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ABSTRACT

Obstfeld and Rogoff (2001) propose that trade frictions lie behind key puzzles in international macroeconomics. We take a dynamic multicountry model of international trade, production, and investment to data from 19 countries to assess this proposition quantitatively. Using the framework developed in Eaton, Kortum, Neiman, and Romalis (2015), we revisit the puzzles in a counterfactual with drastically lower trade frictions. Our results largely support Obstfeld and Rogoff's explanation. Most notably, with lower trade frictions, domestic investment becomes much less correlated with domestic saving, mitigating the Feldstein-Horioka (1980) puzzle. Nominal GDP becomes less variable while real GDP becomes much more closely tied to nominal GDP, mitigating the purchasing power parity and exchange rate disconnect puzzles. Lower trade frictions don't help resolve all of the puzzles, however. The correlation of consumption growth across countries, if anything, diminishes.

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1 Introduction

International macroeconomics has grappled with a number of empirical regularities that are at odds with the simplest canonical model of the international macroeconomy. This canonical model assumes complete markets, frictionless trade (at least for some sectors), and a national representative household. Financial market incompleteness is one explanation for the gap between this formulation and the data. In a provocative paper, Obstfeld and Rogoff (2001, henceforth OR) propose, instead, that trade frictions alone could explain these "puzzles," with no financial market incompleteness required.[1]

Their explanation, if true, would be satisfying for a number of reasons. For one thing, there are myriad ways in which financial markets can be incomplete. Hence a particular puzzle could be resolved by assuming a particular friction consistent with it, imposing little discipline on the endeavor. For another, the force of gravity is strongly evident in the trade data, providing a means of measuring the magnitude of trade frictions. OR's account thus holds out the hope of explaining a wide range of observations in international trade and in international macroeconomics with a single force that is fairly easy to quantify.

OR show how trade frictions have the potential to resolve some of these puzzles qualitatively. Since they pursued their analysis in a set of stylized two-country examples, their ability to show how far this explanation can go quantitatively is limited. As Engel (2001) writes in his comment on their paper, "OR provide us with extraordinary intuition for why goods markets move things in the right direction, but we need more study to be able to reconcile their compelling but simplified examples with the results that emerge from simulation of more fully specified dynamic models."

A barrier to the quantitative analysis of OR's explanation is the technically daunting task of introducing trade frictions into a multi-country dynamic framework. Dealing with a finite number of goods with trade frictions requires grappling with a taxonomy of cases, depending on whether a particular good is traded and, if so, in what directions. As the number of goods or countries rises, the taxonomy explodes.[2]

[1] Dumas (1992) is an earlier paper showing how trade frictions limit financial market integration.

[2] As OR recognize, using a continuum of goods as in Dornbusch, Fischer, and Samuelson (1977) alleviates some of the problem, but one is still stuck with two countries.

Eaton, Kortum, Neiman, and Romalis (2015, henceforth EKNR) recently developed a multicountry dynamic model of international trade and production to investigate the forces behind the collapse of trade in the Global Recession of 2008-2009 and its recovery in the aftermath. Their methodology allows for an arbitrary number of sectors (each with a continuum of goods) and countries and is amenable to realistic calibration with readily available data.

Their methodology relates changes in trade, production, spending, and prices across four sectors in each country to underlying shocks emanating from the other countries, most importantly shocks to trade frictions, productivity, the efficiency of investment, and intertemporal preferences. The framework is one of dynamic equilibrium accounting, in the spirit of Chari, Kehoe, and McGrattan (2007), but in a multicountry context: The shocks fully explain the data. To dissect the forces underlying the trade collapse, EKNR shut down various subsets of shocks and recompute the equilibrium to isolate those most responsible for what happened.

In this paper we apply EKNR's framework to quantify the role of trade frictions in explaining several of OR's puzzles. Since in our methodology the underlying shocks explain the data perfectly, any puzzle in the data is necessarily captured by the model. To give OR's explanation substance we compare the puzzles in the data with a counterfactual in which trade frictions are drastically reduced, but with other shocks kept exactly as in the factual. The disappearance of a puzzle in the counterfactual with lower trade frictions vindicates OR's explanation. To the extent that a puzzle survives, other forces must be at work.

Our results provide quantitative support for OR's explanation as it applies to the Feldstein-Horioka puzzle and to the exchange-rate disconnect. Reducing trade frictions to an extent that world trade would rise by a factor of four greatly reduces the correlation between national investment and saving rates and greatly reduces the disconnect between changes in real and nominal GDP (the purchasing power parity and exchange rate disconnect puzzles). The lack of consumption correlation survives the lowering of trade frictions unscathed, however. We also find that, for almost all the countries in our sample, lower trade frictions reduce the standard deviation of the growth in nominal GDP but raise the standard deviation of the growth in real GDP, bringing the two closer together.

A number of researchers have pursued OR's argument in directions different from ours.

Corsetti, Dedola, and Leduc (2008) explore the role of trade frictions in risk sharing and in the relationship between real exchange rates and relative consumption, the Backus-Smith (1993) puzzle. Coeurdacier (2009) assesses the ability of trade frictions to explain home-bias in equity holdings. Fitzgerald (2012) shows how geographic factors can explain cross-country deviations from perfect consumption risk sharing, finding that, for OECD countries, geographic factors work. Rabitsch (2012) examines the role of trade frictions for monetary policy.

Complementary to our analysis here is Reyes-Heroles (2015). Using a related framework, he shows that, if trade frictions had not declined since 1970, trade imbalances would now be much closer to zero.

We proceed as follows: Section 2 presents our data. Section 3 reviews the puzzles and examines the extent to which they appear in our data. How we adopt the EKNR framework to the task at hand is the topic of Section 4. Section 5 returns to the data introduced in Section 2 to see how OR's explanation fares. We create a counterfactual world with drastically lower trade frictions but with the other shocks driving the world economy unchanged. We repeat the exercises performed on the actual data reported in Section 3 with data generated in this counterfactual world.

2 Our Data

We apply our analysis to 19 countries (18 actual countries and a Rest of World) across four sectors: construction, durable manufactures, nondurable manufactures, and services. We treat the gross output of the two manufacturing sectors as tradable and the gross output of construction and of services as nontradable. We treat the final output of nondurable manufactures and of services as consumption goods and the final output of construction and of durable manufactures as investment goods. We use data from EKNR on production and prices, along with data on bilateral trade for the two manufacturing sectors. Our data are quarterly, extending from 2000:Q1 to 2012:Q4. Table 1 lists the countries and some key magnitudes.[3]

[3]See the online appendix to EKNR for a detailed description of how the data were assembled.

3 The Puzzles

We now turn to OR's puzzles. For those that our analysis has something to say about, we examine their presence in our sample of countries over our period.

3.1 Puzzle 1: The Puzzle of Home Bias in Trade

Why do people have such a strong preference for their home goods? To explain home bias in purchases OR develop a symmetric two-country Armington model which they calibrate to a ratio of home to foreign consumption spending of 4.2. They match this ratio by introducing iceberg trade costs $d = 4/3$ and CES demand with an elasticity of substitution of 6.

For each of our 19 countries, the first two columns of Table 2 report the ratio of purchases from home to imports for durable and nondurable manufactures, the two sectors we treat as tradable. For durables, the implied ratio of home to foreign spending varies from 0.17 (for Denmark) to 6.39 (for Japan). For nondurables, which exhibit more home bias, it varies from 0.42 (for Denmark) to 8.00 (for India). Hence the range of home bias that our countries exhibit in these two sectors spans OR's postulated amount.

In our many-country world, trade frictions can differ between any pair of countries and across sectors. Home bias is just one manifestation of a much more general feature of bilateral trade, gravity: The value of trade between any pair of countries diminishes with distance, with an elasticity around one.

The first two columns of Table 3 report results from running a gravity regression among our 18 actual countries for durable and nondurable manufactures. Specifically we estimate the equation:

$$\ln\left(\frac{\pi_{ni}^{j}}{\pi_{nn}^{j}}\right) = S_i^j + D_n^j + \mathbf{B}^j \cdot \mathbf{x}_{ni} + u_{ni}^j, \tag{1}$$

where π_{ni}^j is the share of country i in country n's total spending on goods in sector j, where $j \in \{D, N\}$, denoting durables and nondurables, respectively, S_i^j is a fixed effect for exporter i, and D_n^j is a fixed effect for importer n. The vector $\mathbf{x}_{ni}$ corresponds to a set of bilateral characteristics for countries i and n that commonly show up in the gravity literature: (i) the distance between them, (ii) an indicator for whether countries are contiguous, and (iii) an indicator for whether they share a common language (either official or primary). The data are for 2005:Q4, around the middle of our sample.

Our estimates of the distance elasticity are highly significant and somewhat greater than one, but in the general neighborhood. Common language is also significant while contiguity is not. As is typical in empirical gravity equations, country fixed effects together with geography explain trade very well. The R^2's both exceed 0.9.

While our gravity regression relates bilateral trade flows to geographic indicators, these indicators play no role in what follows. Our analysis below takes into account the trade frictions that give rise to the actual bilateral trade shares π_{ni}^j in sector j.

3.2 Puzzle 2: Feldstein-Horioka

A classic paper by Feldstein and Horioka (1980, henceforth FH) establishes that long-period averages of domestic investment rates are highly correlated with similar averages of national saving rates. If individual countries are part of an integrated global market for investment funds then (i) a positive shock to saving in a particular country should raise investment everywhere, while (ii) a positive shock to investment should attract funding from everywhere. If investment and saving shocks are uncorrelated with each other across countries, there is no reason for the local response to be more pronounced than anywhere else. Hence FH's finding constitutes a puzzle under an assumption of global market integration.

In FH's original paper, cross-country regressions of investment on saving, both as shares of GDP, averaged over the period 1960 to 1974, yielded a slope of 0.89, nearly one. OR perform the equivalent regression, averaged over 1990-1997. They get a coefficient of 0.60 for the OECD, lower than FH but still substantially greater than zero.

To assess the extent to which the puzzle survives in our sample of countries in our period we perform the corresponding exercise. We define country n's investment spending in year t, $X_{n,t}^I$, as the sum of final spending on construction and on durable manufactures.[4] We construct

[4] Here we follow EKNR in treating consumer durables as a component of the stock of durable manufactures. Hence household spending on durable manufactures constitutes investment spending, just like business spending

a measure of country n's saving in year t, $S_{n,t}$, by augmenting investment spending $X^I_{n,t}$ by the trade balance calculated from the excess of production over absorption in country n.[5] Following FH and OR, we normalize both measures by country n's GDP in period t, creating the investment rate, $i_{n,t} = X^I_{n,t}/GDP_{n,t}$, and the savings rate, $s_{n,t} = S_{n,t}/GDP_{n,t}$. We take averages $\bar{\imath}_n$ and $\bar{s}_n$ over different subperiods of our sample.

We estimate the relationships:

$$\bar{\imath}_n = \alpha + \beta \bar{s}_n + \varepsilon_n \tag{2}$$

and:

$$\Delta(i_n) = \alpha + \beta \Delta(s_n) + \varepsilon_n, \tag{3}$$

where $\Delta(i_n) = i_{n,2012} - i_{n,2001}$ and $\Delta(s_n) = s_{n,2012} - s_{n,2001}$. The first four columns of Table 4 report the results, for different subperiods and for the long difference from the beginning to the end of the sample.[6]

Several results stand out. In terms of the relationship in levels, in the period before the Great Recession (2001-2008) the coefficient is 0.24 and not significantly different from 0, much smaller than in the earlier studies mentioned above. This result suggests that the puzzle, at least among the countries in our sample, had been waning. But it comes back with a vengeance during and after the recession (2009-2012), with a significant coefficient of 0.63, in line with OR's estimate. Moreover, the puzzle remains very pronounced in looking at differences over the entire period, with a significant coefficient of 0.88, in line with FH.

on durable manufactures.

[5]FH constructed two different saving measures using the trade balance and the current account to augment investment to get saving. We pursue only the trade balance definition as our framework below does not generate predictions about the current account.

[6]While our data begin in 2000, we examine the puzzles starting in 2001. The reason is that we drop 2000 from our counterfactuals below to minimize the impact on our results of the transition from the factual, as we explain further below. Hence we examine the puzzles in the data and in our counterfactuals over the same period, 2001-2012.

3.3 Puzzle 3: Home-Bias in Equity Portfolios

OR, like EKNR, assume complete Arrow-Debreu markets. They show that in a special case of their model (if the parameters for relative risk aversion and the elasticity of substitution in their two-country Armington model satisfy a particular condition), equities are sufficient to span the markets. They then show that in this special case equity holding would exhibit home-bias.

The general version of EKNR would not satisfy OR's condition for equities to span markets, so that additional cross-country transfers would be needed to achieve market completeness. Addressing this puzzle requires a detailed modeling of financial markets which lies beyond the scope of our current framework.[7] We leave integrating this puzzle into our framework for future research.

3.4 Puzzle 4: The International Consumption Correlations Puzzle

In the canonical model, frictionless trade, complete markets, and identical, risk-averse preferences imply identical consumption growth rates across countries. Earlier papers, notably Backus, Kehoe, and Kydland (1992) and Stockman and Tesar (1995), show that the correlation of consumption growth is highly imperfect, even when limited to consumption of highly tradable goods.

OR report the correlation of real annual per capita consumption growth among 6 major economies during 1973-1992. Coefficients range from a low of 0.13 (between Italy and the United States) to a high of 0.65 (between the United Kingdom and the United States), with a simple average of 0.40.

Turning to our sample, because they are relatively tradable and spending is likely to correlate with final enjoyment of the good, we focus on the cross-country correlation of real household purchases of nondurable manufactures. Among our countries, the coefficients vary between -0.53 (between Canada and Greece) and 0.94 (between Austria and Japan), with a simple average of 0.40 and a median of 0.47. The first column of Table 5 reports summary statistics. The solid line in Figure 1 shows the density of correlation coefficients.

In summary, even though we focus only on a particularly tradable component of consumption

[7] There is a large literature on home bias in portfolios. Heathcote and Perri (2013b) make a recent contribution justifying home bias on the basis of risk characteristics.

and consider a much later period, the lack of perfect correlation found in previous studies remains very evident.

3.5 Puzzle 5: The Purchasing-Power-Parity Puzzle and Puzzle 6: The Exchange-Rate Disconnect Puzzle

OR lump their last two puzzles together. They concern long deviations from purchasing power parity (PPP) and how little large fluctuations in nominal exchange rates affect real outcomes other than the real exchange rate.

We pursue the puzzles together by examining the (dis)connection between real and nominal GDP. To show how this disconnect relates to these puzzles, denote country i's nominal local currency GDP as Y_i and its price level in terms of its local currency as P_i. Let e_i denote the value of country i's currency in terms of a numéraire currency (its nominal exchange rate). Translating magnitudes into the numéraire, country i's nominal GDP is e_iY_i and its price level is e_iP_i. Its real GDP relative to country n's is:

$$\frac{Y_i/P_i}{Y_n/P_n} = \frac{(e_iY_i)\,/\,(e_iP_i)}{(e_nY_n)\,/\,(e_nP_n)} = \frac{(e_iY_i)\,/\,(e_nY_n)}{(e_iP_i)\,/\,(e_nP_n)}.$$

Hence country i's relative real GDP is its relative nominal GDP divided by its real exchange rate.[8] Taking log differences, the variance in the growth of relative real GDP equals the variance in the growth of relative nominal GDP plus the variance in the growth of the real exchange rate less twice their covariance. Relative Purchasing Power Parity (RPPP) implies a constant real exchange rate, so that the latter two terms equal zero. With RPPP, therefore, the variance in the growth of relative real GDP and of relative nominal GDP are the same.

The first two columns of Table 6 report, for our set of countries, the standard deviation of log changes in nominal and in real GDP, after first removing quarterly time effects from each series.[9] Note that, for every country, nominal GDP is much more volatile, by a factor that ranges from

[8] We define the real exchange rate as the relative price of GDP rather than the relative price of consumption.

[9] We calculate the standard deviation as the residuals of a regression of the relevant series, either the log difference of real GDP or the log difference of nominal GDP, on a full set of time effects for each quarter in the sample. By removing time effects common across all countries, the results are invariant to the choice of numeraire and to the choice of the normalizing country n.

around two up to six. This finding implies a massive failure of RPPP. Growth in relative nominal GDP largely moves together with growth in the real exchange rate.

Is the comovement of nominal GDP growth and real exchange rate growth so complete that growth in nominal GDP has no predictive power for growth in real GDP? The first column of Table 7 shows, for our set of countries, the results of a panel regression of log changes in real GDP on log changes in nominal GDP, with country and time fixed effects.[10] Under perfect RPPP, the slope should be one. In our data the slope coefficient is highly significant, but only 0.12. Fluctuations in real GDP are quite disconnected from fluctuations in nominal GDP and in the nominal and real exchange rates.

4 A Multi-Country Dynamic Framework

We now turn to the EKNR framework that we use to tie our data to underlying shocks, including shocks to trade frictions.[11] We then replace the shocks to trade frictions that we back out with an alternative set that moves the world drastically toward frictionless trade. We use these alternative trade shocks to construct a counterfactual dataset with much lower trade frictions.

We allow for an arbitrary number $\mathcal{N}$ of countries and four sectors: construction (C), durable manufactures (D), nondurable manufactures (N), and services (S), which aggregates everything else. We denote the set of all sectors as $\Omega = \{C, D, N, S\}$.

Country i at time t has an endowment of labor $L_{i,t}$ and two types of capital $K^k_{i,t}$, $k \in \Omega_K = \{C, D\}$, corresponding to structures (produced by its construction sector) and consumer and producer durables. Firms use the services of these stocks of capital for production while households consume the services of these stocks. Each sector's output also serves as an intermediate input for all four sectors.

[10] Again, time fixed effects make the results invariant to the numéraire.

[11] A note that derives and analyzes a simplified version of the model can be found on the authors' web pages.

4.1 Technology

Production in each sector is Cobb-Douglas in labor, capital, and intermediates. In country i, sector j has a labor share $\beta_i^{L,j}$, a share of capital of type k of $\beta_i^{K,jk}$, and a share of intermediates from sector l, $\beta_i^{M,jl}$ for $j, l \in \Omega$, $k \in \Omega_K$.

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

$$F_{i,t}^j(a) = \Pr\left[a_{i,t}^j \leq a\right] = \exp\left[-\left(\frac{a}{\gamma^j A_{i,t}^j}\right)^{-\theta}\right], \tag{4}$$

drawn independently for each z across countries i.[12] Here, $A_{i,t}^j > 0$ is country i's average productivity in sector j. The parameter θ is an inverse measure of the dispersion of efficiencies.

As in OR, trade in a good incurs iceberg trade frictions, meaning that delivering one unit of a good produced by sector j in country i to country n requires shipping $d_{ni,t}^j \geq 1$ units, with $d_{ii,t}^j = 1$. We treat the output of sectors $j \in \{C, S\}$ as nontradable by setting $d_{ni,t}^j \to \infty$, $n \neq i$, for these sectors.

The capital stock of type $k \in \{C, D\}$ in country i evolves according to:

$$K_{i,t+1}^k = \chi_{i,t}^k \left(I_{i,t}^k\right)^{\alpha^k} \left(K_{i,t}^k\right)^{1-\alpha^k} + \left(1-\delta^k\right) K_{i,t}^k, \tag{5}$$

where $I_{i,t}^k$ is investment and δ^k is the depreciation rate. As in Lucas and Prescott (1971), not all the resources $I_{i,t}^k$ put into investment wind up as capital. With $\alpha^k < 1$, less emerges when investment is large relative to the stock of capital. The term $\chi_{i,t}^k$ allows the efficiency of investment to vary across countries and over time.

[12] Here γ^j is a parameter that depends on only θ and σ^j. Except for the requirement that $\theta > \sigma^j - 1$, σ^j and γ^j play no further role.

4.2 Preferences

As in the canonical model of the global economy, each country has a representative household that makes consumption and investment decisions. Each period t country n's household consumes nondurables and services in amounts $C_{n,t}^{N}$ and $C_{n,t}^{S}$ and the services of its stocks of durables and structures in amounts $K_{n,t}^{H,D}$ and $K_{n,t}^{H,C}$. From the perspective of the beginning of time ($t = 0$), its utility is:

$$U_n = \sum_{t=0}^{\infty} \rho^t \phi_{n,t} \left(\sum_{j \in N,S} \psi_{n,t}^{j} \ln C_{n,t}^{j} + \sum_{k \in C,D} \psi^{k} \ln K_{n,t}^{H,k} \right), \tag{6}$$

where $\psi_{n,t}^{j}$ are Cobb-Douglas weights. To accommodate shocks in the data, we allow country-specific shifts between nondurables and services over time. Here ρ is a constant discount factor that applies globally while $\phi_{n,t}$ represents country and time-varying shocks to that discount factor.[13]

4.3 Market Structure

As in OR, markets are perfectly competitive and complete. We also assume that foresight is perfect. Market perfection and completeness allow us to solve for the competitive equilibrium by solving the corresponding social planner's problem. EKNR describes our solution method.

4.4 Some Basic Expressions

The model delivers some basic expressions that are useful for understanding how we connect it to data.

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

$$c_{i,t}^{j} = (w_{i,t})^{\beta_i^{L,j}} \prod_{k \in \Omega_K} \left(r_{i,t}^{k}\right)^{\beta_i^{K,jk}} \prod_{l \in \Omega} \left(p_{i,t}^{l}\right)^{\beta_i^{M,jl}}, \tag{7}$$

where $w_{i,t}$ is the wage, $r_{i,t}^{k}$ the rental rate on capital of type k, and $p_{i,t}^{l}$ is the price index of sector l goods, all in country i at time t. These price indices are determined by production costs in each

[13] Stockman and Tesar (1995) introduce such shocks into an international real business cycle model. Heathcote and Perri (2013a) discuss their role in the subsequent literature.

country as:

$$p^j_{n,t} = \left[\sum_{i=1}^{\mathcal{N}} \left(\frac{c^j_{i,t} d^j_{ni,t}}{A^j_{i,t}} \right)^{-\theta} \right]^{-1/\theta}. \tag{8}$$

The share of what country n spends on sector j that comes from country i is:

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

Taking the ratio of what i exports to n relative to what i buys from itself, we obtain:

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

A simple rearrangement gives us an expression for the trade friction in terms of trade shares and prices:

$$d^j_{ni,t} = \left(\frac{\pi^j_{ni,t}}{\pi^j_{ii,t}} \right)^{-1/\theta} \frac{p^j_{n,t}}{p^j_{i,t}}. \tag{9}$$

4.5 The Shocks driving the Evolution of the Global Economy

EKNR describes the solution to the model which connects observed outcomes to underlying shocks. As in EKNR, we solve the model in changes to facilitate its calibration. For any variable x we define:

$$\hat{x}_{t+1} = \frac{x_{t+1}}{x_t},$$

as the change in x from t to $t+1$. Hence, $\hat{x}_{t+1} > 1$ means that x grew from t to $t+1$ and $\hat{x}_{t+1} < 1$ means it shrank, with $\hat{x}_{t+1} = 1$ meaning no change.

From period t to $t+1$ the shocks hitting the global economy are:

$$\hat{\Psi}_{t+1} = \{\hat{d}^j_{ni,t+1}, \hat{A}^j_{i,t+1}, \hat{\chi}^j_{i,t+1}, \hat{\phi}_{i,t+1}, \hat{\psi}^N_{i,t+1}, \hat{L}_{i,t+1}, D^S_{i,t+1}\},$$

consisting of:

1. trade friction shocks $\hat{d}^j_{ni,t+1}$ for $j \in \{D, N\}$, the two tradable sectors,

2. productivity shocks $\hat{A}^j_{i,t+1}$ in any sector,

3. investment efficiency shocks $\hat{\chi}^k_{i,t+1}$ for $k \in \{C, D\}$,

4. intertemporal preference shocks $\hat{\phi}_{i,t}$,

5. shocks to the demand for nondurables relative to services $\hat{\psi}^N_{i,t+1}$,

6. labor supply shocks $\hat{L}_{i,t+1}$,

7. services deficit shocks $D^S_{i,t+1}$, in levels.

The first six reflect changes in the corresponding terms in levels in the model above. We need the seventh to accommodate our treatment of the services sector as nontraded. In fact, not all trade is in manufactures, so that nonmanufacturing deficits are nonzero. To make our model consistent with adding-up constraints in the national accounts, we treat $D^S_{i,t+1}$ as exogenous and take its value from the data.

4.6 Quantification

We now turn to how we connect the model to our quarterly data. We refer to the initial period of our data, 2000:Q1, as t^I and the final period, 2012:Q4, as t^E.

4.6.1 Calibration

As described in EKNR, we choose some parameter values based on other studies and calibrate others to match steady-state moments. We use:

ρ	θ	α^C	α^D	δ^C	δ^D	ψ^C	ψ^D
0.987	2	0.50	0.55	0.011	0.026	0.280	0.015

Input-output coefficients are from the 2009 edition of the OECD's country tables. Labor shares $\beta^{L,j}_i$ are total employee compensation in sector j divided by the value of sector j's total output. The total capital shares $\beta^{K,jC}_i + \beta^{K,jD}_i$ are value added less compensation of employees divided by the value of total output in sector j, assigning 43 percent to structures. Intermediate shares $\beta_i^{M,jl}$ are total spending in sector j on inputs from sector l divided by sector j's total output.

4.6.2 Paths of Capital

To back out the shocks over our period requires knowing the paths of the changes in the capital stocks $\hat{K}_{i,t+1}^k$, which in turn requires specifying $\{\hat{\Psi}_{t+1}\}$ for the period after our data. We assume that, after date t^E, all shocks stop changing, setting:

$$\hat{d}_{ni,t+1}^j = \hat{A}_{i,t+1}^j = \hat{\chi}_{i,t+1}^j = \hat{\phi}_{i,t+1} = \hat{\psi}_{i,t+1}^N = \hat{L}_{i,t+1} = 1,$$

and $D_{i,t+1}^S = D_{i,t^E}^S$ for $t > t^E$. The world then converges to a stationary state in which all magnitudes, including capital stocks, are constant. We solve for the $\hat{K}_{i,t+1}^k$ for t beyond t^E that allow the economy to glide along a perfect foresight path to this stationary state.

We then iterate backwards to $t^I + 1$, using the following equation derived by combining (5) and the Euler equation for intertemporal utility maximization:

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

Along with the parameters above, we use data on investment spending for $X_{i,t}^{I,k}$ and obtain $r_{i,t}^k K_{i,t}^k$ from data on production, spending, and our Cobb-Douglas preference shares and capital shares.

4.6.3 Paths of Shocks

Given paths for changes in capital $\hat{K}_{i,t+1}^k$ and the parameter values described above, we back out the shocks from our data as follows:

1. For the traded sectors, equation (9) delivers an expression relating (unobserved) changes in trade frictions to (observable) changes in trade shares and in price indices:

$$\hat{d}_{ni,t+1}^j = \left(\frac{\hat{\pi}_{ni,t+1}^j}{\hat{\pi}_{ii,t+1}^j} \right)^{-1/\theta} \frac{\hat{p}_{n,t+1}^j}{\hat{p}_{i,t+1}^j}. \tag{10}$$

2. Since $\psi^N_{i,t} + \psi^S_{i,t} = 1 - \psi^C - \psi^D$:

$$\hat{\phi}_{i,t+1} = \frac{X^{C,N}_{i,t+1} + X^{C,S}_{i,t+1}}{X^{C,N}_{i,t} + X^{C,S}_{i,t}}, \tag{11}$$

and:

$$\hat{\psi}^N_{i,t+1} = \frac{\hat{X}^{C,N}_{i,t+1}}{\hat{\phi}_{i,t+1}}, \tag{12}$$

letting us back out demand shocks from observations on final consumption spending on nontradables $X^{C,N}_{i,t}$ and on services $X^{C,S}_{i,t}$.

3. Changes in labor $\hat{L}_{i,t}$ are from data.

4. Services trade deficits $D^S_{i,t+1}$ are from data.

5. The law of motion for capital in changes:

$$\hat{\chi}^k_{i,t+1} = \left(\frac{\hat{X}^{I,k}_{i,t+1}}{\hat{p}^k_{i,t+1}\hat{K}^k_{i,t+1}}\right)^{-\alpha^k} \frac{\hat{K}^k_{i,t+2} - (1-\delta^k)}{\hat{K}^k_{i,t+1} - (1-\delta^k)}, \tag{13}$$

lets us back out shocks to the efficiency of investment from data on spending on durables and on construction.

6. We back out productivity shocks $\hat{A}^j_{i,t+1}$ using the expression:

$$\hat{A}^j_{i,t+1} = \frac{\hat{c}^j_{i,t+1}}{\hat{p}^j_{i,t+1}} \left(\hat{\pi}^j_{ii,t+1}\right)^{1/\theta}, \tag{14}$$

where $\hat{c}^j_{i,t+1}$ is the change in input costs $c^j_{i,t+1}$ given in (7). For $\hat{p}^l_{i,t}$ we use data on the relevant price indices. We back out $\hat{w}_{i,t}$ and $\hat{r}^k_{i,t}$ from data on changes in output and changes in consumer spending, and our parameters $\beta^{L,j}_i$, $\beta^{K,jk}_i$, and ψ^k.

This procedure delivers our factual shocks $\{\hat{\Psi}_{t+1}\}$, with all values of the shocks frozen as described above for $t \geq t^E$. By construction, the solution to the model with the factual shocks replicates our data for the period of 2000:Q1 to 2012:Q4. After that date the solution glides toward the steady state.

5 The Puzzles in a World with Low Trade Frictions

We now ask how well OR's puzzles survive in a counterfactual world with much lower trade frictions in manufactures, continuing to treat construction and services as nontraded. To construct this world we first extract the shocks driving the world economy during 2000:Q1 through 2012:Q4, as described in Section 4. We then solve the dynamic equilibrium of the model in a counterfactual in which we introduce alternative trade friction shocks $\hat{d}^{jC}_{ni,t+1}$ for $j \in \{D, N\}$ that bring the levels of trade frictions $d^{j}_{ni,t+1}$ closer to one. We now describe how we derive these shocks.

5.1 Reducing Frictions

We reduce trade frictions toward frictionless trade at the beginning of our period and hold them fixed thereafter. We simulate such a world as follows:

1. For our initial period t^I we insert data on trade shares and prices into the right-hand side of expression (9) to calculate a measure of actual trade frictions, in levels, denoted $\tilde{d}^{j}_{ni,t^I}$ for each pair of countries i, n, $i \neq n$.[14]

2. We construct a counterfactual change in trade frictions between period t^I and $t^I + 1$ as:

$$\hat{d}^{jC}_{ni,t^I+1} = \left(\tilde{d}^{j}_{ni,t^I}\right)^{-\upsilon}.$$

   This change lowers trade frictions in period $t^I + 1$ away from their measured t^I value toward 1. Here $\upsilon \in [0, 1]$ is a term that modulates the reduction in trade frictions, with $\upsilon = 0$ corresponding to no change from t^I and $\upsilon = 1$ corresponding to a move to completely frictionless trade after t^I.

3. We set $\hat{d}^{jC}_{ni,t+1} = 1$ for $t > t^I + 1$, thus freezing trade frictions at this lower level.

[14]We calculate price levels from the World Bank's International Comparisons Project for 2005. We assume relative price levels for durables in 2005:Q4 equals the relative price level indices in the data for "Machinery and equipment." We assume relative price levels for nondurables equals the relative level of expenditure-share weighted averages of "Food and non-alcoholic beverages", "Alcoholic beverages and tobacco", and "Clothing and Footwear." We then use the quarterly growth of durables and of nondurables prices from the EKNR dataset to trace those relative price levels back to 2000:Q1.

4. The counterfactual values of the shocks $\hat{\Psi}^C_{t+1}$ keep all elements of $\hat{\Psi}_{t+1}$ other than $\hat{d}^j_{ni,t+1}$ at their factual values.

5. We solve the model over the period 2000:Q1 to 2012:Q4 using $\hat{\Psi}^C_{t+1}$. Since our initial conditions reflect the expectation of the factual outcome we continue to treat the initial period t^I as generated by the expectation of $\hat{\Psi}_{t+1}$ through 2012:Q4. The switch to the counterfactual $\hat{\Psi}^C_{t+1}$ in 2000:Q2 is a surprise at that date, but the agents subsequently anticipate $\hat{\Psi}^C_{t+1}$ through the final period t^E, which is 2012:Q4. In either scenario, all shocks remain at their 2012:Q4 values as the system transits from 2013:Q1 onward to the steady state.

We perform this exercise for $\upsilon = 2/3$. (Our solution algorithm becomes prohibitively slow if we set υ greater than this value.)

Having computed this counterfactual, we now revisit OR's puzzles. We perform exactly the same exercises on the data generated by this counterfactual that we performed on the actual data that we described in Section 3. A weakening of a puzzle supports OR's explanation for it. Since the drop in trade frictions from 2000:Q1 to 2000:Q2 comes as a surprise, we drop the first four quarters to minimize the implications of the transition for our results. Hence, we limit our analysis to the period 2001:Q1 to 2012:Q4.[15]

Note that our counterfactual continues to treat the construction (C) and services (S) sectors as nontraded. Hence we are moving not to a frictionless world but toward a Balassa-Samuelson (1964) world in which some goods are not traded at all while others are costlessly traded.

5.2 Puzzle 1: The Puzzle of Home Bias in Trade

While we are still far from a world of frictionless trade, our reduction in the trade frictions creates a substantial increase in trade. Overall, world trade rises by a factor of around four. Figure 2 depicts the large increase in trade in our counterfactual.

[15] Including the first year changes the results significantly from what we report here due to the sharp changes in the first quarter following the counterfactual drop in trade costs. But once the first year is eliminated, dropping additional years has little effect on what we report.

The third and fourth columns of Table 2 report what happens to the ratio of purchases from home to foreign purchases for each of our countries. The results are dramatic. The ratio falls in the counterfactual by a factor of between five and ten. Every country purchases more from abroad than from itself.

The third and fourth columns of Table 3 report the results of rerunning our gravity equation using our counterfactual bilateral trade data. While the effect of distance on trade is still significant, its effect has fallen to about a third of what it is in the data. Note that we have reduced trade frictions by about two-thirds.

Hence our counterfactual generates a significant decline both in home bias in absorption and in the force of gravity.

5.3 Puzzle 2: Feldstein-Horioka

The last four columns of Table 4 report the results of regressing the investment rate on the saving rate in our counterfactual. Where the Feldstein-Horioka puzzle was most puzzling, during and after the recession and in differences, lowering trade frictions mitigates or eliminates the puzzle. The coefficient on the savings rate in levels during 2009-2012 drops from 0.63 to 0.34. In differences over the entire period it drops from 0.87 to an (insignificant) -0.01.

Figure 3 illustrates the effect of lowering trade frictions on fluctuations in trade deficits for four of our countries. The solid lines depict the ratio of the actual trade deficit to GDP. Note that trade deficits tend to hover in the neighborhood of zero. The dotted lines depict the ratio in our counterfactual. Trade deficits vary over a much wider range and display much more volatility.[16]

5.4 Puzzle 4: The International Consumption Correlations Puzzle

Here OR's story comes up short. The average correlation of consumption of nondurables actually falls from 0.40 to 0.30. The median, maximum, and minimum also fall. The second column of Table 5 reports a summary of the counterfactual results. We find no tendency for a world with

[16] Note that the actual and counterfactual lines start at the same point, as we start our counterfactual at the same point as the factual. The big changes in the first period reflects the effect of the "surprise" of learning about the counterfactual decline in trade frictions.

lower trade frictions to have more correlated consumption. If anything, correlation falls.

Shocks driving consumption variation are much more associated with demand-side shocks (such as our shocks to country-specific intertemporal preferences ϕ_{it} and to the share of non-durables in preferences $\hat{\psi}^N_{i,t+1}$) rather than with than with shocks on the supply-side (such as shocks to productivity $\hat{A}^j_{i,t+1}$). High trade frictions hamper consumers' ability to shift consumption to periods when they want to consume more relative to other countries. For this reason lower frictions can actually reduce observed consumption correlation.

5.5 Puzzle 5: The Purchasing-Power-Parity Puzzle and Puzzle 6: The Exchange-Rate Disconnect Puzzle

The third and fourth columns of Table 6 report the standard deviations of log changes in nominal and in real GDP in our counterfactual, again removing time effects. Overall, and for all countries but Austria and Denmark, the volatility in nominal GDP falls compared with its volatility in the data. Overall, and for all countries but Germany, the volatility in real GDP actually rises compared with its volatility in the data. Since nominal GDP is much more volatile than real GDP in the data, these changes bring real and nominal GDP volatility closer together. The counterfactual is thus more consistent with RPPP and implies less of a disconnect between nominal exchange rates changes (driving movements in nominal GDP) and real outcomes (here changes in real GDP).

Not only does the volatility in real and in nominal GDP become more similar, the two become more connected. The second column of Table 7 reports the results of regressing log changes in counterfactual real GDP against log changes in counterfactual nominal GDP. The slope rises to 0.42, more than triple the slope using the actual data. Hence real magnitudes are tied much more closely to nominal ones in our counterfactual with lower trade frictions.

6 Conclusion

We find support for Obstfeld and Rogoff's proposition that trade frictions not only drive the home bias in consumption but also the Feldstein-Horioka puzzle. We also find that lower trade frictions bring real and nominal magnitudes more into line. The explanation for the lack of cross-country correlation in consumption growth, however, lies elsewhere.

An interpretation of our results is that lower trade frictions allow countries to go their own way. The vindication of OR's explanation for the Feldstein-Horioka puzzle means that lower frictions let countries save more without having to invest more and vice-versa. But the failure of lower trade frictions to raise consumption correlation means that countries have no desire to consume in unison. Lower trade frictions seem, if anything, to accommodate dissimilarity.

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Country	**Code**	**Share of Global GDP (%)**	**Share of Global Trade (%)**	**Trade/GDP (%)**	**Production/GDP (%)**
Austria	AUT	0.7	1.7	36.4	51.5
Canada	CAN	2.5	4.0	22.2	46.6
Czech Republic	CZE	0.3	1.1	53.6	94.7
Denmark	DNK	0.6	1.1	26.8	35.5
Finland	FIN	0.4	0.8	27.7	65.4
Germany	DEU	6.0	11.9	28.2	62.5
Greece	GRC	0.5	0.4	11.6	29.1
India	IND	1.8	1.2	9.6	52.0
Italy	ITA	3.9	5.0	18.1	65.0
Japan	JPN	10.0	6.8	9.7	61.4
Mexico	MEX	1.9	2.9	21.4	55.0
Poland	POL	0.7	1.3	27.2	63.6
Romania	ROU	0.2	0.4	28.4	52.2
South Korea	KOR	1.8	3.4	26.3	108.2
Spain	ESP	2.5	3.1	17.6	53.4
Sweden	SWE	0.8	1.6	28.5	56.7
United Kingdom	GBR	5.1	5.8	16.2	33.4
United States	USA	28.5	15.9	7.9	35.6
Rest of World	ROW	32.0	31.6	14.0	56.4

Table 1: Summary Statistics on GDP, Trade, and Production, 2005

Notes: Trade and production data are for manufacturing only. Trade is defined as the average of exports and imports.

Country	**Data**		**Counterfactual**	
	Durables	**Nondurables**	**Durables**	**Nondurables**
Austria	0.30	0.50	0.06	0.08
Canada	0.75	1.99	0.17	0.19
Czech Republic	0.62	1.15	0.12	0.20
Denmark	0.17	0.42	0.03	0.05
Finland	1.19	2.14	0.13	0.13
Germany	1.16	1.37	0.21	0.21
Greece	1.12	1.84	0.10	0.12
India	3.24	8.00	0.29	0.73
Italy	2.42	3.14	0.28	0.31
Japan	6.39	6.50	0.61	0.39
Mexico	0.77	3.39	0.16	0.45
Poland	0.88	2.04	0.13	0.26
Romania	0.61	1.11	0.06	0.13
South Korea	3.30	4.56	0.44	0.36
Spain	1.50	2.56	0.23	0.29
Sweden	0.86	1.12	0.12	0.10
United Kingdom	0.63	1.67	0.13	0.18
United States	2.18	5.13	0.40	0.51
Rest of World	2.54	4.82	0.40	0.61

Table 2: Ratio of Home Purchases to Imports, 2005:Q4

Country	Data		Counterfactual	
	Durables	**Nondurables**	**Durables**	**Nondurables**
Distance (logged,1000kms)	-1.301***	-1.432***	-0.444***	-0.473***
	(0.113)	(0.105)	(0.044)	(0.037)
Contiguous	0.073	0.148	0.042	0.048
	(0.200)	(0.210)	(0.077)	(0.073)
Common Language	0.508***	0.554***	0.183***	0.210***
	(0.163)	(0.120)	(0.057)	(0.048)
Constant	-3.217***	-4.188***	-1.150***	-1.603***
	(0.187)	(0.167)	(0.058)	(0.053)
Importer FE	YES	YES	YES	YES
Exporter FE	YES	YES	YES	YES
Observations	306	306	306	306
R-squared	0.93	0.92	0.97	0.97

Table 3: Gravity Regressions, 2005:Q4

Notes: Dependent variable is the log of the ratio of bilateral trade share to destination country's own trade share. Robust standard errors in parentheses. $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by $***$, $**$, and $*$, respectively.

	Data				Counterfactual			
	00-12	**00-08**	**09-12**	**Diff.**	**00-12**	**00-08**	**09-12**	**Diff.**
Saving	0.372**	0.243	0.633***	0.880***	0.262***	0.217***	0.339***	-0.007
	(0.144)	(0.151)	(0.127)	(0.178)	(0.068)	(0.064)	(0.083)	(0.264)
Constant	0.142***	0.173***	0.0829***	0.002	0.169***	0.199***	0.116***	-0.026
	(0.033)	(0.035)	(0.028)	(0.010)	(0.027)	(0.027)	(0.033)	(0.026)
Observations	18	18	18	18	18	18	18	18
R-squared	0.32	0.16	0.62	0.63	0.39	0.29	0.40	0.00

Table 4: Feldstein-Horioka Regressions, 2005:Q4

Notes: Dependent variable is investment. Investment and saving are expressed relative to GDP. Saving is defined as investment plus trade balance. Robust standard errors in parentheses. $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by $***$, $**$, and $*$, respectively.

	Data	**Counterfactual**
Mean	0.40	0.30
Median	0.47	0.38
Maximum	0.94	0.92
Minimum	-0.53	-0.70

Table 5: Consumption Correlations (2001-2012)

Notes: Table gives moments of the distribution of annual consumption growth correlations between the 18 countries.

	Data		Counterfactual	
	Nominal	**Real**	**Nominal**	**Real**
Austria	0.033	0.010	0.034	0.015
Canada	0.059	0.014	0.040	0.018
Czech Republic	0.069	0.015	0.049	0.028
Denmark	0.028	0.011	0.041	0.014
Finland	0.035	0.017	0.021	0.018
Germany	0.032	0.017	0.024	0.013
Greece	0.077	0.047	0.041	0.049
India	0.077	0.023	0.049	0.034
Italy	0.040	0.007	0.025	0.010
Japan	0.106	0.018	0.065	0.026
Mexico	0.091	0.017	0.045	0.021
Poland	0.083	0.019	0.043	0.023
Romania	0.033	0.007	0.025	0.008
South Korea	0.102	0.034	0.063	0.047
Spain	0.092	0.018	0.051	0.023
Sweden	0.053	0.013	0.037	0.021
United Kingdom	0.056	0.014	0.034	0.020
United States	0.053	0.011	0.049	0.020
Rest of World	0.085	0.012	0.062	0.021
Pooled	0.073	0.026	0.048	0.032

Table 6: Standard Deviation of Log Changes in GDP

Notes: Calculations in the table are based on quarterly changes from 2001 through 2012 (residuals from a regression of the log change on time fixed effects).

	Data	Counterfactual
Log Quarterly Change in Nominal GDP	0.121***	0.415***
	(0.014)	(0.018)
Constant	0.014***	0.046***
	(0.004)	(0.003)
Country FE	YES	YES
Time FE	YES	YES
Observations	836	836
R-squared	0.75	0.87

Table 7: Exchange Rate Disconnect (2001-2012)

Notes: Dependent variable is log quarterly change in Real GDP. Robust standard errors in parentheses. $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by $***$, $**$, and $*$, respectively.

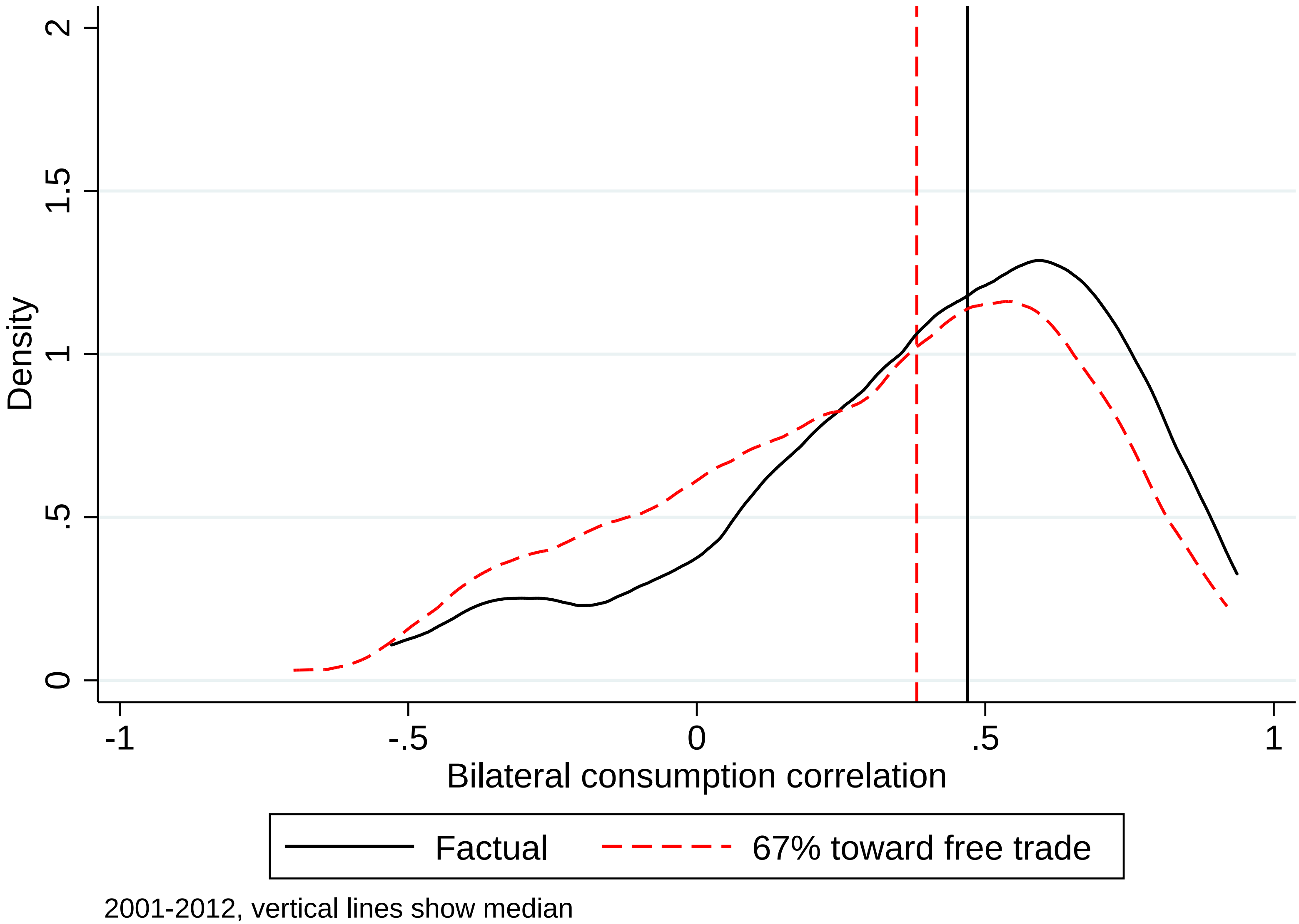

Figure 1: Distribution of Consumption Correlations in Data and in Counterfactual

Figure 2: Global Trade / GDP in Data and in Counterfactual

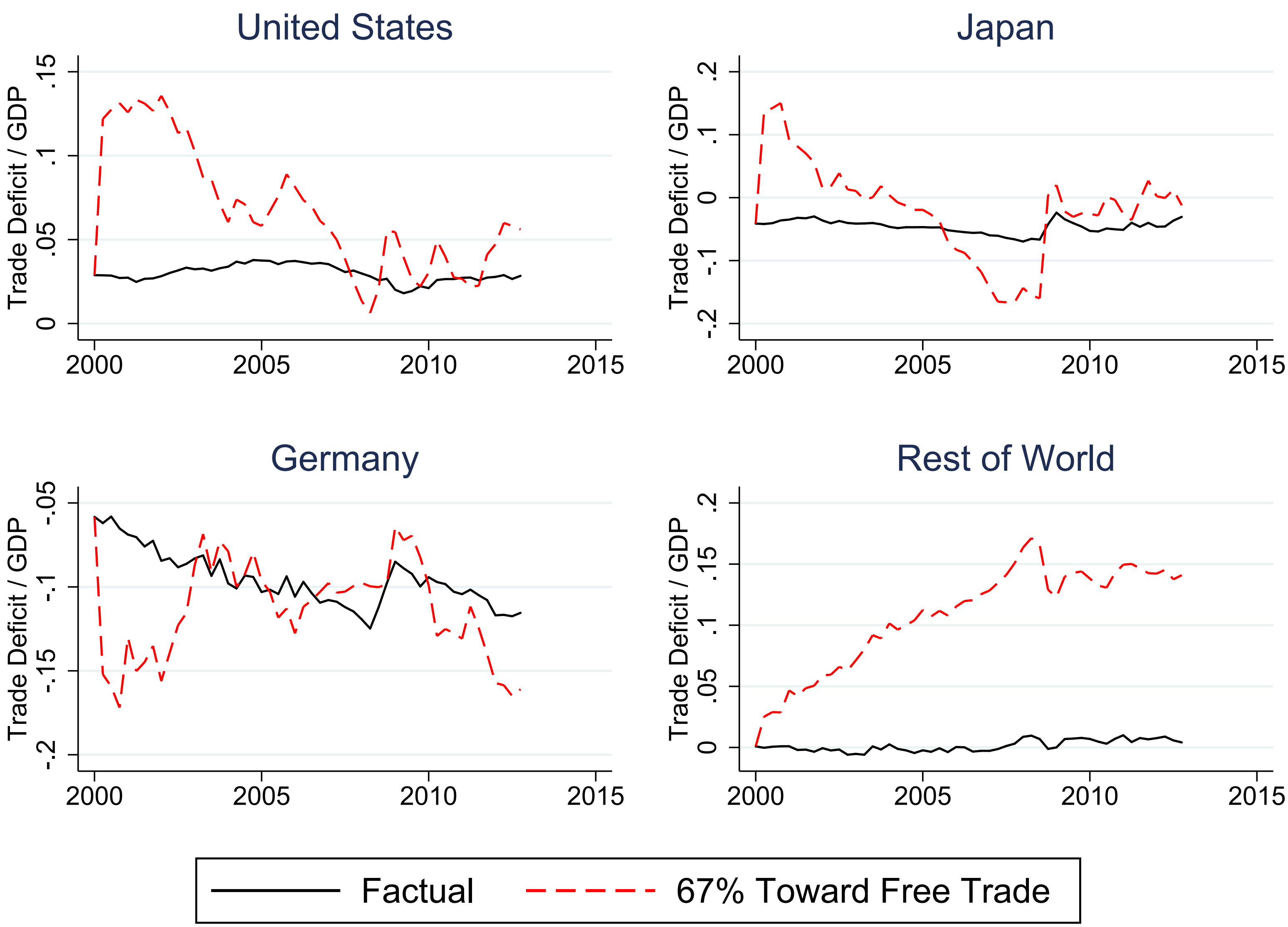

Figure 3: Trade Deficits / GDP in Data and in Counterfactual for Selected Countries