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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 (2016), we revisit the puzzles in a counterfactual world without trade frictions in manufactures. Removing these trade frictions goes a long way toward resolving a number of the puzzles: The dependence of domestic investment on domestic saving falls by half or disappears entirely, mitigating the Feldstein-Horioka (1980) puzzle. Changes in nominal GDPs in U.S. dollars become less variable across countries and line up with changes in real GDPs as much as with real exchange rates, mitigating the exchange rate disconnect puzzle. Less dramatically, changes in consumption become more correlated across countries, mitigating the consumption correlations puzzle and changes in real exchange rates become less variable across countries, mitigating the relative purchasing power parity puzzle.

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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 with a constant discount factor. 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 proposition, 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 these puzzles qualitatively. Since they pursue 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." According to the notes on the general discussion of OR at the *NBER Macroeconomics Annual* conference in 2000, "John Leahy expressed the concern that the effects identified in this paper might turn out to be quantitatively small in a realistically calibrated model."

A barrier to the quantitative analysis of OR's proposition 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

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

a particular good is traded and, if so, in what directions. As the number of goods or countries rises, the taxonomy explodes.[2]

Eaton, Kortum, Neiman, and Romalis (2016, henceforth EKNR) recently developed a multicountry dynamic model of international trade and production, with complete markets, 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.

EKNR's methodology relates changes in trade, production, spending, and prices across four sectors in each country to underlying shocks in every country, 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: Together, 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 five of OR's puzzles. Since in our methodology the underlying shocks explain the data perfectly, the model necessarily captures any puzzle. To give OR's explanation substance we compare the puzzles in the data (which are accounted for in our baseline model) with a counterfactual in which we eliminate trade frictions in manufactures, but hold other shocks at their baseline values. This counterfactual lets us observe a world like the one we live in only without these trade frictions. The disappearance of a puzzle in this counterfactual vindicates OR's explanation. To the extent that a puzzle survives, forces other than trade frictions must be at work.

Our results provide quantitative support for OR's proposition. Not surprisingly, removing trade frictions in manufactures eliminates home bias for those goods. More interesting is that eliminating trade frictions in manufactures greatly reduces the correlation between national investment and saving rates, mitigating the Feldstein-Horioka puzzle. Real consumption becomes

[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 only two countries.

positively correlated across countries on average, mitigating the consumption correlations puzzle. Price changes become much less variable across countries, even for nontraded goods, mitigating the relative purchasing power parity (RPPP) puzzle. Changes in nominal GDP (translated into a common currency) become less variable across countries and more in line with changes in real GDP, mitigating the exchange rate disconnect puzzle.

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 that, for OECD countries, geographic factors alone can explain cross-country deviations from perfect consumption risk sharing.[3]

Complementary to our analysis here are Reyes-Heroles (2015) and Alessandria and Choi (2015). Using a related framework, Reyes-Heroles shows that, if trade frictions had not declined since 1970, global trade imbalances would now be much closer to zero. Alessandria and Choi attribute roughly half of the growth in the U.S. trade deficit from the 1980s to the 2000s to global trade integration.

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. In Section 5 we create a counterfactual world without trade frictions in manufactures but with the other shocks driving the world economy unchanged. We repeat the exercises performed on the actual data in Section 3 with data generated in this counterfactual world. The elimination or diminution of a puzzle supports OR's proposition.

2 Our Data

We apply our analysis to 19 countries (18 actual countries and a Rest of World) across four sectors: construction (C), durable manufactures (D), nondurable manufactures (N), and services (S), which aggregates everything else. We treat the gross output of the two manufacturing sectors

[3] Rabitsch (2012) examines the role of trade frictions for monetary policy.

D and N as tradable and the gross output of construction C and of services S as nontradable. We treat the final output of nondurable manufactures N and of services S as consumption goods and the final output of construction C and of durable manufactures D as investment goods. We use data from EKNR on production and prices for all four sectors, 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.[4]

3 The Puzzles

We now turn to OR's puzzles. We examine their presence in our sample of countries over our period.

3.1 Puzzle 1: 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, columns 1 and 2 in Table 2 report the ratio of purchases from home to imports for durable and nondurable manufactures, the two sectors we treat as tradable.[5] 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. The solid line in Figure 1 depicts the evolution of global trade relative to world GDP. The ratio remains well below 0.2.

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

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

[5]We refer to statistics calculated from the actual data as "baseline" to distinguish them from those calculated in our counterfactual, which we call "frictionless trade."

elasticity around one.

Table 3 reports results from running a gravity regression among our 18 actual countries for durable (column 1) and nondurable (column 2) manufactures. Specifically we estimate the equation:

$$\ln\left(\frac{\pi^j_{ni}}{\pi^j_{nn}}\right) = S^j_i + D^j_n + \mathbf{B}^j \cdot \mathbf{x}_{ni} + u^j_{ni}, \tag{1}$$

where π^j_{ni} is the share of country i in country n's total spending on goods in sector j, where $j \in \{D, N\}$ respectively, S^j_i is a fixed effect for exporter i, and D^j_n 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 (in logs) 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 significantly greater than one (in absolute value), but in the general neighborhood. Common language and contiguity are positive, but only the first is significant. 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 joint contribution from all sources of trade frictions that give rise to the actual bilateral trade shares π^j_{ni} 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, a cross-country regression of investment on saving, both as shares of GDP and averaged over the period 1960 to 1974, yields a slope of 0.89, nearly one. When they instead use long differences in investment and saving rates, they estimate a slope of 0.72. OR run the equivalent of the first regression specification using investment and saving rates averaged over the period 1990 to 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 investment country n's investment spending in year t, $X^I_{n,t}$, as the sum of final spending on construction and on durable manufactures.[6] We construct a measure of country n's saving in year t, $S_{n,t}$, by augmenting investment spending $X^I_{n,t}$ with the trade balance calculated from the excess of production over absorption in country n.[7] 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 saving 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 and also look at long differences over the entire period, $\Delta i_n = i_{n,2012} - i_{n,2001}$ and $\Delta s_n = s_{n,2012} - s_{n,2001}$. Figure 2 plots the individual observations. While the level of the investment rate is only moderately responsive to the level of the saving rate over 2001-2012 or 2001-2008, the investment and saving measures line up quite closely during 2009-2012 and in long differences.

To examine the relationships more formally we estimate:

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

and:

$$\Delta i_n = \alpha + \beta \Delta s_n + \varepsilon_n. \tag{3}$$

[6] 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 on durable manufactures.

[7] 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.

Columns 1 to 4 of Table 4 report the results, for different subperiods and for the long difference from the beginning to the end of the sample.[8]

Several results stand out. In terms of the relationship in levels, in the period before the Great Recession (2001-2008) the coefficient is 0.25 (only marginally 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.[9] Moreover, the puzzle remains very pronounced in looking at long differences over the entire period, with a significant coefficient of 0.88, even larger than the corresponding coefficient in FH.

Another way of thinking about FH's puzzle is that countries rely very little on external finance to fund investment. The solid lines in Figure 3 illustrate actual trade deficits relative to GDP in our four largest countries. Note that trade imbalances rarely stray beyond 10 percent of GDP.

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.[10] We leave the integration of this puzzle into our framework for future research.

[8]While our data begin in 2000, we examine the puzzles starting in 2001. We drop 2000 from our counterfactuals with frictionless trade below to minimize the impact on our results of the transition from the baseline, as we later explain. Hence we examine the puzzles in our baseline and in our counterfactuals over the same period, 2001-2012.

[9]Baxter and Crucini (1993) use a two-country dynamic stochastic general equilibrium model to show how, even in the absence of trade barriers, the Feldstein-Horioka puzzle can arise because of country size and correlation across countries in productivity shocks. To the extent that the great recession constituted a correlated productivity shock across countries, their model suggests why the Feldstein-Horioka puzzle is more pronounced in that period.

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

3.4 Puzzle 4: International Consumption Correlations

In the canonical model, frictionless trade, complete markets, and identical, risk-averse preferences imply identical rates of growth of marginal utility, or with log utility, 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, we consider cross-country correlations of log changes in real consumption.[11] At quarterly frequency, bilateral correlations range from -0.55 (between Germany and Romania) to 0.45 (between Germany and South Korea). The mean correlation is only 0.03 and the median is 0.04. At annual frequency the range is much broader, from -0.80 (between Germany and the United States) to 0.84 (between the United Kingdom and the United States). But the mean and median are both only 0.01.[12] Hence there is little evidence at either frequency that countries are using trade imbalances to smooth consumption.[13]

3.5 Puzzles 5 and 6: (Relative) Purchasing Power Parity and Exchange Rate Disconnect

OR lump their last two puzzles together. They focus on persistent deviations from purchasing power parity (PPP) and how little large fluctuations in nominal exchange rates affect real

[11] We use the structure of our model to impute consumption spending from data on sectoral production, GDP, and input-output coefficients obtained from the OECD, as described in the online appendix to EKNR. As we discuss in Section 4, our measure includes final purchases by households of nondurable manufactures and services as well as household rental payments for the services of durable manufactures and structures. Footnote 14 explains how we construct the corresponding price deflator used to obtain a measure of real consumption.

[12] The solid lines in Figures 4 and 5 show the distribution of consumption correlations, at quarterly and at annual frequency, respectively, with solid vertical lines at the means. Table 5 reports summary statistics, at quarterly frequency in column 1 and at annual frequency in column 3.

[13] We find more evidence of correlation looking at consumption of just nondurable manufactures, which are tradable. Using this narrower measure, the mean and median correlations of log changes are both 0.16 at quarterly frequency. At annual frequency the mean correlation is 0.42 and the median is 0.49.

outcomes other than the real exchange rate.

We first examine the standard deviations across countries of log changes in price indices for each of our four sectors. RPPP would imply no cross-country variation. Columns 1 and 3 of Table 6 report the standard deviation of quarterly and annual log changes, averaged across 2001-2012, for each sector. With quarterly data the standard deviations for the two sectors we treat as tradable (durable and nondurable manufactures) are both around 0.1, and are about half that using annual data. The standard deviations for the two nontradable sectors (construction and services) are only somewhat higher. Deviations from RPPP for traded sectors are not much lower than for nontraded ones. This finding is consistent with Engel (1999), who finds that variation in the overall real exchange is driven as much by variation in the real exchange rate for traded goods as for nontraded ones.

We can also ask how cross-country variation in price changes in individual sectors combine to generate cross-country variation in changes in a consumer price index (CPI). As reported in the last line of Table 6, the cross country standard deviation is just above 0.11 at a quarterly frequency and just below 0.06 at an annual frequency.[14] While our focus is on prices, complete markets, as assumed both by OR and in our model below, imply a common world nominal interest rate. Hence differences in real interest rates correspond to differences in changes in the CPI.

How do changes in the CPI relate to changes in trade imbalances? Columns 1 and 2 of Table 7 report the results of regressing the log changes in the CPI against the changes in the trade deficit relative to GDP. At a quarterly frequency the slope coefficient is 0.29 regardless of whether country fixed effects are included. At an annual frequency the relationship is much more pronounced, with coefficients well above one.[15] At either frequency the relationship is noisy, with an R^2 at or below 0.33 even if time and country fixed effects are both included.

Having established that deviations from RPPP remain substantial in our data, we explore the

[14] As a CPI should reflect the rental costs rather than the prices of durables and structures, our CPI index uses rental costs for these two sectors extracted from the numerical procedure we describe in the next section. The relevant rental and goods prices for the four sectors are combined using Törnqvist weights based on parameters and expenditure shares whose derivation we describe below.

[15] A scatter plot of annual changes in the CPI against annual changes in the trade deficit relative to GDP suggests that a single observation, Romania between 2008 and 2009, is responsible for the high slope coefficient. Removing this outlier reduces the slopes from those reported in the columns 5 and 6 of Table 7 by about 0.3 in each case. If we remove time fixed effects each slope coefficient rises by around 0.3.

exchange rate disconnect as the disconnect between log changes in nominal and real GDP.[16] We begin with the basic identity relating changes in nominal GDP (in the local currency) $\hat{Y}^L_{i,t+1}$, in real GDP $\hat{y}_{i,t+1}$, and in the GDP deflator $\hat{P}^L_{i,t+1}$ (where for any magnitude x_t, $\hat{x}_{t+1} = x_{t+1}/x_t$):

$$\hat{Y}^L_{i,t+1} = \hat{y}_{i,t+1}\hat{P}^L_{i,t+1}.$$

We translate local currency values into a common currency using the nominal exchange rate $e_{i,t}$, defining the change in nominal (common currency) GDP as $\hat{Y}_{i,t+1} = \hat{e}_{i,t+1}\hat{Y}^L_{i,t+1}$ and the change in the (common currency) price level as $\hat{P}_{i,t+1} = \hat{e}_{i,t+1}\hat{P}^L_{i,t+1}$, so that:

$$\hat{Y}_{i,t+1} = \hat{y}_{i,t+1}\hat{P}_{i,t+1}.$$

Taking logs of this expression relative to its analog for country n, we get:

$$\ln(\hat{Y}_{i,t+1}) - \ln(\hat{Y}_{n,t+1}) = \ln \hat{y}_{i,t+1} - \ln \hat{y}_{n,t+1} + \ln(\hat{P}_{i,t+1}) - \ln(\hat{P}_{n,t+1}).$$

Thus, log changes in relative nominal GDP's equal log changes in relative real GDP's plus log changes in the real exchange rate.[17]

To avoid having to consider this expression for all bilateral pairs, for each country i we average the expression above across n to obtain:

$$\tilde{Y}_{i,t+1} = \tilde{y}_{i,t+1} + \tilde{P}_{i,t+1} \tag{4}$$

where, for any variable $\hat{x}_{i,t+1}$,

$$\tilde{x}_{i,t+1} = \ln \hat{x}_{i,t+1} - \frac{1}{\mathcal{N}}\sum_{n=1}^{\mathcal{N}} \ln \hat{x}_{n,t+1}.$$

[16] Itskhoki and Mukhin (2016) interpret exchange rate disconnect in a similar manner. In a two-country model (without money or nominal rigidities) they take the exchange rate to be the countries' relative wage and explore why its variation is largely disconnected from real magnitudes.

[17] Note that here we are defining log changes in the real exchange rate in terms of log changes in the GDP deflator rather than (as is more conventional) log changes in the CPI.

In words, the growth in country i's nominal GDP (relative to the simple world average) is its growth in real GDP (relative to the simple world average) plus the growth in its real exchange rate.[18]

Columns 1 to 3 of Table 8 report the standard deviation of growth in: (i) nominal GDP $\tilde{Y}_{i,t+1}$, (ii) real GDP $\tilde{y}_{i,t+1}$, and (iii) real exchange rate $\tilde{P}_{i,t+1}$ at quarterly frequency. Note that, for every country, nominal GDP growth is much more volatile, by a factor that ranges from just below 2 up to over 7, than real GDP growth. In contrast, the standard deviation of growth in the real exchange rate is close to that for nominal GDP. Hence the magnitudes $\tilde{Y}_{i,t+1}$ and $\tilde{P}_{i,t+1}$ (which both embody nominal exchange rates) are much more volatile than the real magnitude $\tilde{y}_{i,t+1}$. Columns 7 to 9 report the corresponding decomposition at an annual frequency. The main difference is that standard deviations at this lower frequency are about half those at the quarterly frequency. But the standard deviation of real GDP changes remains much lower than that of nominal GDP or the real exchange rate.

How is variation in the growth of nominal GDP $\tilde{Y}_{i,t+1}$ divided between variation in the growth of real GDP $\tilde{y}_{i,t+1}$ and variation in the growth of the real exchange rate $\tilde{P}_{i,t+1}$? Table 9 shows, for our set of countries, results of panel regressions of $\tilde{y}_{i,t+1}$ on $\tilde{Y}_{i,t+1}$, at quarterly (in columns 1 and 2) and annual (in columns 5 and 6) frequency. The slope coefficients in Table 9 rise in moving to an annual frequency and fall with the inclusion of country fixed effects. But in all cases the slope coefficients are far below one half, barely making it up to a quarter. Hence $\tilde{Y}_{i,t+1}$ and $\tilde{P}_{i,t+1}$ are very connected to each other but largely disconnected from the real magnitude $\tilde{y}_{i,t+1}$.[19]

[18] Here, the growth in country i's real exchange rate is the simple average of the growth in its real exchange rate with each country.

[19] Our interpretation of these regressions follows from (4), which implies:

$$\text{var}(\tilde{Y}_{i,t+1}) = \text{cov}(\tilde{y}_{i,t+1}, \tilde{Y}_{i,t+1}) \ + \ \text{cov}(\tilde{P}_{i,t+1}, \tilde{Y}_{i,t+1}).$$

Thus, the OLS slope coefficients in Table 9 give the fraction of $\tilde{Y}_{i,t+1}$'s variance attributed to its covariance with $\tilde{y}_{i,t+1}$.

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.[20] We allow for an arbitrary number $\mathcal{N}$ of countries and four sectors. Country i at time t has an endowment of labor $L_{i,t}$ and two types of capital $K_{i,t}^{k}$, $k \in \{C, D\}$, 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.

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 $j, l \in \{C, D, N, S\}$, $k \in \{C, D\}$.

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:

$$\Pr\left[a_{i,t}^j \leq a\right] = \exp\left[-\left(\frac{a}{\gamma^j A_{i,t}^j}\right)^{-\theta}\right], \tag{5}$$

drawn independently for each z across countries i.[21] 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 an iceberg trade friction, 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 letting $d_{ni,t}^j \to \infty$, $n \neq i$, for these sectors.

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

[21] 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.

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

$$K_{i,t+1}^{k} = \chi_{i,t}^{k} \left(I_{i,t}^{k}\right)^{\alpha^k} \left(K_{i,t}^{k}\right)^{1-\alpha^k} + \left(1 - \delta^k\right) K_{i,t}^{k}, \tag{6}$$

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.

4.2 Preferences

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 $K_{n,t}^{H,C}$.[22] From the perspective of the beginning of time ($t = 0$), its utility is:

$$U_n = \sum_{t=0}^{\infty} \rho^t \phi_{n,t} \left(\sum_{j \in \{N,S\}} \psi_{n,t}^{j} \ln C_{n,t}^{j} + \sum_{k \in \{C,D\}} \psi^k \ln K_{n,t}^{H,k} \right), \tag{7}$$

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.[23]

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 describe the solution method used

[22] Hence, capital of type $k \in \{C, D\}$ available for production in country n at date t is $K_{n,t}^{k} - K_{n,t}^{H,k}$.

[23] Stockman and Tesar (1995) introduce such shocks into an international real business cycle model. Heathcote and Perri (2014) discuss their role in the subsequent literature.

here.

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:

$$c_{i,t}^{j} = (w_{i,t})^{\beta_i^{L,j}} \prod_{k \in \Omega_K} \left(r_{i,t}^{k}\right)^{\beta_i^{K,jk}} \prod_{l \in \Omega} \left(p_{i,t}^{l}\right)^{\beta_i^{M,jl}}, \tag{8}$$

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 level of sector l goods, all in country i at time t. These price levels are determined by production costs in each country as:

$$p_{n,t}^{j} = \left[\sum_{i=1}^{\mathcal{N}} \left(\frac{c_{i,t}^{j} d_{ni,t}^{j}}{A_{i,t}^{j}}\right)^{-\theta}\right]^{-1/\theta}. \tag{9}$$

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

$$\pi_{ni,t}^{j} = \left(\frac{c_{i,t}^{j} d_{ni,t}^{j}}{A_{i,t}^{j} p_{n,t}^{j}}\right)^{-\theta}.$$

Taking the ratio of what i exports to n relative to what i buys from itself, we obtain:[24]

$$\frac{\pi_{ni,t}^{j}}{\pi_{ii,t}^{j}} = \left(\frac{p_{i,t}^{j} d_{ni,t}^{j}}{p_{n,t}^{j}}\right)^{-\theta}.$$

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

$$d_{ni,t}^{j} = \left(\frac{\pi_{ni,t}^{j}}{\pi_{ii,t}^{j}}\right)^{-1/\theta} \frac{p_{n,t}^{j}}{p_{i,t}^{j}}. \tag{10}$$

[24] If, instead, we take the ratio of what n imports from i to what n buys from itself we get a version of the gravity equation (1) above, with:

$$S_i^j = \ln\left(c_i^j / A_i^j\right).$$

See Eaton and Kortum (2002).

4.5 The Shocks Driving the Evolution of the Global Economy

EKNR describe 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, where, again, for any variable x we define:

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

as the change in x from t to $t+1$.

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 $\hat{\phi}_{i,t+1}$,
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.

We need the seventh shock 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

The following parameters are from EKNR:

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	0.33	0.08

As in EKNR, input-output coefficients are from the 2009 edition of the OECD's country tables. Labor shares $\beta_i^{L,j}$ are total employee compensation in sector j divided by the value of sector j's total output. The total capital shares $\beta_i^{K,jC} + \beta_i^{K,jD}$ 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 $t \geq t^E$. 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 (6) and the Euler equation for intertemporal utility maximization:

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

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, Cobb-Douglas preference shares, and capital shares.[25]

4.6.3 Paths of Shocks

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

1. For the traded sectors, equation (10) delivers an expression relating (unobserved) changes in trade frictions to (observable) changes in trade shares and in price indices:

$$\hat{d}^j_{ni,t+1} = \left(\frac{\hat{\pi}^j_{ni,t+1}}{\hat{\pi}^j_{ii,t+1}}\right)^{-1/\theta} \frac{\hat{p}^j_{n,t+1}}{\hat{p}^j_{i,t+1}}. \tag{11}$$

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

$$\hat{\phi}_{i,t+1} = \frac{X^{F,N}_{i,t+1} + X^{F,S}_{i,t+1}}{X^{F,N}_{i,t} + X^{F,S}_{i,t}}, \tag{12}$$

   and:

$$\hat{\psi}^N_{i,t+1} = \frac{\hat{X}^{F,N}_{i,t+1}}{\hat{\phi}_{i,t+1}}, \tag{13}$$

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

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:

$$\hat{\chi}^k_{i,t+1} = \left(\frac{\hat{X}^{I,k}_{i,t+1}}{\hat{p}^k_{i,t+1}\hat{K}^k_{i,t+1}}\right)^{-\alpha^k} \frac{\hat{K}^k_{i,t+2} - (1-\delta^k)}{\hat{K}^k_{i,t+1} - (1-\delta^k)}, \tag{14}$$

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

[25]See EKNR for more detail on this procedure, which builds on the two-country framework of Kehoe, Ruhl, and Steinberg (2014).

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

$$\hat{A}^j_{i,t+1} = \frac{\hat{c}^j_{i,t+1}}{\hat{p}^j_{i,t+1}} \left(\hat{\pi}^j_{ii,t+1}\right)^{1/\theta}, \tag{15}$$

where $\hat{c}^j_{i,t+1}$ is the change in input costs $c^j_{i,t+1}$ given in (8). 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 baseline 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 baseline shocks replicates the data for the period of 2000:Q1 to 2012:Q4. After that date the solution glides toward the steady state. Tables 2 through 4 in EKNR summarize the values of the shocks delivered by this procedure.

5 The Puzzles in a World without Trade Frictions

We now ask how well OR's puzzles survive in a counterfactual world without trade frictions in manufactures, continuing to treat construction and services as nontraded. To create this world we first extract the shocks driving the global 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 imply $d^j_{ni,t+1} = 1$. We now describe how we derive these shocks.

5.1 Eliminating Frictions

We eliminate trade frictions at the beginning of our period and 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 (10) to measure actual trade frictions in levels d^j_{ni,t^I}, where we calculate price

levels from the World Bank's International Comparisons Project for 2005.[26]

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

$$\hat{d}^{jC}_{ni,t^I+1} = \frac{1}{d^j_{ni,t^I}},$$

which lowers trade frictions in period t^I+1 from their measured t^I value to 1.

3. We set $\hat{d}^{jC}_{ni,t+1} = 1$ for $t > t^I+1$, maintaining frictionless trade.

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 baseline 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 baseline 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 $\hat{\Psi}^C_{t+1}$ thereafter. In either scenario, all shocks remain at their 2012:Q4 values (in levels) as the system transits from 2013:Q1 onward to the steady state.

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 as described in Section 3. The elimination or weakening of a puzzle supports OR's explanation for it. Since the elimination of trade frictions in manufactures between 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.[27]

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 world as in Balassa

[26]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.

[27]The surprise elimination of trade frictions causes sharp changes in a number of magnitudes in the first period of the counterfactual. Hence including the first year changes some results substantially from what we report here. But once the first year is dropped, dropping subsequent years has little effect on what we report.

(1964) or Samuelson (1964), where some goods are not traded at all while others are costlessly traded.

5.2 Puzzle 1: Home Bias in Trade

In this world, for $j \in \{D, N\}$, $\pi^j_{ni} = \pi^j_{ii}$ for all n. Not surprisingly, eliminating trade frictions in manufactures generates a large increase in trade. The dashed line in Figure 1 depicts this increase in our counterfactual, with trade rising from about 14 percent to over 70 percent of world GDP before settling down above 50 percent.[28]

Columns 3 and 4 of Table 2 report what happens to the ratio of purchases from home to purchases from abroad for each of our countries. The ratio falls in the counterfactual by a factor of between 15 and 108. Every country purchases more from abroad than from itself.

As revealed by columns 3 and 4 of Table 3, by eliminating trade frictions we have destroyed gravity. Our bilateral characteristics have been rendered powerless with importer and exporter fixed effects fully explaining trade, as each source country has the same market share across all destinations.

5.3 Puzzle 2: Feldstein-Horioka

Figure 6 portrays the relationship between investment and saving rates with frictionless trade. In all periods and in long differences the relationship appears much weaker. Columns 5 to 8 of Table 4 report the results of regressing the investment rate on the saving rate with frictionless trade. When the Feldstein-Horioka puzzle was most puzzling, during and after the recession and in long differences, lowering trade frictions mitigates or eliminates the puzzle. The coefficient on the saving rate in levels during 2009-2012 drops from 0.63 to 0.14. In differences over the entire period it drops from 0.88 to an (insignificant) -0.29. Over the entire period the coefficient falls by more than half. For the period 2001-2008 the effect falls in magnitude in moving to frictionless trade but gains statistical significance.[29]

[28]Trade in intermediates accounts for how manufacturing trade as a ratio to world GDP can exceed the share of manufacturing value added in world GDP.

[29]That remnants of the Feldstein-Horioka puzzle survive, although in diminished form, suggests that shocks to saving and investment are themselves correlated, as proposed by Baxter and Crucini (1993). Ford and Horioka

With frictionless trade, the waning of the Feldstein-Horioka puzzle means countries rely much more on external finance for investment, suggesting a more active role for trade deficits. The dashed lines in Figure 3 illustrates counterfactual trade deficits relative to GDP in our four largest countries. Trade imbalances go as high as 30 percent of GDP and display much more volatility than the actual ones.[30]

5.4 Puzzle 4: International Consumption Correlations

With frictionless trade, log changes in consumption become more correlated across countries. The dashed lines in Figures 4 and 5 show the distribution of bilateral correlations at quarterly and annual frequencies, respectively. In moving to the counterfactual both distributions have shifted noticeably to the right, particularly at annual frequency. Columns 2 and 4 of Table 5 report summary statistics. At quarterly frequency the correlations range from -0.45 (between Mexico and Spain) to 0.74 (between Finland and Italy) with a mean and median bilateral correlation of 0.10. At annual frequency the correlations range from -0.83 (between the rest of the world and the United Kingdom) to 0.98 (between Finland and Germany). The mean correlation is 0.24 and the median is 0.23. We conclude that eliminating trade frictions in manufactures generates noticeable positive cross-country correlation in log changes in consumption, while little tendency for positive correlation is evident in our baseline.[31]

Why aren't log changes in consumption even more correlated with frictionless trade in manufactures? Country-specific intertemporal preference shocks, the $\hat{\phi}_{n,t}$'s in the model above, mean that countries don't want their consumption to be too correlated. Eliminating these shocks (by setting $\hat{\phi}_{n,t} = 1$ for all countries in all periods) as well as trade frictions in manufactures, the

(2016) discuss how impediments either to the international mobility of capital or to the international mobility of goods can generate a correlation between national saving and investment rates. Bai and Zhang (2010) provide a general equilibrium model in which a constellation of financial frictions generates a Feldstein-Horioka relationship, with trade remaining frictionless.

[30] Note that the lines for the data and frictionless trade start at the same point, as we start our counterfactual at the same point as the factual. The big changes in the first period reflect the effect of the enormous drop in trade barriers going from the baseline to our counterfactual of frictionless trade.

[31] As mentioned above, looking at consumption of just nontradable manufactures, we did observe more correlation in our baseline. For this narrower measure of consumption, correlation of log changes actually falls in moving to frictionless trade, from an average of 0.16 to 0.11 at quarterly frequency and from 0.42 to 0.29 at annual frequency. An explanation for the fall is that variation across countries in shocks to the preference weight on nondurables, the $\hat{\psi}^N_{n,t+1}$'s in the model above, creates cross-country variation in demand for nontradables. Without trade frictions countries can fulfill these differences in demand more easily.

mean and median correlation rises to 0.57 and 0.66 at quarterly frequency and to 0.69 and 0.79 at annual frequency.[32]

5.5 Puzzles 5 and 6: (Relative) Purchasing Power Parity and Exchange Rate Disconnect

Table 6 reports averages of the standard deviations of log changes in price indices for each of our sectors in our counterfactual, at quarterly frequency in column 2 and at annual frequency in column 4. As we should expect, the absence of trade frictions in manufactures delivers perfectly correlated prices for these sectors. Even for the nontraded sectors the standard deviation falls by around 0.03. Input-output relationships between traded and nontraded sectors contribute to this decline. Solving for the effects on the rental cost of durables and structures, the average standard deviation of log changes in the CPI falls by not quite a half.[33]

How does frictionless trade alter the relationship between log changes in the CPI and changes in trade deficits relative to GDP? Most interestingly, as shown in Table 7, it becomes much tighter, with R^2 rising from around a quarter to over 0.65 in all cases. The slope coefficients fall, however. The fall is small and not significant at quarterly frequency, where they were already below 0.3. At annual frequency, however, the fall is from over 1 to just above one third.

Table 8 reports the standard deviations of growth in nominal GDP, growth in real GDP, and growth in the real exchange rate with frictionless trade, at quarterly frequency in columns 4 to 6 and at annual frequency in columns 10 to 12.

Overall, and for every country except Austria, the Czech Republic, and Denmark at quarterly frequency and Denmark alone at annual frequency, the volatility in nominal GDP falls with frictionless trade compared with its volatility in the baseline. Overall and for most countries

[32]Consumption correlations remain below one because, among other things, services remain nontraded and consumption of the services of durables and structures depends on the different histories of investment in these sectors across countries.

[33]Section 4.6.3 explains how we use our model to extract changes in rental prices $\hat{r}^k_{i,t+1}$ from data. We construct the change in our CPI, using the Törnqvist formula, as:

$$\hat{p}^U_{i,t+1} = \left(\hat{p}^N_{i,t+1}\right)^{\frac{1}{2}\left(\psi^N_{i,t}+\psi^N_{i,t+1}\right)} \left(\hat{p}^S_{i,t+1}\right)^{\frac{1}{2}\left(\psi^S_{i,t}+\psi^S_{i,t+1}\right)} \left(\hat{r}^C_{i,t+1}\right)^{\psi^C} \left(\hat{r}^D_{i,t+1}\right)^{\psi^D}.$$

individually, the volatility in real GDP with frictionless trade actually rises compared with its volatility in the data. Real exchange rate volatility falls overall and for every country except Denmark. Since nominal GDP is much more volatile than real GDP in the data, these changes bring volatility in real and in nominal GDP closer together.

How does frictionless trade affect the relationship between real and nominal GDP? As reported in Table 9, the slope of a regression of $\tilde{y}_{i,t+1}$ on $\tilde{Y}_{i,t+1}$ rises toward one half at quarterly frequency and exceeds one half at annual frequency. With frictionless trade, in stark contrast to the baseline, changes in nominal GDP reflect changes in real GDP about as much as changes in real exchange rates.

5.6 Robustness to the Trade Elasticity

To create our world of frictionless trade we needed to take stand on a particular parameterization of a particular model. The parameter θ, governing heterogeneity in the distribution of efficiencies within sectors, becomes, in our context, the elasticity with which changes in trade costs affect changes in trade flows, the well-known trade elasticity. We have taken the value of 2 from EKNR. Some studies have identified values of this elasticity around 4.[34] We computed an alternative frictionless trade counterfactual using this larger value. We see no differences from what we report above worth mentioning.[35]

6 Conclusion

We find that eliminating trade frictions in manufactures goes a long way toward resolving a host of puzzles in international macroeconomics. Most dramatically, domestic investment depends much less or not at all on domestic saving. Real and nominal GDP become much more closely aligned. We also find that overall consumption becomes more correlated and prices changes, and therefore real interest rates, become more similar across countries.

[34] See, e.g., Simonovska and Waugh (2014).

[35] A higher value of θ implies that we back out values of the $\hat{d}_{ni}$'s closer to one to explain movements in trade shares, as shown in equation (11). The effects of the two changes together on the outcomes we examine here largely offset each other.

To explore the role of trade frictions in isolation, we conducted our analysis in a perfect world.[36] Our analysis hasn't addressed such issues as unemployment, variable markups, or the determination of nominal exchange rates. There is no scope for monetary or fiscal policy. We hope someday to see our framework extended in ways to address these issues. While we are not arguing that the world is perfect, our analysis suggests that the 5 puzzles we address above are not necessarily evidence of imperfection.

[36] We interpret trade frictions as describing the technology for moving goods between countries, and not as imperfections.

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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 the average of exports and imports.

Country	Baseline		Frictionless Trade	
	Durables	Nondurables	Durables	Nondurables
Austria	0.30	0.50	0.02	0.02
Canada	0.75	1.99	0.05	0.04
Czech Republic	0.62	1.15	0.03	0.05
Denmark	0.17	0.42	0.01	0.01
Finland	1.19	2.14	0.03	0.02
Germany	1.16	1.37	0.07	0.05
Greece	1.12	1.84	0.02	0.02
India	3.24	8.00	0.06	0.12
Italy	2.42	3.14	0.07	0.07
Japan	6.39	6.50	0.13	0.06
Mexico	0.77	3.39	0.05	0.08
Poland	0.88	2.04	0.03	0.05
Romania	0.61	1.11	0.01	0.02
South Korea	3.30	4.56	0.14	0.06
Spain	1.50	2.56	0.06	0.06
Sweden	0.86	1.12	0.03	0.02
United Kingdom	0.63	1.67	0.04	0.04
United States	2.18	5.13	0.11	0.12
Rest of World	2.54	4.82	0.14	0.18

Table 2: Home Bias in Trade

Notes: Table reports the ratio of home purchases to imports by sector in 2005:Q4.

Country	Baseline		Frictionless Trade	
	Durables	**Nondurables**	**Durables**	**Nondurables**
Distance	-1.301***	-1.432***	0.000	0.000
	(0.113)	(0.105)	(0.000)	(0.000)
Contiguous	0.073	0.148	0.000	0.000
	(0.200)	(0.210)	(0.000)	(0.000)
Common Language	0.508***	0.554***	0.000	0.000
	(0.163)	(0.120)	(0.000)	(0.000)
Constant	-3.217***	-4.188***	0.000	0.000
	(0.187)	(0.167)	(0.000)	(0.000)
Importer FE	YES	YES	YES	YES
Exporter FE	YES	YES	YES	YES
Observations	306	306	306	306
R-squared	0.93	0.92	1.00	1.00

Table 3: Gravity Regressions

Notes: Dependent variable is the log of the ratio of bilateral trade share to destination country's own trade share in 2005:Q4. We exclude ROW (and home country observations) so the number of observations equals $306 = 18^2 - 18$. Robust standard errors in parentheses. $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by $***$, $**$, and $*$, respectively.

	Baseline				Frictionless Trade			
	2001-12	**2001-08**	**2009-12**	**Long Difference**	**2001-12**	**2001-08**	**2009-12**	**Long Difference**
Saving	0.378**	0.254*	0.630***	0.881***	0.146**	0.148**	0.141	-0.292
	(0.134)	(0.142)	(0.120)	(0.179)	(0.068)	(0.058)	(0.092)	(0.441)
Constant	0.144***	0.174***	0.0852***	0.003	0.263***	0.280***	0.232***	-0.0822*
	(0.032)	(0.034)	(0.028)	(0.010)	(0.041)	(0.036)	(0.053)	(0.042)
Observations	19	19	19	19	19	19	19	19
R-squared	0.34	0.18	0.63	0.63	0.20	0.20	0.12	0.02

Table 4: Feldstein-Horioka Regressions

Notes: Dependent variable is investment. Investment and saving are expressed relative to GDP. Saving is defined as investment plus trade balance. "Long Difference" calculated as the 2012 value less the 2001 value. Robust standard errors in parentheses. $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by $***$, $**$, and $*$, respectively.

	Quarterly		Annual	
	Baseline	**Frictionless Trade**	**Baseline**	**Frictionless Trade**
Mean	0.03	0.10	0.01	0.24
Median	0.04	0.10	0.01	0.23
Maximum	0.45	0.74	0.84	0.98
Minimum	-0.55	-0.45	-0.80	-0.83

Table 5: Consumption Correlations

Notes: Table gives moments of the distribution of correlations in quarterly and annual log changes in consumption (both at an annual rate) between each pair among the 19 countries from 2001 through 2012.

	Quarterly		Annual	
	Baseline	**Frictionless Trade**	**Baseline**	**Frictionless Trade**
Construction	0.177	0.147	0.073	0.049
Durables	0.095	0.000	0.048	0.000
Nondurables	0.100	0.000	0.051	0.000
Services	0.124	0.088	0.063	0.039
CPI	**0.114**	**0.060**	**0.059**	**0.030**

Table 6: Relative Purchasing Power Parity

Notes: We report standard deviations in quarterly and annual log changes in prices (both at an annual rate) across 19 countries, averaged over 2001-2012.

	Quarterly				Annual			
	Baseline		**Frictionless Trade**		**Baseline**		**Frictionless Trade**	
Change in Trade Deficit / GDP	0.291**	0.294**	0.253***	0.246***	1.123***	1.252***	0.366***	0.336***
	(0.019)	(0.120)	(0.034)	(0.021)	(0.404)	(0.446)	(0.041)	(0.038)
Constant	0.004	0.003	-0.002	-0.002	-0.054***	0.056***	-0.066***	-0.072***
	(0.014)	(0.005)	(0.004)	(0.007)	(0.020)	(0.017)	(0.005)	(0.010)
Country FE	NO	YES	NO	YES	NO	YES	NO	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	893	893	893	893	209	209	209	209
R-squared	0.24	0.25	0.61	0.65	0.25	0.33	0.71	0.83

Table 7: The CPI and Trade Deficits

Notes: Dependent variable is quarterly or annual log changes in the CPI. Robust standard errors in parentheses. $p < 0.01$, $p < 0.05$, and $p < 0.1$ denoted by $***$, $**$, and $*$, respectively.

	Quarterly						Annual					
	Baseline			Frictionless Trade			Baseline			Frictionless Trade		
	Nominal GDP	Real GDP	RER	Nominal GDP	Real GDP	RER	Nominal GDP	Real GDP	RER	Nominal GDP	Real GDP	RER
Austria	0.066	0.026	0.066	0.095	0.044	0.056	0.031	0.008	0.031	0.028	0.014	0.015
Canada	0.109	0.021	0.107	0.077	0.028	0.062	0.046	0.011	0.044	0.026	0.015	0.021
Czech Republic	0.102	0.020	0.100	0.117	0.073	0.050	0.062	0.014	0.057	0.043	0.028	0.018
Denmark	0.068	0.031	0.059	0.163	0.060	0.112	0.025	0.007	0.029	0.047	0.019	0.033
Finland	0.057	0.037	0.068	0.052	0.039	0.033	0.032	0.016	0.033	0.018	0.017	0.011
Germany	0.057	0.024	0.064	0.045	0.023	0.040	0.029	0.017	0.036	0.024	0.013	0.023
Greece	0.119	0.060	0.097	0.081	0.063	0.055	0.079	0.046	0.042	0.032	0.045	0.020
India	0.120	0.043	0.112	0.068	0.051	0.046	0.065	0.018	0.051	0.041	0.035	0.014
Italy	0.066	0.014	0.066	0.038	0.018	0.028	0.038	0.006	0.039	0.021	0.010	0.015
Japan	0.209	0.034	0.207	0.125	0.048	0.092	0.093	0.015	0.088	0.054	0.024	0.037
Mexico	0.164	0.027	0.164	0.082	0.029	0.062	0.084	0.016	0.072	0.034	0.016	0.022
Poland	0.152	0.031	0.167	0.070	0.031	0.063	0.070	0.018	0.076	0.033	0.022	0.026
Romania	0.179	0.066	0.170	0.104	0.067	0.085	0.095	0.032	0.075	0.052	0.043	0.019
South Korea	0.147	0.032	0.133	0.072	0.038	0.044	0.085	0.016	0.081	0.041	0.019	0.025
Spain	0.075	0.020	0.064	0.045	0.028	0.020	0.052	0.013	0.042	0.031	0.021	0.012
Sweden	0.086	0.028	0.079	0.061	0.032	0.039	0.049	0.012	0.041	0.032	0.019	0.015
United Kingdom	0.091	0.020	0.090	0.086	0.031	0.065	0.053	0.010	0.049	0.045	0.019	0.030
United States	0.153	0.020	0.147	0.119	0.033	0.096	0.067	0.012	0.060	0.053	0.020	0.040
Rest of World	0.050	0.007	0.050	0.048	0.019	0.040	0.030	0.003	0.029	0.025	0.009	0.019
Pooled	0.120	0.042	0.115	0.089	0.051	0.065	0.064	0.033	0.056	0.042	0.037	0.030

Table 8: Variation in Nominal GDP, Real GDP, and the Real Exchange Rate

Notes: Table reports standard deviations of $\tilde{Y}_{i,t+1}$, $\tilde{y}_{i,t+1}$, and $\tilde{P}_{i,t+1}$ from equation (4), constructed using quarterly and annual log changes from 2001 through 2012.

	Quarterly				Annual			
	Baseline		**Frictionless Trade**		**Baseline**		**Frictionless Trade**	
Log Change in Nominal GDP	0.099***	0.064***	0.401***	0.369***	0.257***	0.146***	0.627***	0.505***
	(0.019)	(0.017)	(0.024)	(0.021)	(0.045)	(0.027)	(0.062)	(0.041)
Constant	0.019*	0.007	0.142***	0.138***	0.019***	0.013***	0.108***	0.100***
	(0.006)	(0.008)	(0.007)	(0.007)	(0.007)	(0.004)	(0.005)	(0.003)
Country FE	NO	YES	NO	YES	NO	YES	NO	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	893	893	893	893	209	209	209	209
R-squared	0.37	0.63	0.70	0.82	0.48	0.86	0.70	0.92

Table 9: Exchange Rate Disconnect Regressions

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

Figure 1: Global Trade / GDP in the Baseline and with Frictionless Trade

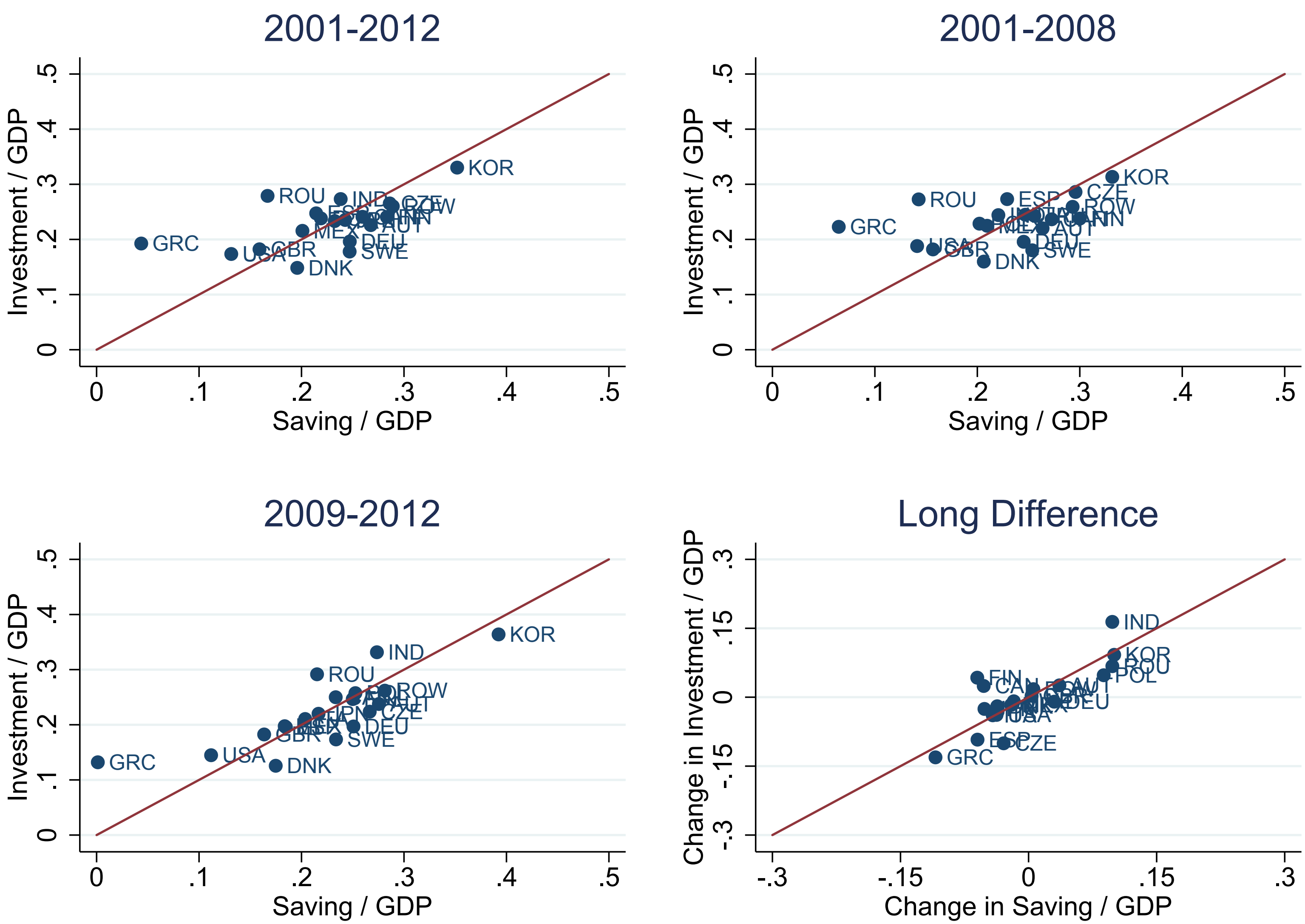

Figure 2: Feldstein-Horioka Plots, Baseline

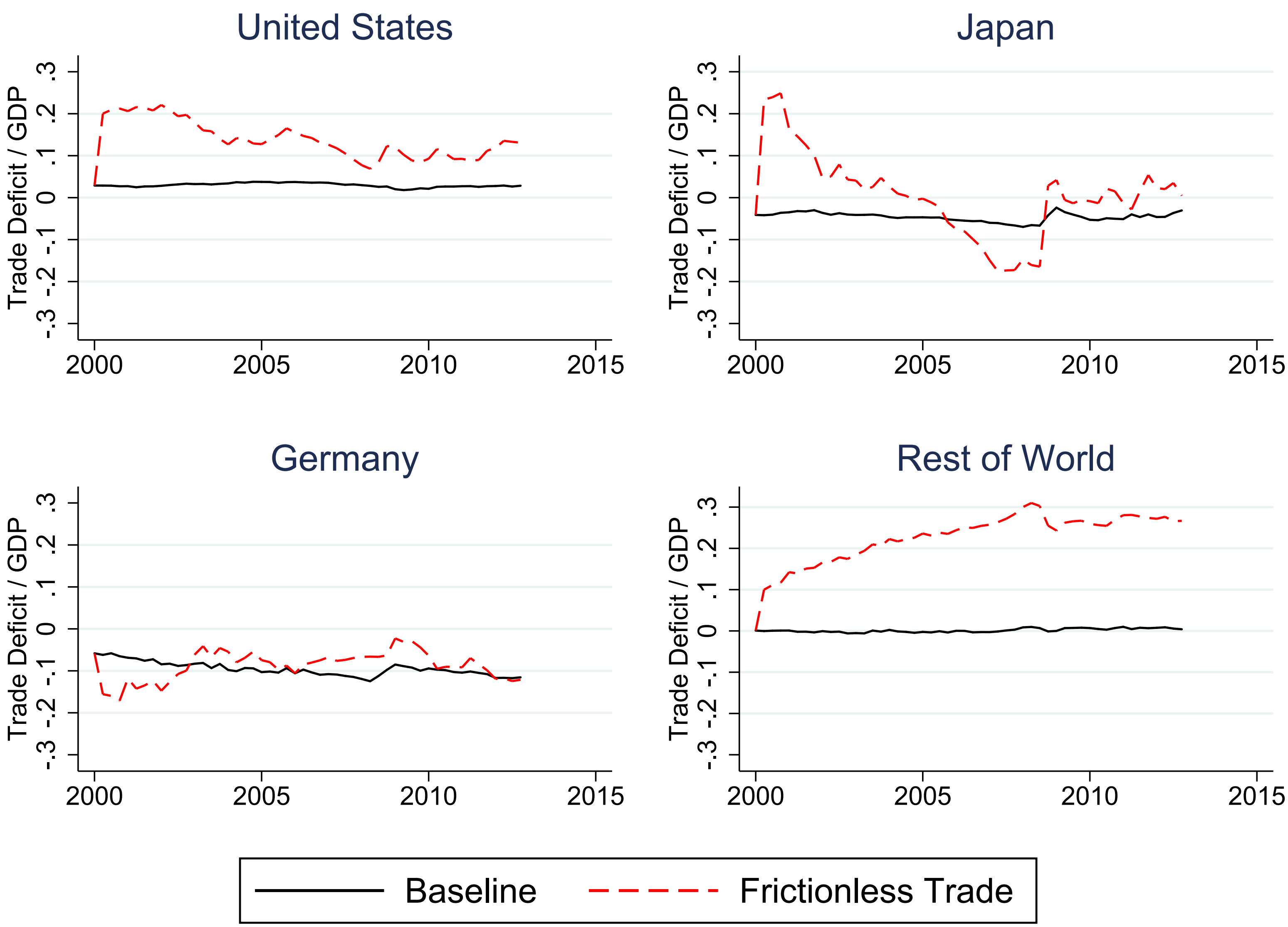

Figure 3: Trade Deficits / GDP in the Baseline and with Frictionless Trade for Selected Countries

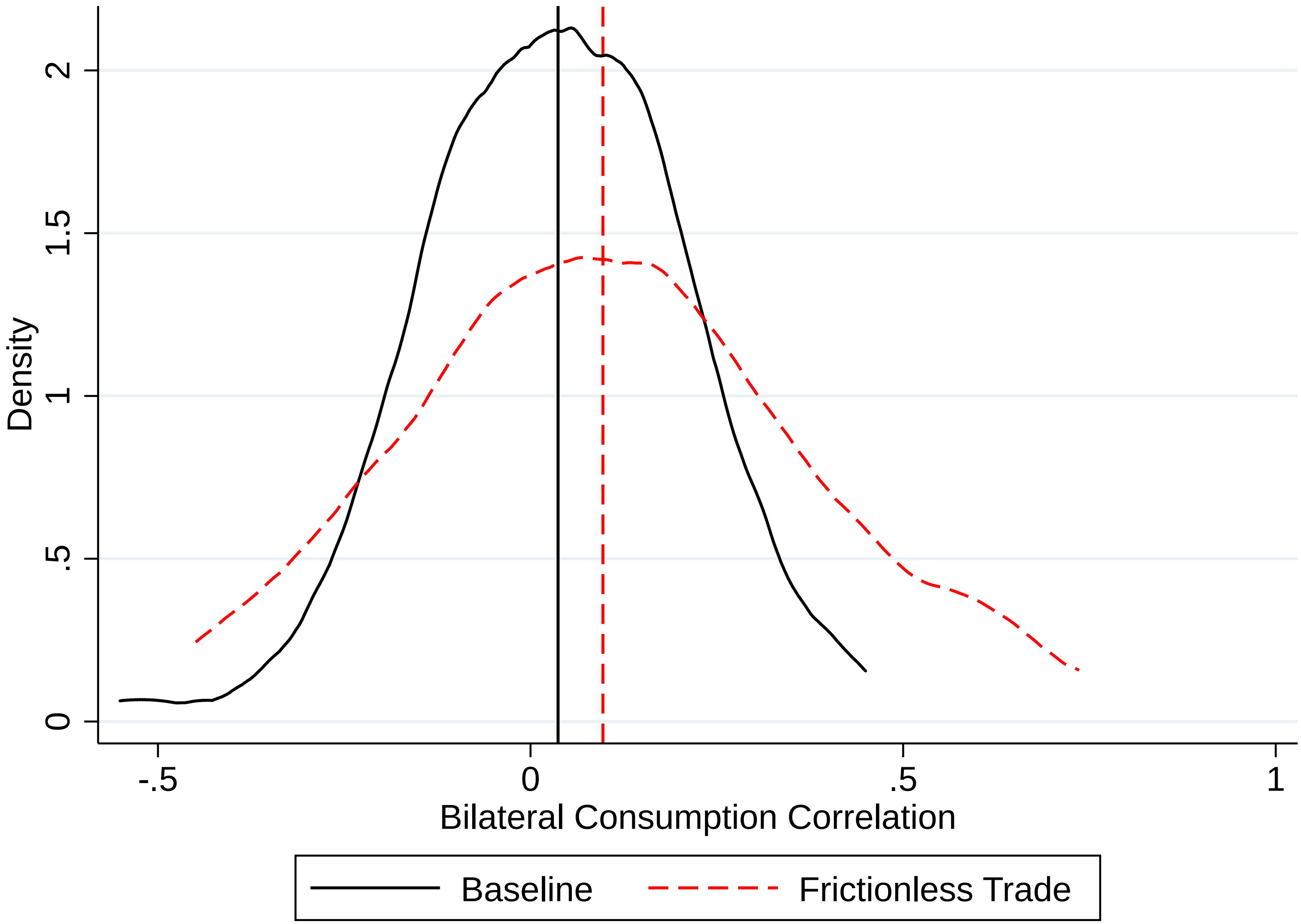

Figure 4: Distribution of Quarterly Consumption Correlations in the Baseline and with Frictionless Trade

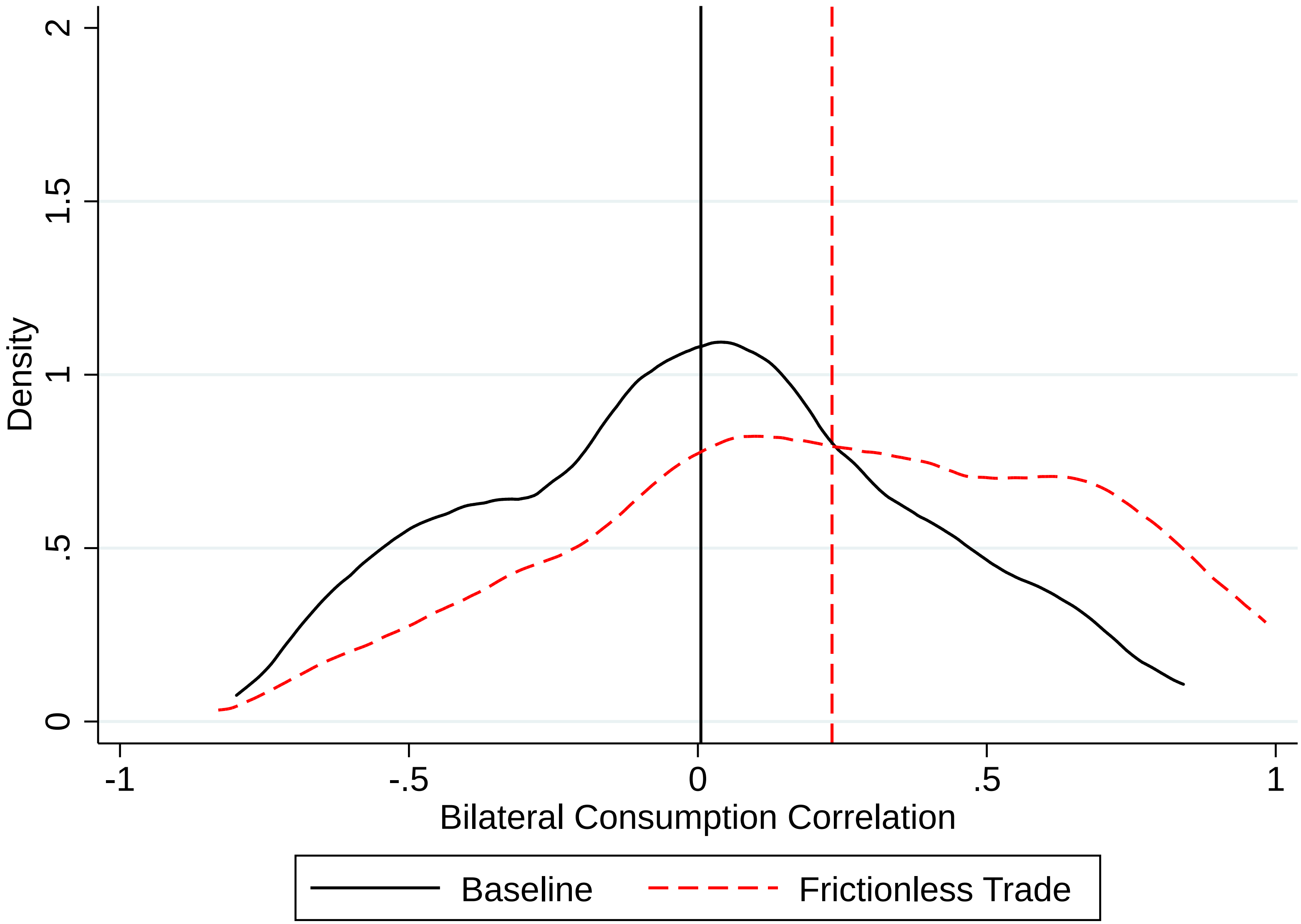

Figure 5: Distribution of Annual Consumption Correlations in the Baseline and with Frictionless Trade

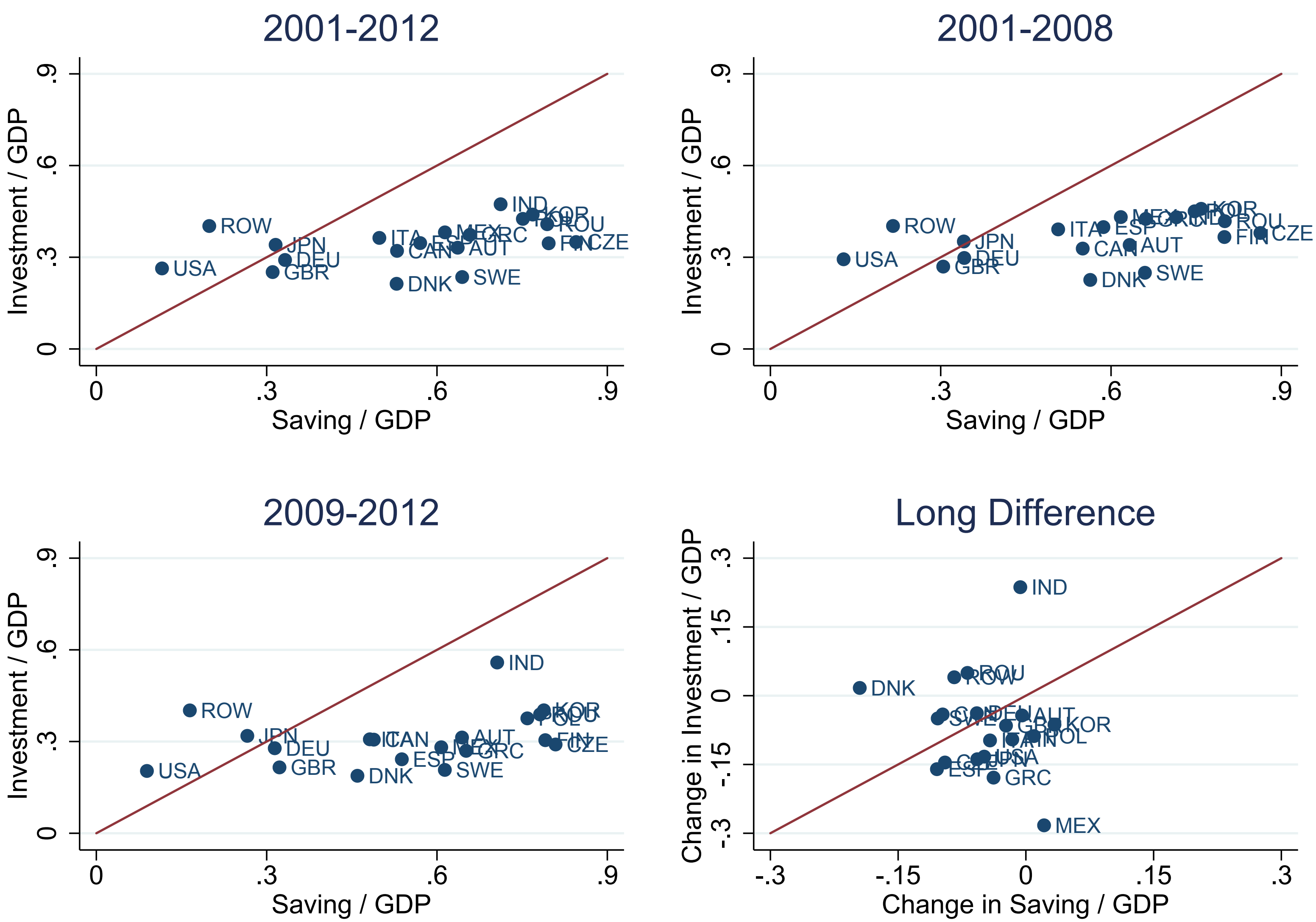

Figure 6: Feldstein-Horioka Plots, Frictionless Trade