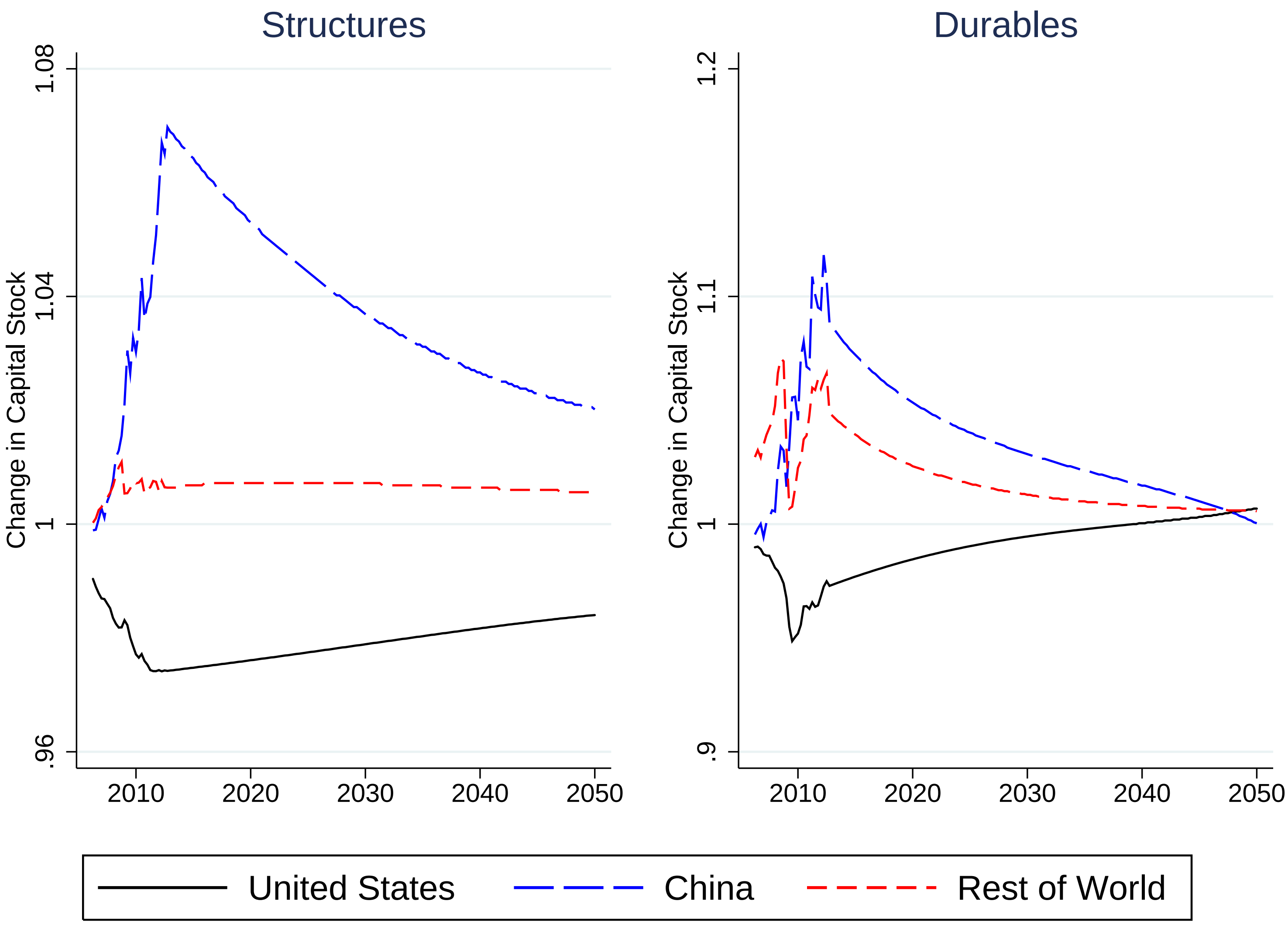


Figure 3: Simulated Transition of Capital Stocks Toward Steady State

Notes: The figures plot, for the three largest countries, the evolution of annualized changes 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.

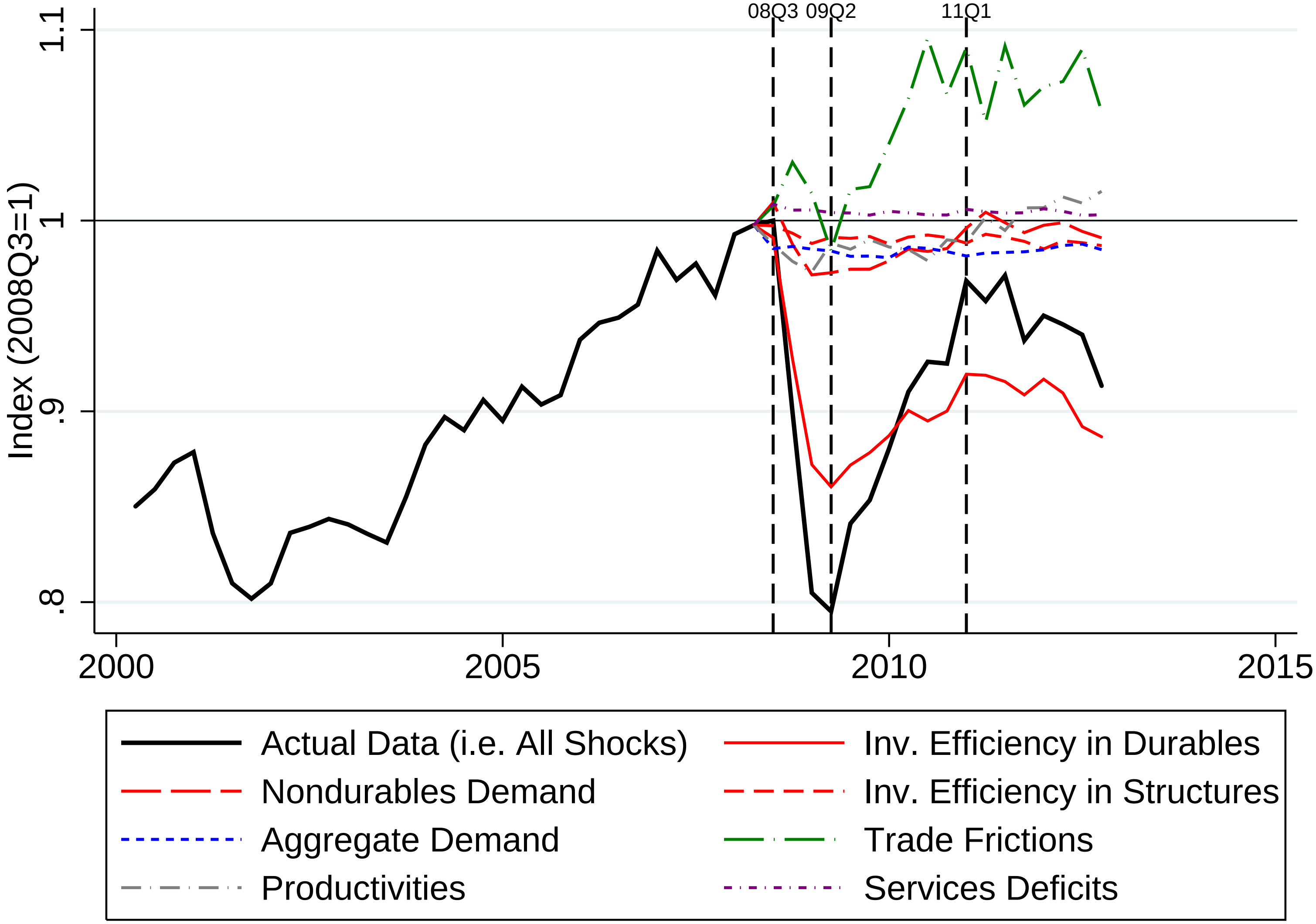


Figure 4: Actual and Counterfactual Evolution of Global Trade

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.

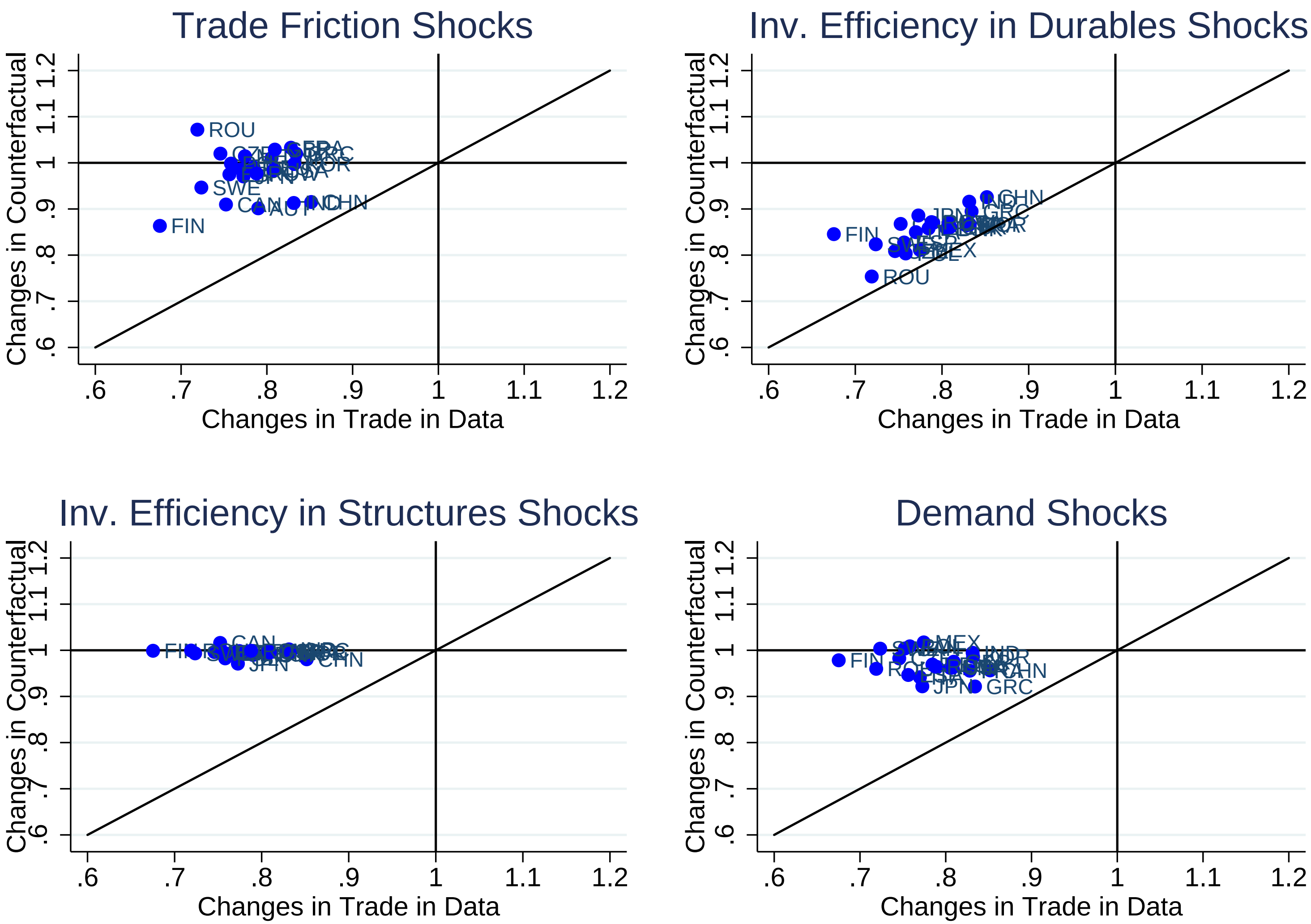


Figure 5: Cross-Sectional Explanatory Power of Various Shocks for Trade during the Global Recession

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.

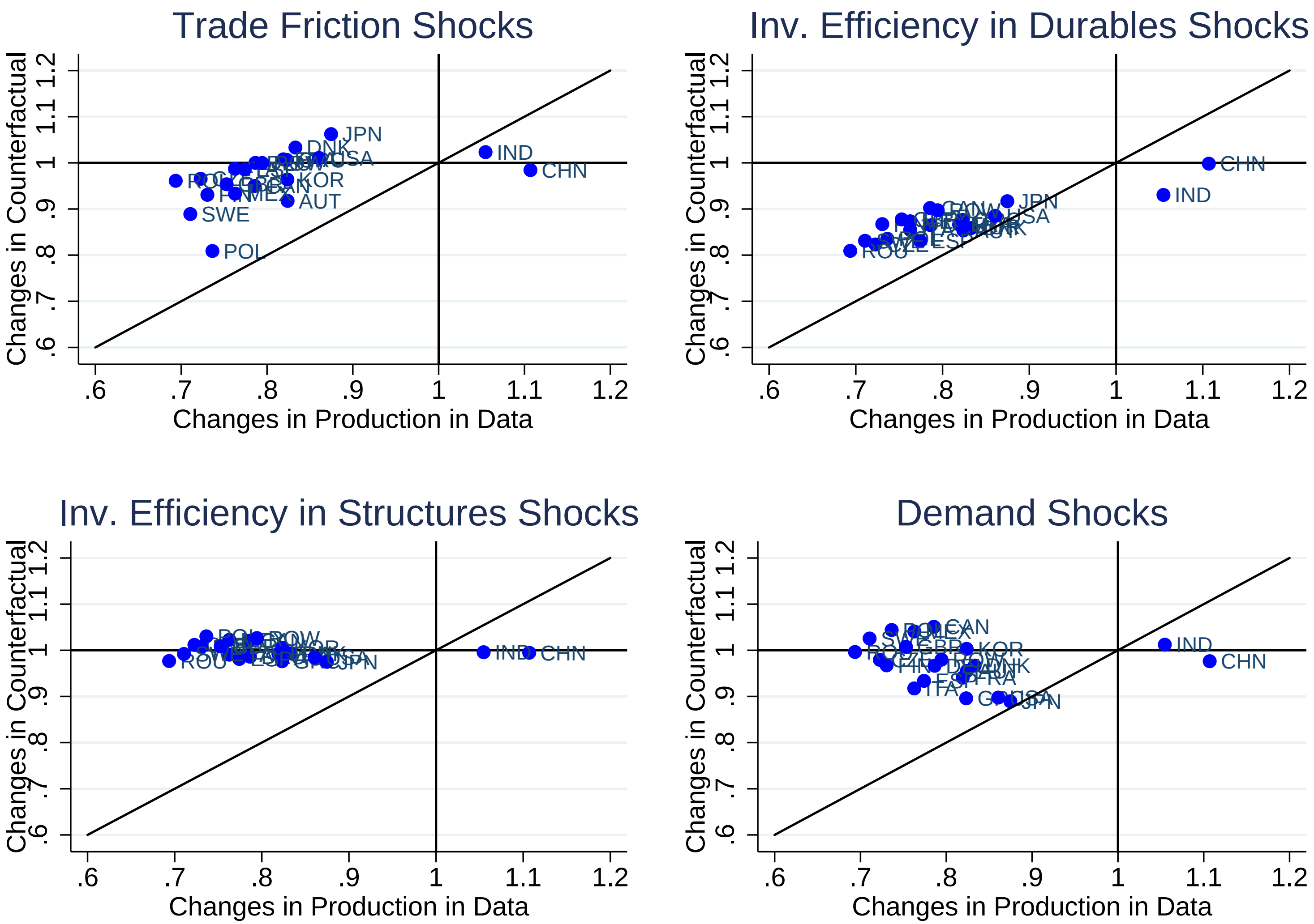


Figure 6: Cross-Sectional Explanatory Power of Various Shocks for Production during the Global Recession

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.

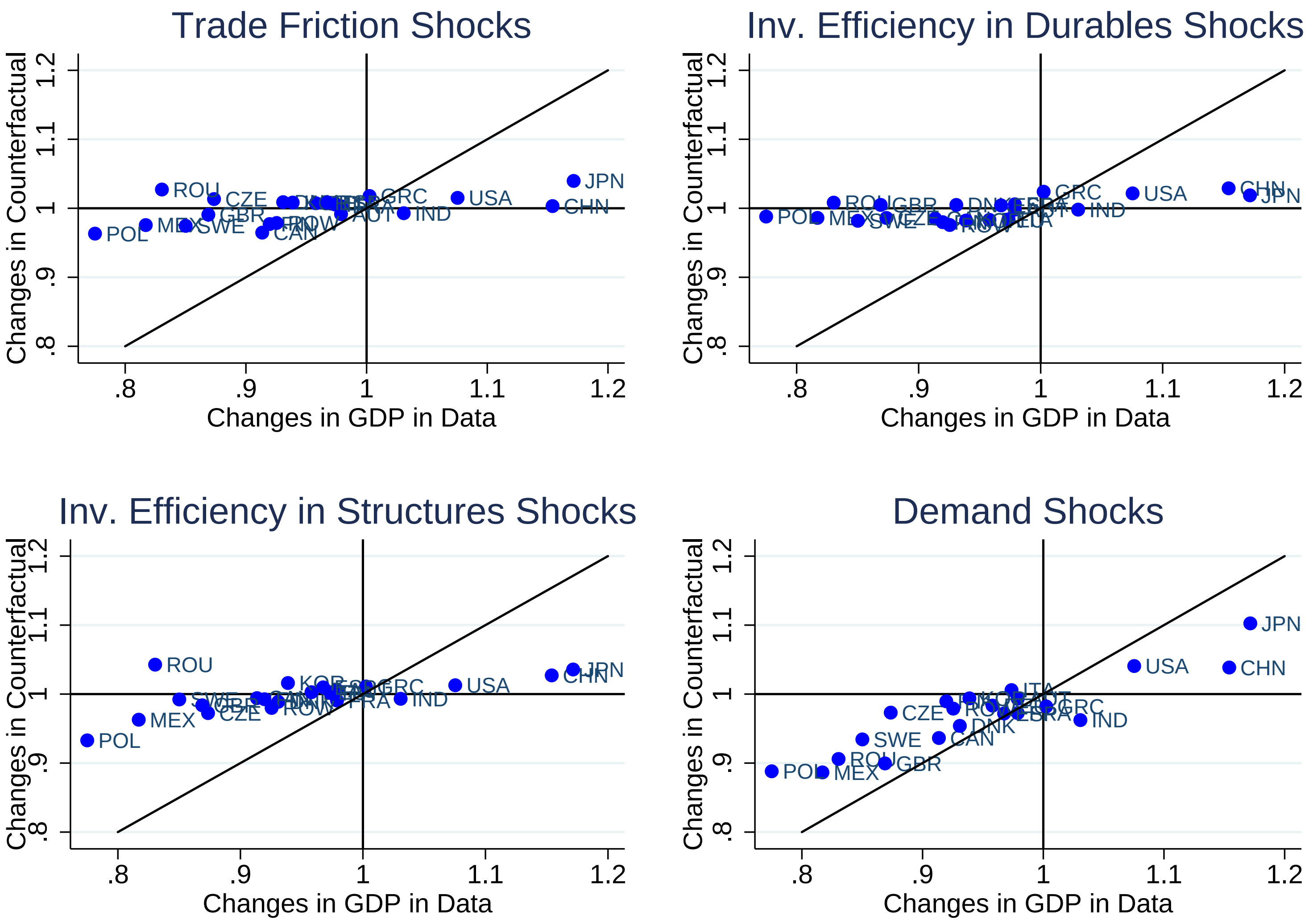


Figure 7: Cross-Sectional Explanatory Power of Various Shocks for GDP during the Global Recession

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.

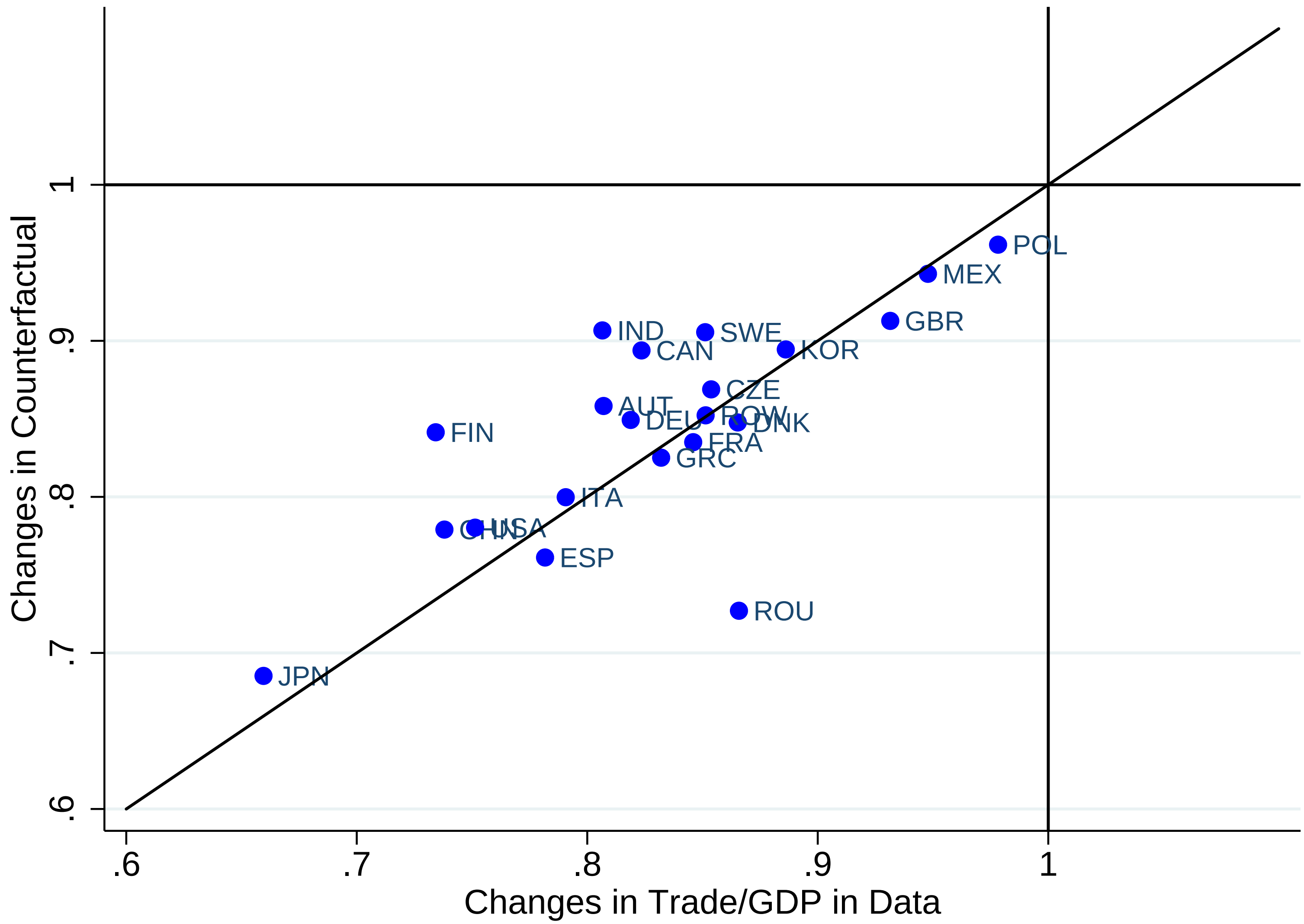


Figure 8: Explanatory Power of Investment Efficiency and Demand Shocks for Trade/GDP during the Global Recession

Notes: The figure plots, against the actual changes in 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.

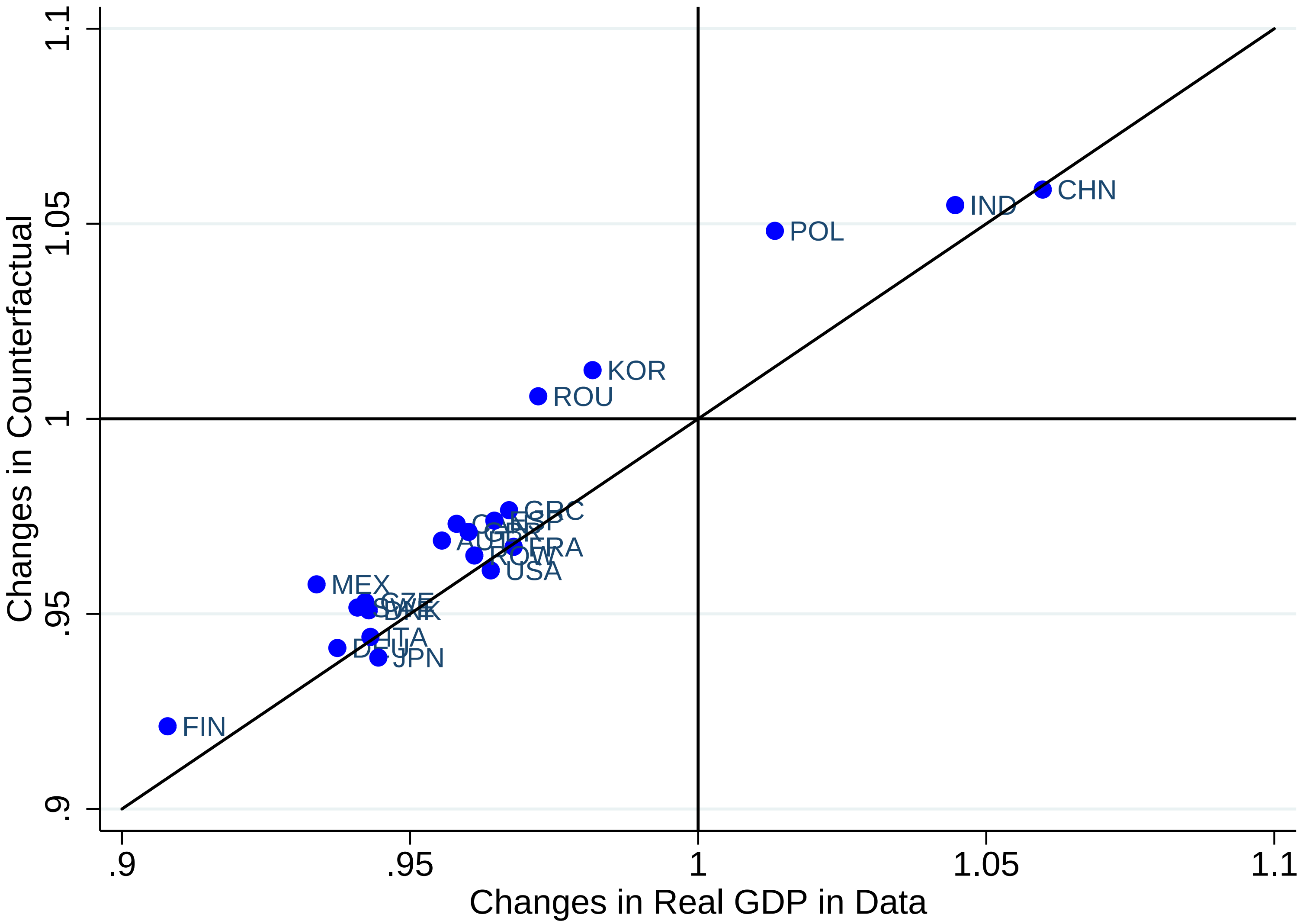


Figure 9: Explanatory Power of Labor and Productivity Shocks for Real GDP during the Global Recession

Notes: The figure plots, against the actual changes in a country's real GDP during the three quarter recession, the changes that occur over that period in a counterfactual exposed only to the path of shocks to labor and productivity.

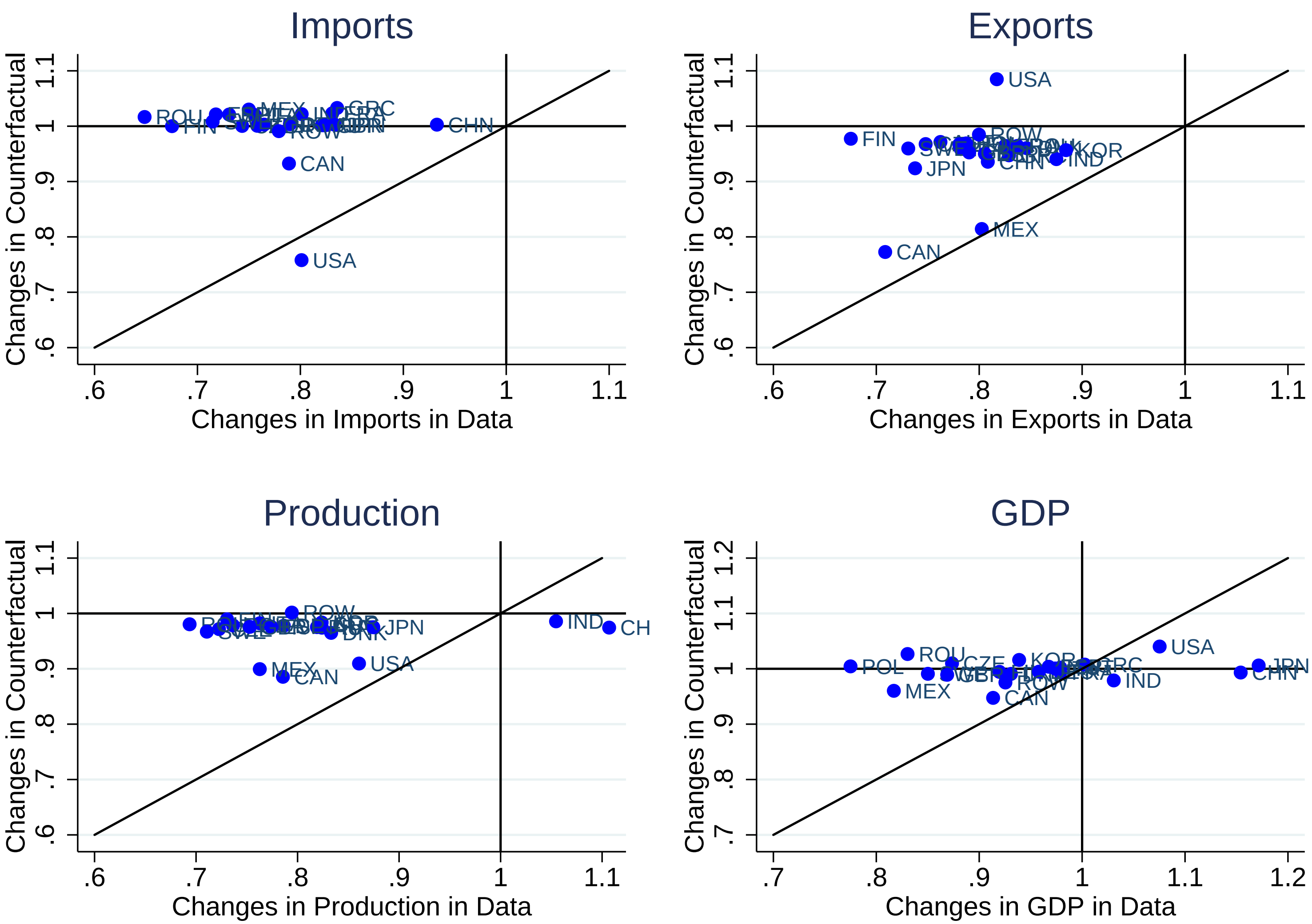


Figure 10: Counterfactual Response to U.S. Shocks during the Global Recession

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.

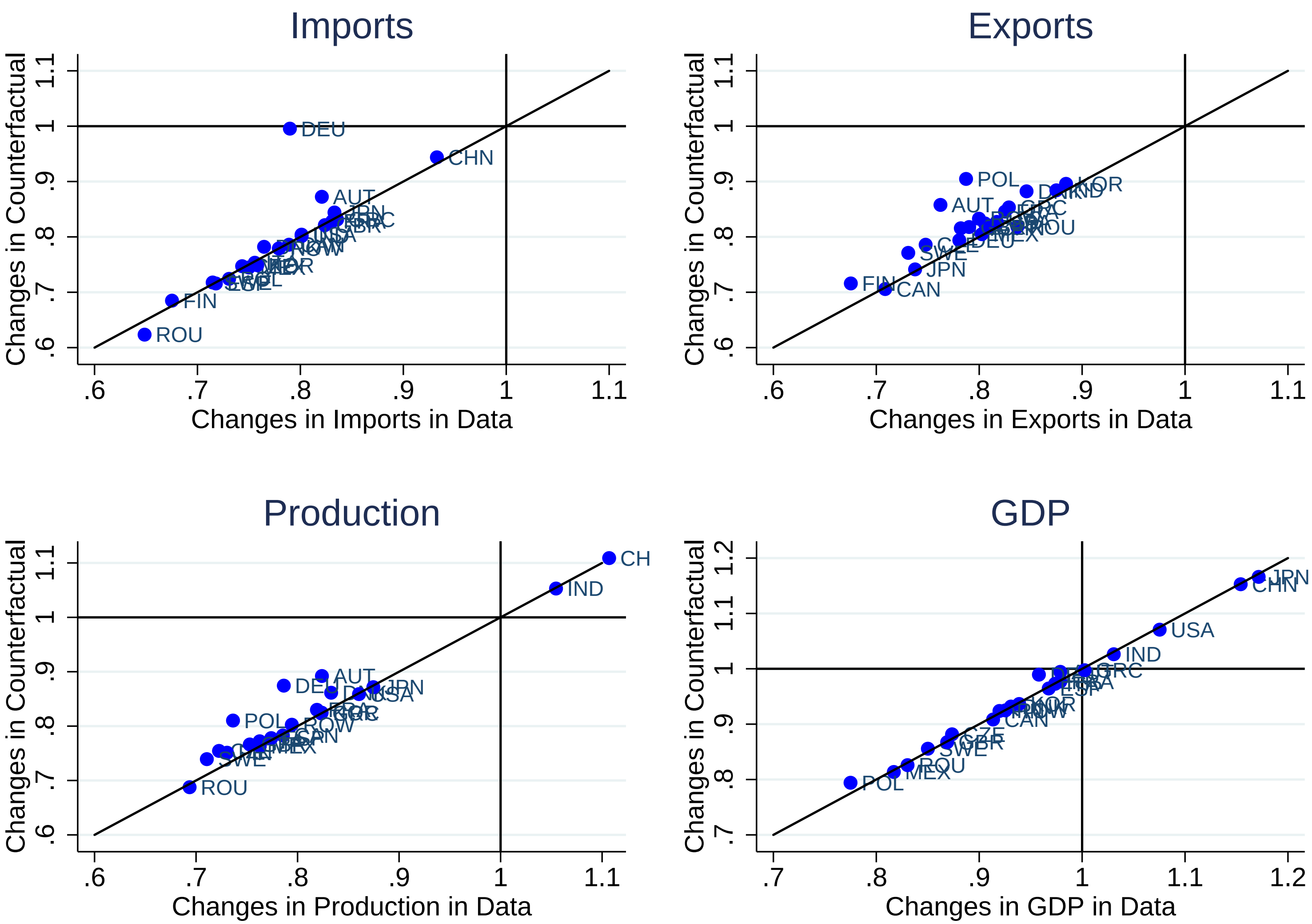


Figure 11: Counterfactual Response to Shocks other than Germany's during the Global Recession

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.