A Gravity View of Exchange Rate Disconnect*

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Abstract

The empirical "gravity" equation is extremely successful in explaining bilateral trade. This paper shows how a multi-country model of specialization and costly trade (i.e. a microfounded gravity model) can be applied to explain empirical exchange rate puzzles. One such puzzle is the fact that nominal exchange rates are enormously volatile, but that this volatility does not appear to affect inflation. The gravity model is very successful in explaining this puzzle. In a sample of 25 OECD countries in the post-Bretton Woods period, the gravity prediction of inflation substantially outperforms the purchasing power parity prediction. The gravity prediction matches the volatility of actual inflation, and tracks its path closely. The superior performance of the gravity prediction is explained primarily by the fact that it takes account of the interaction of specialization with home bias. The stability of inflation in very open economies is explained in addition by the fact that the size of bilateral trade is negatively correlated with bilateral exchange rate volatility.

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1 Introduction

The literature on real and nominal exchange rate determination is vast. While the econometric techniques used in the empirical literature have progressed greatly in sophistication

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since the 1970s, until recently, this has been less true of the models being tested. One way in which progress has been made is in the realization of the importance of trade costs.[1] However, because of its simplicity relative to alternatives, the workhorse remains a two-country model with a single traded good. This paper contributes to this literature in two ways. The first contribution is to show how a tractable multi-country model of endogenous specialization and costly trade (i.e. a microfounded "gravity" model) can provide a framework for analyzing multilateral exchange rates. The second is to show using this model that specialization and costly trade can explain why inflation is generally stable despite the volatility of bilateral exchange rates.

The first section of the paper follows Krugman (1980) in describing a multi-country world where specialization and costless trade is motivated by increasing returns to scale and a desire for variety. Geography does not matter for trade in this world. Bilateral imports as a share of importing-country consumption are equal to the exporting country's share in world GDP. The model yields a multilateral counterpart to bilateral purchasing power parity (PPP). Bilateral PPP says that consumer price inflation is given by foreign CPI inflation plus nominal exchange rate depreciation against the foreign currency. In contrast, under multilateral PPP, consumer price inflation is an import-share-weighted average of contributions to inflation from all countries in the world, not omitting "imports" from self. It is shown that since the weights are the same in all countries, PPP holds when trade is costless.

The second section modifies the model by adding an iceberg cost of trade. The result is a reduced form model similar to those in recent papers that provide theoretical foundations for the empirical gravity equation [Eaton and Kortum (2002) and Anderson and Van Wincoop (2003)]. It has the advantage of being extremely simple and tractable. Trade costs induce systematic asymmetry in trade patterns. Bilateral imports as a share of importing-country consumption depend not just on the exporting country's share in world GDP. They are also negatively related to bilateral trade costs, and to the access of both importing and exporting countries to other potential trade partners. Consumer price inflation is still an import-share-weighted average of the contributions to inflation from all countries in the world, not omitting "imports" from self. However it is shown that because trade costs induce asymmetry

[1] For example, Obstfeld and Rogoff (2000), Betts and Kehoe (2001), Bergin and Glick (2003) and Ghironi and Melitz (2004) among others.

in trade patterns, purchasing power parity fails. In addition, because of the asymmetry of trade, bilateral exchange rates depend on prices and exchange rates of all trading partners and hence on appropriately defined multilateral fundamentals.

The third and fourth sections of the paper use the theory developed in the first two sections to re-evaluate empirically the exchange rate disconnect puzzle in a sample of 25 OECD countries. Using data on nominal exchange rates and prices, predictions of inflation consistent with both the zero trade cost model (the multilateral PPP prediction) and the trade cost model (the gravity prediction) are constructed. These predictions are weighted averages of the contributions to inflation from all countries in the sample, where the weights are consistent with zero trade costs and costly trade respectively. The contribution of each country is given by its producer price inflation plus bilateral exchange rate depreciation. In contrast to the multilateral PPP prediction, the mean and standard deviation of the gravity prediction are very close to those of actual inflation. In addition, the gravity prediction tracks actual inflation very closely - much more closely than the multilateral PPP prediction.

The superior performance of the gravity prediction is shown to be due primarily to the interaction of specialization and home bias induced by trade costs. The volume of gross trade tells us that there must be specialization. Because countries specialize, the price of domestic output is only weakly linked to the price of imports. As a result, home bias implies that exchange rate volatility has only a limited effect on inflation. For very open economies, an additional role is played by fact that bilateral exchange rate volatility is negatively correlated with bilateral trade. Since countries trade little with partners against whom they have volatile exchange rates, this volatility does not affect inflation. It should be noted that these explanations for disconnect do not rely in any way on sticky prices, and are consistent with the stylized fact that pass-through of exchange rate changes into import prices measured at the border is swift.

The fifth section of the paper discusses additional implications of the multi-country multi-good trade cost model for empirical work on exchange rates. This framework has the potential to resolve a number of exchange rate puzzles in addition to exchange rate disconnect. By providing a coherent framework within which analyze trade-weighted exchange rates - how they should be constructed, and for which purposes they, rather than bilateral exchange rates are the appropriate choice - the results are potentially of relevance to a very large body of empirical work on exchange rates. The sixth section of the paper concludes.

2 Multilateral purchasing power parity

Following Krugman (1980), this section presents a multi-country model, where there is endogenous specialization of production and trade due to the interaction of a desire for variety and increasing returns in production. As a benchmark, the case with costless trade is analyzed.

There are N countries, indexed $i = 1, \ldots, N$. No restrictions are placed on the distribution of country size or bilateral distances between countries. Each country has an inelastically supplied endowment of labor, L_i. Labor is used to produce a number of differentiated intermediate goods that can be traded. The number of varieties of the intermediate is potentially infinite. But due to fixed costs of production, each country specializes in the production of a distinct set of varieties, the (finite) number of which is endogenously determined. Varieties of the intermediate are combined using a Dixit-Stiglitz-type production function to produce a non-traded final consumption good. This functional form generates the desire for variety.

There is only one period, and all variables are deterministic, so there is no motive for investment, trade across time or across states of the world. Abstracting from the question of nominal exchange rate determination, it is assumed that there is a single currency in the world. Since all prices are flexible, this assumption does not affect the results in any way. Equilibrium real exchange rates are tied down by (balanced) trade in goods. Irrespective of asymmetry in size, productivity and bilateral distance, trade patterns are symmetric. Because of this symmetry, purchasing power parity holds.

I. Consumption good

The non-traded consumption good is produced by combining traded intermediate inputs using a Dixit-Stiglitz production function with elasticity of substitution η. Intermediates are indexed by x and $C(x)_i$ is the amount of intermediate x used in final goods production in country i

$$C_i = \left[\sum_x C(x)_i^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{1}$$

The market for the consumption good is assumed perfectly competitive. The price P_i of the consumption good is set equal to marginal cost:

$$P_i = \left[\sum_x P(x)_i^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{2}$$

where $P(x)_i$ is the price of intermediate x in country i. Demands for individual intermediate inputs take the constant price-elasticity form

$$C(x)_i = \left(\frac{P(x)_i}{P_i}\right)^{-\eta} C_i \tag{3}$$

There is no value added in this stage of production.

II. Intermediates

Intermediate inputs are produced using labor. There is a fixed cost and a variable cost of production in each period. The fixed cost is in terms of labor, while the variable cost depends on productivity-adjusted labor. Within country i, labor productivity is the same across all varieties. The production function for intermediate x is

$$Y(x)_i = A_i \left[L(x)_i - \alpha\right] \tag{4}$$

Intermediate producers maximize profits. They ignore the externalities from individual firm behavior on the overall price level. Given the constant-elasticity form of demand, prices are set as a constant markup over marginal cost.

$$P(x)_i = \frac{\eta}{\eta - 1} \frac{W(x)_i}{A_i} \tag{5}$$

With free entry, the zero profit condition is

$$\alpha W(x)_i = Y(x)_i \left[P(x)_i - \frac{W(x)_i}{A_i}\right] \tag{6}$$

Together with pricing behavior, this implies that the quantity produced is the same for all intermediates produced in country i, while more productive countries produce more of each intermediate:

$$Y(x)_i = \alpha(\eta - 1) A_i \tag{7}$$

In equilibrium, a country with labor force s_i will produce v_i varieties, where

$$v_i = \frac{L_i}{L(x)_i} = \frac{L_i}{\alpha + Y(x)_i / A_i} = \frac{L_i}{\alpha \eta} \tag{8}$$

That is, more populous countries produce more varieties.

III. Law of one price

The law of one price holds for all intermediates:

$$P(x)_i = P(x)_j \tag{9}$$

Note that though the law of one price holds, each variety is produced in only one country. Since the final good production function is identical everywhere and trade is costless, purchasing power parity holds for the consumption aggregate. Substituting (9) into (2):

$$P_i = P_j \tag{10}$$

IV. Market clearing

Labor markets are integrated and perfectly competitive so wages are the same in all sectors

$$W(x)_i = W(x')_i = W_i \tag{11}$$

and the labor market clears

$$\sum_x^{v_i} L(x)_i = L_i \tag{12}$$

In this one-period deterministic setting, it is natural to assume that each country has a balanced current account, i.e. the value of goods produced is equal to the value of goods consumed:

$$P_i C_i = W_i L_i = \sum_x^{v_i} P(x)_i Y(x)_i \tag{13}$$

V. Equilibrium

Equilibrium is described by the vectors of wages, $\mathbf{W}$ and consumer prices $\mathbf{P}$ that satisfy (2), (3), (5), (7), (8), (9), (11), (12), (13) and market clearing for each variety.

VI. Trade and inflation

Remembering that no value is added in the final stage of production, the share of value added produced by country j in i's consumption is given by

$$\frac{IM_{ij}}{P_i C_i} = \frac{v_j P(j)_i C(j)_i}{P_i C_i} = \frac{GDP_j}{GDP^W} \tag{14}$$

where IM_{ij} denotes i's imports from j if $i \neq j$ and GDP_i less the total value of exports from

i if $i = j$. GDP^W is world GDP. This yields the following result:

Result 1: *When there are no trade costs, trade patterns are symmetric.*

That is, the share of value added produced by j in i's consumption is exactly the same as the share of value added produced by j in k's consumption.

Since PPP holds, the relative price level or real exchange rate between country i and country j (P_j/P_i) is always equal to 1. However, it will be useful to have a deeper understanding of the process through which changes in producer prices for intermediates produced by one country affect consumer prices throughout the world. Taking the derivative of the price index holding population fixed, and substituting from (14) yields the following relationship between consumer price inflation in one country and producer price inflation in all countries:

$$d \ln P_i = \sum_{k=1}^{N} \frac{GDP_k}{GDP^W} d \ln P(k)_k \tag{15}$$

This is the second result:

Result 2: *When there are no trade costs, consumer price inflation in country i is an import-share-weighted average of producer price inflation in all countries from which country i uses some intermediate inputs.*

This simple relationship is based on four assumptions: (i) the Dixit-Stiglitz aggregator; (ii) perfect specialization; (iii) the inelastic response of the number of varieties produced to productivity; and (iv) zero trade costs. The weighted average includes the appropriately weighted change in the price of domestically produced intermediates. Note that weights are identical for all countries i. It is clear that this requirement must be satisfied in order for purchasing power parity to hold. This result will be referred to as *multilateral PPP* in sections 4 and 5 where the model is taken to the data.

3 Trade costs and the failure of PPP

Now, per unit trade costs are introduced. Trade costs induce asymmetry in trade patterns. Purchasing power parity fails, but conditioning on the pattern of trade, it is still possible to make a strong statement about cross-country aggregate price relationships.

I. Trade cost

There is an iceberg cost of trade, assumed to be increasing in the economic distance between countries. When this cost is non-zero, the prices of identical varieties of the intermediate good differ across countries. Because relative prices differ, relative demands differ across countries. Countries import more from partners that are close to them than from partners that are far.

If variety x is produced in country i, then the relationship between the price of that variety in country i and any other country j is given by:

$$t_{ij}P\left(x\right)_i = P\left(x\right)_j \tag{16}$$

where t_{ij} is one plus the fraction that "melts" en route. When a country consumes a variety it has produced itself, none of the good melts, i.e. $t_{ii} = 1$. When a country consumes a variety produced abroad, $t_{ij} \geq 1$. It is assumed that $t_{ij} = t_{ji}$. The presence of trade costs implies that the law of one price fails for all goods, and purchasing power parity also fails.

II. Consumption good

The iceberg trade cost does not affect production of the non-traded consumption good. Equations (1) to (3) hold as in the case without trade costs.

III. Intermediates

As a result of trade costs, relative prices for intermediates differ across countries. However because of the iceberg form of the trade cost and the CES form of demand, the intermediate producer's problem is identical to the case without trade costs. Equations (4) to (8) hold.

IV. Internal market clearing

As before, the labor market is perfectly competitive and the current account is balanced. Equations (11) to (13) hold as in the case without trade costs.

VI. Equilibrium

Equilibrium is described by the vectors of wages, $\mathbf{W}$ and consumer prices $\mathbf{P}$ that satisfy (2), (3), (5), (7), (8), (11), (12), (13), (16) and market clearing for each individual traded variety. Market clearing takes account of the fact that some amount of each variety melts in transit, so the physical quantity that is exported from the producer country is larger than the corresponding physical quantity imported by all importing countries. The market clearing condition for intermediate x produced in country i is

$$Y(x)_i = \sum_{k=1}^{N} t_{ik} \left(\frac{P(x)_k}{P_k} \right)^{-\eta} C_k \tag{17}$$

Appropriate substitution yields an equilibrium relationship between wages, productivity, and consumer prices for country i:

$$W_i^{\eta} A_i^{1-\eta} = \left[\frac{\eta}{\eta - 1} \right]^{1-\eta} \frac{1}{\alpha\eta} \sum_{k=1}^{N} W_k L_k P_k^{\eta-1} t_{ik}^{1-\eta} \tag{18}$$

The equality of consumer prices and the marginal cost of producing the consumer good yields a second equilibrium relationship beween wages, productivity and consumer prices for country i

$$P_i^{1-\eta} = \left[\frac{\eta}{\eta - 1} \right]^{1-\eta} \frac{1}{\alpha\eta} \sum_{k=1}^{N} L_k \left(\frac{W_k}{A_k} t_{ik} \right)^{1-\eta} \tag{19}$$

(19) and (18) together yield a system of equations the solution to which is the vector of relative wages.

VII. Trade and inflation

In the Appendix, it is shown that with iceberg trade costs, the share of value added produced by country j in i's consumption is given by

$$\frac{IM_{ij}}{P_i C_i} = \frac{v_j P(j)_i C(j)_i}{P_i C_i} = \frac{GDP_j}{GDP^W} \left(\frac{P_i P_j}{t_{ij}} \right)^{\eta-1} \tag{20}$$

Bilateral imports as a share of importing-country consumption depend not just on the exporting country's share in world GDP. They are also negatively related to bilateral trade costs. They are negatively related to the access of both importing and exporting countries to other potential trade partners, as measured by aggregate price levels. This the phenomenon of *multilateral resistance* identified by Anderson and van Wincoop (2003). From (20) comes the third result:

Result 3: *When trade is costly, trade patterns are asymmetric.*

The share of country j in i's consumption is in general different from the share of country j in k's consumption. Asymmetry arises for two reasons. First, countries trade more with countries that are close than with countries that are far. So if $t_{ij} \neq t_{kj}$, import shares will differ. Second, as we know from (19), $P_j \neq P_i$. This implies that even if $t_{ij} = t_{kj}$, import shares will differ as long as country k and country i are not symmetrically positioned with respect to *all* other countries in the world.

Although PPP fails, the model still predicts a systematic relationship between changes in consumer prices, and producer prices in all countries. This can be seen by taking the derivative of the price index holding population and trade costs constant, and using (20) to show that:

$$d\ln P_i = \sum_{k=1}^{N} \frac{GDP_k}{GDP^W} \left(\frac{P_i P_k}{t_{ik}} \right)^{\eta-1} d\ln P(k)_k \tag{21}$$

This yields the fourth result:

Result 4: *When trade is costly, consumer price inflation is an import-share-weighted average of producer price inflation in all countries.*

This simple relationship is based on four assumptions: (i) the Dixit-Stiglitz aggregator; (ii) perfect specialization; (iii) the inelastic response of the number of varieties produced to productivity; and (iv) iceberg trade costs. Importantly, as described by (20), import weights are not identical across countries when trade is costly. Changes in the price of goods produced by country k affect inflation more in countries that are close to country k than in countries that are far. (21) will be referred to the *gravity prediction* of inflation in sections 4 and 5 where the model is taken to the data.

3.1 Additional results

Using (21), bilateral real exchange rate changes can be expressed as

$$d\ln \left(\frac{P_j}{P_i} \right) = \sum_{k=1}^{N} \left[\frac{IM_{jk}}{P_j C_j} - \frac{IM_{ik}}{P_i C_i} \right] d\ln P(k)_k \tag{22}$$

As this implies, if import shares are symmetric, real depreciation is always zero. But if trade is costly, import shares will not be symmetric, and changes in the real exchange rate between country i and country j depend on (appropriately weighted) changes in prices in all countries. It is possible to have persistent bilateral real depreciations or appreciations because inflation in a country that is "close" to one member of the pair but not the other will persistently have a differential effect on inflation in the two countries.

While persistent *bilateral* real depreciations or appreciations are possible, the model predicts zero depreciation for the appropriate import-share-weighted real exchange rate:

$$0 = \sum_{k=1}^{N} \frac{IM_{ik}}{P_i C_i} \left[d \ln P(k)_k - d \ln P_i \right] \tag{23}$$

This import-share-weighted real exchange rate is distinct from the import-weighted (or similar trade-weighted) real exchange rates frequently used in empirical work in that it treats consistently bilateral "imports" of own output and bilateral imports from abroad. The relationship between this import-share-weighted real exchange rate and the standard import-weighted real exchange rate used in the literature is given by

$$\begin{aligned} \sum_{k=1}^{N} \frac{IM_{ik}}{P_i C_i} \left[d \ln P(k)_k - d \ln P_i \right] &= \frac{GDP_i - EX_i}{P_i C_i} \cdot \left[d \ln P(i)_i - d \ln P_i \right] + \\ &\quad + \frac{IM_i}{P_i C_i} \cdot \underbrace{\sum_{\substack{k=1 \\ k \neq i}}^{N} \frac{IM_{ik}}{IM_i} \left[d \ln P(k)_k - d \ln P_i \right]}_{\text{Standard import-weighted real exchange rate}} \end{aligned}$$

where EX_i is total exports of country i and IM_i is total imports of country i. There is no prediction of zero depreciation for the import-weighted real exchange rate as usually constructed.

3.2 Discussion

Equation (21) is not an identity, either theoretically, or because of the way consumer price indices are constructed. As already mentioned, equation (21) relies on the Dixit-Stiglitz aggregator, perfect specialization, the inelastic response of the number of varieties produced to productivity, and iceberg trade costs.

In general, any model that generates a gravity structure for bilateral imports by combining a Dixit-Stiglitz aggregator, some degree of specialization, and trade costs will predict that domestic inflation is an import-share-weighted average of the variables that contribute to foreign producer price inflation. Where these models break crucially with the existing literature on exchange rates is that they emphasize the role of *specialization* and trade within periods. Because of specialization, exchange rates are tied down not by arbitrage for individual goods, but by general equilibrium relations between prices and wages across countries (here (18) and (19)). Depending on the elasticity of substitution, the price of output produced in one country may respond very little to changes in the price of output produced in another country.

In contrast, classic one-good or one-traded-good models of exchange rate determination emphasize the importance of trade across periods in tying down exchange rates. Naturally, if there is only one traded good, there is no motive for trade within periods. In addition, even in the presence of trade costs, arbitrage ties relative prices very closely together, much more closely than the general equilibrium relationships referred to above. If the price of output produced in one country changes, the price of output produced in another country will change by a similar amount.

Since for most countries and most periods, intra-temporal trade accounts for a much higher fraction of consumption than inter-temporal trade, it makes sense to investigate the role of intra-temporal trade in determining exchange rates.

4 Explaining exchange rate disconnect

The focus of the remaining part of the paper is on showing that the model described in the previous section can reconcile both theoretically and empirically the volatility of nominal exchange rates with the stability of consumer price inflation. Once the single-currency assumption is relaxed, equation (21) makes a strong prediction about how consumer price inflation depends on nominal exchange rate changes. Given the substantial evidence that trade is in fact costly, there are several reasons why exchange rate volatility need not be reflected in consumer prices.

First, costly trade implies home bias in consumption. As long as the elasticity of substitution between domestic output and imports is low, there will be at best a very weak link between the price of imports and the price of domestic output. Since there is no nominal exchange rate involved in consuming your own output, home bias reduces the sensitivity of inflation to exchange rate changes.[2] In the limiting case, if two countries do not trade

[2] The point that home bias affects pass-through to consumer prices in a two-country world is also made

at all, their bilateral exchange rate can be infinitely volatile without affecting any domestic variables.

Second, as pointed out by several authors, bilateral nominal exchange rate volatility and bilateral trade are negatively correlated.[3] Irrespective of the direction of causality in this relationship, if trade patterns are skewed towards partners with whom bilateral exchange rates are more stable, the impact of exchange rate volatility on consumer prices will be lower than if this were not the case.

In addition, specialization alone may contribute to smoothing the effect of volatile exchange rates on inflation. Unless the elasticity of substitution between the output of different countries is equal to one, the weight on the price of imports from a particular foreign country in overall inflation changes endogenously with relative prices. In the model, the relationship between this weight and the relative price of the output of the foreign country is given by

$$\frac{IM_{ij}}{P_i C_i} = \frac{L_j}{\alpha \eta} \left(\frac{P_i}{t_{ij} P(j)_j} \right)^{\eta - 1} \tag{24}$$

With $\eta > 1$, the import share shrinks if the relative price rises, offsetting the effect of the price increase on the overall basket.

The remainder of the paper empirically evaluates the performance of the trade cost model in explaining exchange rate disconnect. It focuses on the ability of the gravity prediction (21) to match the first and second moments of actual inflation, and to track inflation's path as measured by the bias and root mean squared error of the prediction. As a benchmark, the performance of the gravity prediction along these dimensions is compared with that of the multilateral PPP prediction (15). Equation (15) as an expression of PPP is perfectly consistent with the traditional one-good zero trade cost model of purchasing power parity, but has the advantage that in a multi-country world, there is no need to choose a single numeraire currency. Finally, the empirical importance of the three mechanisms just mentioned in explaining exchange rate disconnect is explored.

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by Obstfeld and Rogoff (2000), Hau (2002), Corsetti and Dedola (2003) and Campa and Goldberg (2004a) among others. This point is also related to the literature on the role of distribution margins in explaining disconnect, e.g. Burstein et al (2001).

[3] see Frankel and Wei (1993), Rose (2000), Broda and Romalis (2003) and Tenreyro (2004)

4.1 Taking the model to the data

In laying out the model the assumption that trade is balanced on aggregate is maintained throughout. It is also assumed that bilateral trade costs are symmetric. Neither of these assumptions is true in practice. The Appendix shows that these two assumptions can be relaxed with minimal effects on the theoretical results. Once the single-currency assumption is relaxed, foreign output price inflation must be replaced by the sum of the rate of change of the relevant bilateral nominal exchange rate and foreign output price inflation. The theoretical model must also be modified to take account of the existence of government consumption and investment. The empirical counterpart to consumption is absorption, the sum of private consumption, investment and government consumption.

Combining these modifications, the empirical counterpart to equation (15) that will be used to construct a multilateral PPP prediction of inflation is:

$$\Delta \ln API_{it} = \sum_{k=1}^{N} \frac{GDP_{kt}}{GDP_t^W} \left[\Delta \ln E_{ikt} + \Delta \ln PPI_{kt}\right] \tag{25}$$

where E_{ikt} denotes the nominal exchange rate between country i and country k in period t, API denotes the absorption price index and PPI represents the GDP deflator, which is used to capture changes in producer prices. Equation (21) becomes

$$\Delta \ln API_{it} = \sum_{k=1}^{N} \frac{GDP_{kt}}{GDP_t^W} \frac{\Theta_{it}\Phi_{kt}}{t_{ikt}^{\eta-1}} \left[\Delta \ln E_{ikt} + \Delta \ln PPI_{kt}\right] \tag{26}$$

where and Θ_{it} and Φ_{kt} are importer-year and exporter-year multilateral resistance terms.

4.1.1 Estimating the gravity equation

As it stands, (26) cannot be used to predict inflation in the absorption price deflator. First Θ_{it}, Φ_{kt} and $t_{ikt}^{\eta-1}$ must be estimated. Luckily, the substantial empirical literature on gravity equations gives some guidance on how to do this. The value added absorbed in country i but produced in country j is given by:

$$IM_{ijt} = \frac{ABS_{it}.GDP_{jt}}{GDP_t^W} \frac{\Theta_{it}\Phi_{kt}}{t_{ikt}^{\eta-1}} \tag{27}$$

where ABS_{it} denotes the value of absorption in country i and year t.

It is usual to assume that trade costs t_{ij} are a function of "gravity" variables such as bilateral distance, dummies for common language, contiguity, common colonial heritage and so on. It is frequently assumed that these variables affect trade costs multiplicatively:

$$t_{ijt}^{1-\eta} = \prod_{m=1}^{M} \left(z_{ij}^{m}\right)^{\gamma_t^m}, \; z_{ij}^{m} = 1 \text{ if } i = j, \; z_{ij}^{m} \geq 1 \text{ otherwise} \tag{28}$$

For this exercise, it is a matter of concern that standard gravity variables are constant across time while the evidence suggests that trade costs have fallen. Time-varying trade costs are captured by allowing the coefficients on gravity variables to change over time.

Substituting in for trade costs, subsuming the effect of size into the importer-year and exporter-year fixed effects and adding an error term yields

$$IM_{ijt} = \Theta_{it}\Phi_{jt}\left[\prod_{m=1}^{M} \left(z_{ij}^{m}\right)^{\gamma_t^m}\right]^{1-\eta} v_{ijt} \tag{29}$$

In the empirical gravity literature, equation (29) is almost always estimated in logs. There are three problems with this. First, bilateral trade may be equal to zero. Since the log of zero does not exist, these observations are usually dropped. Second, as explained by Santos Silva and Tenreyro (2004), size-related hetereoskedasticity in the level equation translates into biased estimates of the log transformation. Finally, while the R^2 from estimating the log-tranformed equation is frequently high, the fit in levels is poor, as there is systematic overprediction of high levels of bilateral trade due to Jensen's inequality. This problem is of particular concern here, since a good fit in levels is required particularly for the large observations on own-country bilateral trade.

Santos Silva and Tenreyro note that if the conditional variance of the dependent variable in (29) is assumed proportional to its conditional expectation, the first order conditions for minimizing the sum of squared errors are identical to the first order conditions for a Poisson regression. Hence (29) can be estimated as a Poisson regression under this plausible assumption about variance. They demonstrate in a Monte Carlo exercise that this approach is successful in terms of producing relatively unbiased estimates of the coefficients. Further, zeros in the dependent variable do not have to be dropped, and the fit in terms of levels is far superior to that arising from estimation of the log-transformed equation. This approach is adopted here. The estimating equation becomes:

$$IM_{ijt} = \exp\left(\theta_{it} + \phi_{jt} + \sum_{m=1}^{M} \gamma_t^m \ln z_{ij}^m\right) \upsilon_{ijt} = \exp\left(x'_{ijt}\beta_t\right) \upsilon_{ijt} \tag{30}$$

where θ_{it} and ϕ_{jt} are importer-year and exporter-year fixed effects respectively. The Poisson pseudo-maximum likelihood estimator can be applied under the assumption that the variance of IM_{ijt} conditional on the independent variables X is proportional to the conditional expectation of IM_{ijt}.

As there are no cross-equation coefficient restrictions, (30) is estimated year-by-year. The resulting predicted values for bilateral trade are used to predict import shares using:

$$\frac{\widehat{IM_{ijt}}}{ABS_{it}} = \frac{\widehat{IM}_{ijt}}{\sum_{k=1}^{N} \widehat{IM}_{ikt}} \tag{31}$$

Note that in order for the sum of predicted imports to be an appropriate estimate of absorption, imports from self should be treated exactly as bilateral imports from abroad. These predicted shares may then be used to construct the baseline inflation prediction according to (26)

4.2 Data

The empirical implementation requires data on the value of bilateral imports, total imports, total exports and GDP. It also requires absorption price deflators, GDP deflators, nominal exchange rates and gravity variables. Annual data on these variables are collected for 25 OECD countries and 31 years, 1970-2000. The countries are Australia, Austria, Belgium (bilateral import data is for Belgium-Luxembourg, but all other data refer to Belgium alone), Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the UK and the US. In principle, one would like to use data from all partner countries to construct the inflation predictions. In practice, on average over the sample period domestic output plus imports from the other 24 sample countries accounts for no less than 89% of absorbtion for any given sample country. As a result, the rest of the world is ignored, and all shares are calculated as within-sample shares.

Bilateral imports in current US dollars for the years 1970-2000 are taken from the IMF's *Direction of Trade Statistics* (DOTS). In order to construct bilateral import shares in absorption, the value share of total imports in absorption measured in current domestic currency is calculated using national accounts data from the World Bank's *World Development Indicators* (WDI). Bilateral import shares are then calculated as follows:

$$\frac{IM_{ij,t}}{ABS_{i,t}} = \frac{IM_{ij,t}^{DOTS}}{\sum_k IM_{ik,t}^{DOTS}} \cdot \frac{IM_{i,t}^{WDI}}{GDP_{i,t}^{WDI} + IM_{i,t}^{WDI} - EX_{i,t}^{WDI}} \text{ for } j \neq i$$

The domestic import share is calculated as:

$$\frac{IM_{ii,t}}{ABS_{i,t}} = 1 - \frac{IM_{i,t}^{WDI}}{ABS_{i,t}^{WDI}}$$

To the extent that some part of imported value added is subsequently re-exported rather than being absorbed domestically (e.g. if there is vertical specialization) these shares do not accurately reflect true value added shares. In particular, the domestically produced share of domestic absorption is underestimated, particularly for countries that re-export a substantial fraction of imported value added. The data to control for this - re-exports of imported value added by source and destination country - is not available. An alternative would be to model explicitly re-exports of imported intermediates, and respecify (21) and (26) in terms of shares of gross output. Since gross output data are available for only a limited sample of countries and years, this approach is not practical either.[4]

Value shares of each country in within-sample "world" GDP are calculated using data from the WDI on GDP in current US dollars. In choosing "gravity" variables, attention is restricted to those that are plausibly exogenous to bilateral trade. Bilateral distance in miles is calculated using the great circle distance algorithm provided by Gray (2001). The variable used in the estimation is the log of one plus bilateral distance. Dummy variables indicating common language, colonizer-colony relationship and contiguity are constructed based on the *CIA World Factbook*. Only official languages are used to determine common language. A colonizer-colony relationship is indicated only for pairs where complete independence of the colony from the colonizer was not achieved before 1945. It is also assumed that countries

[4]This works against the model in the tests that follow. Home bias smooths the effect of exchange rate volatility on prices, and in these share calculations, the extent of home bias is underestimated.

share common languages with themselves, are contiguous to themselves, and were formerly ruled by themselves ("in a colony-colonizer relationship"). Indicator variables are coded such that they are zero when the importer country is the same as the exporter country.

The deflator for absorption is calculated using domestic currency national accounts data from the WDI. The GDP deflator (domestic currency) from the WDI is used as the index of producer prices. End-of-period nominal exchange rates are from IFS. In addition, CPI data is used in tests of robustness. This is taken from the WDI.

5 Empirical results

Table 1 reports a summary of the results from estimating the gravity equation using the Poisson approach for each of the years 1971-2000. In addition to the gravity variables previously mentioned, a dummy variable for imports from foreign countries (as distinct from the home country) is included to control for potential home bias.

The gravity equation does an excellent job of matching the variation in the data. The pseudo-R^2 averages 0.99 across the 30 years for which (30) is separately estimated. Results are qualitatively similar to those from standard gravity model estimation. Bilateral imports are lower from countries that are distant than from those that are close, from countries that are not contiguous than from those that are contiguous, and from countries with whom there is no common language than from those with whom there is a common language. All of these effects consistently have the same sign across all years, and are significantly different from zero at the 1% level in each year. The effect of having or not having a colonial relationship on imports is not well identified in this sample. Controlling for all of these effects, imports from a foreign partner with the same characteristics as the home country are predicted to be similar to imports from self. This suggests that for our sample of countries, home bias is driven by trade costs and not by preferences.

Given an assumption about the elasticity of substitution, η, it is possible to back out the implied bilateral trade costs t_{ijt} for each country-pair and year. Anderson and van Wincoop (2004) report estimates of η that range between 5 and 10. The trade costs implied by an elasticity of substition of 6 are on average declining over the period 1970-2000. In 1971, the lowest bilateral trade cost is 1.65, while the highest bilateral trade cost is 3.18. That is, the Dutch pay 1.65 what Belgians pay for goods produced in Belgium, while New Zealanders pay 3.18 times what Spaniards pay goods produced in Spain. In 2000, the range is [1.37, 2.75]. Over this period the (unweighted) mean trade cost for imports from foreign countries falls from 2.71 to 2.32. These estimates are large, but not unreasonably so in the light of the fact that the model does not include non-traded goods.

Having predicted import shares using (30) and (31), equation (26) can be used to predict inflation, and these predictions can be compared with the multilateral PPP prediction given by (25). Note that within-sample GDP shares are used to construct the PPP prediction, as this is consistent with the approach used to predict import shares of absorption.

Table 2 reports for each of the sample countries the mean and standard deviation of actual absorption inflation, the gravity prediction of inflation and the multilateral PPP prediction. In all cases, the standard deviation of the gravity prediction is close to the standard deviation of actual inflation while the standard deviation of the PPP prediction is considerably higher.

Table 3 reports the bias and root mean squared error of the gravity and multilateral PPP predictions relative to actual inflation in the absorption price deflator. The gravity prediction is less biased than the PPP prediction in all but two cases. It has a lower root mean squared error in all cases. On average, the root mean squared error of the gravity prediction is one quarter of the root mean squared error of the PPP prediction. The reason for this can be seen in Figures 1 to 25, which plot for each country the time series of actual inflation, the multilateral PPP prediction and the gravity prediction. The gravity prediction does a good job of tracking the movements of actual inflation, especially for large, relatively closed economies. This is in strong contrast with the multilateral PPP prediction.[5]

From these baseline results, it is clear that specialization in production and costly trade have the ability to reconcile volatile exchange rates with relatively stable inflation. This contrasts with the poor performance of the multilateral counterpart of PPP. The robustness of these results is now explored.

[5] For small countries such as Iceland and Ireland, the gravity prediction is not as strikingly successful. For Iceland, this is due to the poor performance of the gravity equation in predicting bilateral imports. For Ireland it is at least partly explained by mismeasurement of value added shares of absorption. In Ireland in 2000, imports were 97.8% of GDP, implying that a large fraction of imported value added must have been re-exported rather than absorbed domestically.

5.1 Robustness

The literature on exchange rate disconnect and real exchange rates generally tries to explain consumer price inflation rather than absorption price inflation. To check the robustness of the results to the use of the absorption price deflator, Table 2 reports also the mean and standard deviation of consumer price inflation. Table 4 reports the bias and root mean squared error of the different predictions relative to consumer price inflation rather than absorption price inflation. In general, the mean and standard deviation of the CPI are close to the mean and standard deviation of absorption price inflation. Hence the gravity prediction also performs well in predicting the CPI, though it is perhaps marginally less successful than in the case of absorption prices.

Instead of using the shares predicted by a gravity equation, actual within-sample import shares can be used to predict inflation. While comparing this prediction with actual inflation is not as strong a test of the model as looking at the gravity prediction, the comparison is nonetheless informative. Table 2 reports the mean and standard deviation of the actual import weighted prediction. Table 3 reports its bias and root mean squared error relative to absorption price inflation and Table 4 reports its bias and root mean squared error relative to consumer price inflation. Using actual rather than predicted shares results in an improved prediction of the moments inflation for most countries. This is not surprising given the extreme parsimony of the gravity model used to predict consumption shares.

Finally, the multilateral PPP inflation prediction is an innovation with respect to the previous literature. To check robustness, three conventional bilateral PPP predictions of inflation are constructed, i.e. the inflation that would be predicted if PPP held with the US, with Germany, or with Japan. Table 2 reports the first and second moments of these bilateral PPP predictions of inflation. Table 3 reports their bias and root mean squared error relative to absorption price inflation. Table 4 reports their bias and root mean squared error relative to CPI inflation. The relative perfomance of the gravity prediction is even more striking when compared with the bilateral PPP predictions of inflation instead of the multilateral PPP prediction. With the exception of cases where countries are close trading partners (e.g. Canada and the US, the Netherlands and Germany) conventional PPP hugely overpredicts the volatility of inflation.

5.2 What is driving disconnect?

Finally, the empirical importance of the three mechanisms described in section 4 in explaining exchange rate disconnect is explored.

I. The size of consumption shares

The relative importance of home bias and the correlation of trade patterns and exchange rate volatility can be examined by constructing a hybrid "prediction" of inflation. This prediction uses the home bias predicted by the gravity model to weight the domestic contribution to inflation, but GDP shares to weight individual foreign contributions:

$$\Delta \ln API_{it} = \frac{\widehat{IM_{iit}}}{ABS_{it}} \Delta \ln PPI_{it} + \left(1 - \frac{\widehat{IM_{iit}}}{ABS_{it}}\right) \sum_{k=1,k\neq i}^{N} \frac{GDP_{kt}}{GDP_t^W - GDP_{it}} \left[\Delta \ln E_{ikt} + \Delta \ln PPI_{kt}\right]$$

Average actual and predicted domestic shares in absorption over the period 1971-2000 are reported in Table 5. The mean and standard deviation of this hybrid *home bias* prediction are reported in Table 2. Bias and root mean squared error with respect to absorption price inflation are reported in Table 3.

The home bias prediction does less well on average at matching the standard deviation of actual inflation than does the straight gravity prediction. The gap is greatest for small open economies with a strongly asymmetric pattern of trade, such as Austria, Belgium, Ireland and Switzerland. Unlike the gravity prediction, the home bias prediction does not take account of the geographically skewed pattern of imports of these countries. Figures 26 and 27 illustrate why this results in a prediction of higher volatility. Figure 26 shows a scatter plot of the variance of exchange rate depreciation (the variance of $100.\Delta \ln E_{ikt}$) against the average share of bilateral imports in absorption (the average of IM_{ijt}/ABS_{it}) for all country-pairs excluding own-country pairs. Figure 27 shows the same plot, but with the average of the share of bilateral imports in absorption predicted by the gravity model on the x-axis. Clearly, bilateral exchange rate volatility and bilateral imports are negatively correlated, and the estimated gravity model captures this. By failing to pick up this effect, the home bias prediction overpredicts the volatility of inflation for open economies with asymmetric trade.

However it is clear that the greater part of the gap between the standard deviation of the PPP prediction of inflation and the standard deviation of actual inflation is bridged by the assumption of home bias. Together with the variance decomposition, this indicates that home bias plays a crucial role in explaining the success of the gravity-weighted inflation prediction while the negative correlation of bilateral imports and exchange rate volatility plays a lesser role. The importance of home bias is reinforced by performing a decomposition of the variance of the gravity prediction of inflation into domestic and foreign contributions. The gravity prediction (26) can be decomposed as follows:

$$\Delta \ln API_{it} = \frac{\widehat{IM_{iit}}}{ABS_{it}} \Delta \ln PPI_{it} + \sum_{k=1, k \neq i}^{N} \frac{\widehat{IM_{ikt}}}{ABS_{it}} \left[\Delta \ln E_{ikt} + \Delta \ln PPI_{kt} \right]$$

The overall variance is the sum of the variance of the domestic contribution, the variance of the foreign contribution, and (two times) the covariance of the domestic and foreign contributions. Table 5 reports this decomposition in terms of percentages of the variance of the overall prediction. It is clear that for all but the smallest and most open of countries, the foreign contribution to predicted inflation variance is well below 50%, despite the fact that most bilateral exchange rates are much more volatile than inflation.

II. The variability of consumption shares

Table 2 reports the mean and standard deviation of the inflation prediction obtained using the average of predicted import shares over the period 1971-2000:

$$\Delta \ln API_{it} = \sum_{k=1}^{N} \overline{\frac{\widehat{IM_{ik}}}{ABS_i}} \left[\Delta \ln E_{ikt} + \Delta \ln PPI_{kt} \right]$$

The bias and root mean squared error of this prediction relative to absorption price inflation are reported in Table 3. This prediction performs about as well as the gravity prediction, which allows shares to vary year by year. The fact that the gravity prediction allows import shares to vary with relative prices plays little role in explaining its success in predicting inflation. At best this suggests a very limited role for a non-unitary elasticity of substitution in influencing the effect of exchange rate variability on inflation.

To sum up, the evidence suggests that empirically, home bias plays a very important role in explaining disconnect. The negative correlation of bilateral imports and exchange rate volatility plays a more limited role for some countries. Endogenous changes in value shares with respect to relative price changes does not appear to be important.

6 Further implications of the model for empirical work

The theoretical framework presented in this paper has important implications for how empirical work on exchange rates is conducted. The results in section 3.1 strongly suggest that empirical researchers should be careful in how they implement and interpret empirical tests based on bilateral exchange rates. In a multi-country world, bilateral exchange rates depend on prices and exchange rates against all countries as shown by equation (22). An additional implication of the model is that bilateral exchange rates depend on multilateral fundamentals.[6] This dependence may induce persistence in bilateral exchange rates. Furthermore, first-generation panel unit root tests of the type frequently used in the empirical exchange rate literature may not be robust to this form of cross-sectional dependence [see O'Connell (1998)].

A further implication of the gravity model is that multilateral exchange rates should be constructed to take account of the fact that some of domestic output is absorbed domestically. The importance of home bias explains at least partly why PPP tests that use standard trade-weighted exchange rates (which ignore trade with self) yield similar results to tests using bilateral exchange rates. In failing to capture home bias, these exchange rates ignore a crucial mechanism that insulates domestic inflation rates from the effect of exchange rate volatility.

The gravity model has the potential to explain a number of empirical exchange rate puzzles that go beyond the disconnect puzzle. The explicit modelling of multilateral exchange rates can explain the sensitivity of tests for purchasing power parity to the choice of numeraire currency. Trade costs induce asymmetric trade patterns, and as shown in equation (22), bilateral real exchange rates depend on this asymmetry. But the asymmetry is different for different choices of numeraire currency. In particular, where the country of interest and the numeraire country have similar trade patterns and low bilateral exchange rate volatility with each other, it will look more like purchasing power parity holds between them. On the other hand, if the country of interest and the numeraire country have very different trade patterns and high exchange rate volatility with each other, real exchange rates will tend to be volatile and persistent. This is exactly what we observe in comparing results that use the US and Germany as alternative numeraires [Papell and Theodoridis (2001)]. It also explains why

[6] Further details available from the author.

purchasing power parity is less likely to be rejected for country-pairs that are close together than for country-pairs that are distant [Engel and Rogers (1995)].

The model is also able to reconcile estimates of exchange rate pass-through that differ across categories of goods and countries. At the border, pass-through into import prices appears to be rapid [Campa and Goldberg (2004b)]. However pass-through into aggregate prices as reflected by the CPI or other measures is much slower, as documented by a very extensive literature. This is entirely consistent with the model, where there is instantaneous pass-through into import prices, but potentially very small effects of exchange rates changes on overall inflation. The model can in addition explain why pass-through appears more rapid for countries with high inflation. For these countries, exchange rate behavior is driven almost entirely by the same factors that drive domestic inflation.

The model is in addition perfectly consistent with the observation that the law of one price appears to fail for traded goods in much the same way as it fails for non-traded goods [Engel (1999)]. For most goods that are nominally traded, the imported component of value added is in fact relatively small [See Burstein et al (2001) and Campa and Goldberg (2004a)]. Conversely, final goods and services may be produced using imported intermediate inputs, so the traded - non-traded distinction is not very useful for final goods.

Further evidence that the model captures important features of the relationship between exchange rates and prices is presented by Honohan and Lane (2003). They find that differences in inflation rates between countries in the Euro zone can be explained by differences in their relative propensities to trade with the US interacted with the movement of the US dollar against the Euro.

7 Conclusion

The substantial volume of gross trade that we observe is a strong indication that specialization is empirically important. In addition, empirical gravity equations provide evidence that trade costs are large, and can explain the pattern of within-period trade flows. This paper makes two contributions to the literature on exchange rates. The first is to show how a tractable multi-country model of specialization and costly trade can provide a framework for analyzing multilateral exchange rates. The second contribution of the paper is to show that this model can explain both theoretically and empirically why inflation is generally stable despite the enormous volatility of bilateral exchange rates. The crucial mechanism is that specialization breaks the close link between the price of domestic output and imports. Meanwhile, trade costs skew domestic absorption towards domestic output, where the exchange rate is always fixed. This explanation for exchange rate disconnect has the advantage that it does not rely in any way on sticky prices, and is consistent with the different responses of border prices and the CPI to exchange rate changes.

While the model can reconcile volatile exchange rates with stable inflation, it does not explain *why* exchange rates are so volatile in the first place. This would require a dynamic model with intertemporal as well as intratemporal trade, which is beyond the scope of this paper. However, by showing that due to specialization and trade costs, substantial exchange rate volatility need not affect inflation, it is made clear that the economic forces that dampen this volatility are weak. In addition, the theoretical results have important implications for how empirical work on exchange rates is conducted, and have the potential to explain a number of empirical exchange rate puzzles that go beyond the disconnect puzzle.

A Import shares under costly trade

The value share of country j in i's consumption can be expressed as

$$\frac{v_j P(j)_i C(j)_i}{P_i C_i} = \frac{IM_{ji}}{GDP_i} = v_j P(j)_j^{1-\eta} (t_{ij}/P_i)^{1-\eta} \tag{32}$$

The expression for the total value of j's output, which is equal to the total value of its consumption, can be used to solve for $v_j P(j)_j^{1-\eta}$:

$$v_j P(j)_j^{1-\eta} = \frac{P_j C_j}{\sum_{k=1}^{N} (t_{jk}/P_k)^{1-\eta} P_k C_k} = \frac{GDP_j}{\sum_{k=1}^{N} (t_{jk}/P_k)^{1-\eta} GDP_k}$$

Let $\theta_k = GDP_k/GDP^W$ where GDP^W is world GDP. Substituting into (32) yields

$$\frac{IM_{ji}}{GDP_i} = \frac{(t_{ij}/P_i)^{1-\eta} \theta_j}{\sum_{k=1}^{N} (t_{jk}/P_k)^{1-\eta} \theta_k}$$

Define

$$\Pi_i^{1-\eta} = \sum_{k=1}^{N} (t_{ik}/P_k)^{1-\eta} \theta_k$$

Notice that

$$P_i^{1-\eta} = \sum_{k=1}^{N} (t_{ik}/\Pi_k)^{1-\eta} \theta_k$$

A solution to this system is $\Pi_k = P_k$.[7] This implies that

$$\frac{IM_{ji}}{GDP_i} = \frac{GDP_j}{GDP^W} \left(\frac{P_i P_j}{t_{ij}}\right)^{\eta-1}$$

B Unbalanced trade and asymmetric trade costs

The standard approach to iceberg costs is that when good x is produced in country i and shipped to country j

$$t_{ij} P(x)_i = E_{ij} P(x)_j$$

where $t_{ij} > 1$ if $i \neq j$ and $t_{ij} = t_{ji}$. Trade costs need not be symmetric. Tariffs and subsidies are the obvious example of this. To capture a potentially non-zero trade balance, distinguish between GDP_i, the value of i's production and ABS_i, the value of i's consumption. The value share of country j in country i's consumption is given by

$$\frac{IM_{ij}}{ABS_i} = \frac{v_j P(j)_i C(j)_i}{P_i C_i} = v_j \left(\frac{P(j)_i}{P_i}\right)^{1-\eta} = v_j P(j)_j^{1-\eta} \left(\frac{t_{ij}}{P_i}\right)^{1-\eta} \tag{33}$$

We know that j's GDP is equal to the sum of j's sales to all countries:

$$GDP_j = v_j \sum_{k=1}^{N} P(j)_k C(j)_k = v_j \sum_{k=1}^{N} \left(\frac{P(j)_k}{P_k}\right)^{1-\eta} ABS_k \tag{34}$$

Rearranging, this implies that

$$v_j P(j)_j^{1-\eta} = \frac{GDP_j}{\sum_{k=1}^{N} \left(\frac{t_{kj}}{P_k}\right)^{1-\eta} ABS_k} \tag{35}$$

[7] Imposing this solution is equivalent to imposing the normalization that $P_i = 1\ \forall i$ when all trade costs are zero. See Anderson and Van Wincoop (2003a) for a more detailed exposition of this.

Substituting in to the expression for j's share of i's consumption, and dividing top and bottom by GDP^W yields[8]

$$\frac{IM_{ij}}{ABS_i} = \frac{\frac{GDP_j}{GDP^W} t_{ij}^{1-\eta}}{P_i^{1-\eta} \sum_{k=1}^{N} \left(\frac{t_{kj}}{P_k}\right)^{1-\eta} \frac{ABS_k}{GDP^W}} \tag{36}$$

Note that the term $\sum_{k=1}^{N} \left(\frac{t_{kj}}{P_k}\right)^{1-\eta} \frac{ABS_k}{GDP^W} = \Pi_j^{1-\eta}$ depends only on j, not on i. Also

$$P_i = \left[\sum_{j=1}^{N} \frac{GDP_j}{GDP^W} \left(\frac{t_{ij}}{\Pi_j}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

Now $P_i = \Pi_i$ is not a solution. But we still have an equation that looks like the standard gravity equation:

$$IM_{ij} = \frac{ABS_i GDP_j t_{ij}^{1-\eta}}{GDP^W \Theta_i \Phi_j} \tag{37}$$

where Θ_i is an importer fixed effect, and Φ_j is an exporter fixed effect.

[8] World GDP is introduced for consistency with the standard gravity formulation.

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Figure 1: Australia

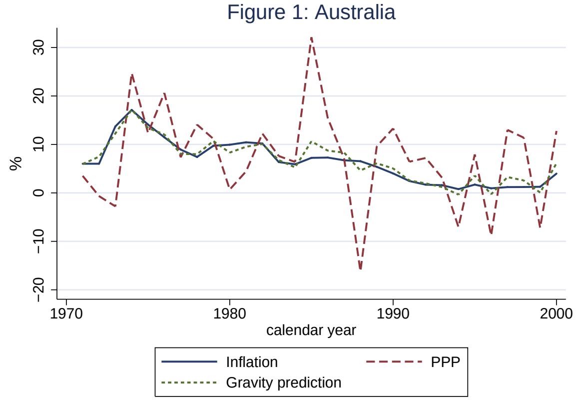


Figure 2: Austria

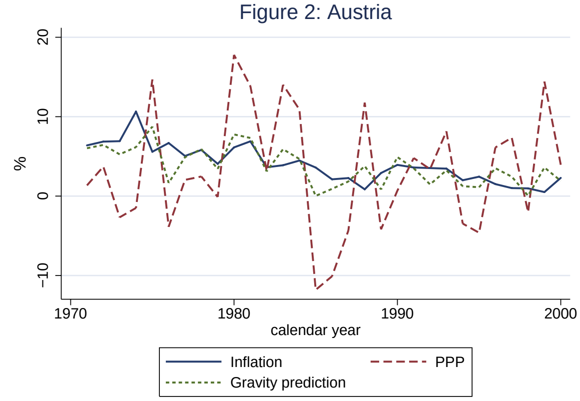


Figure 3: Belgium

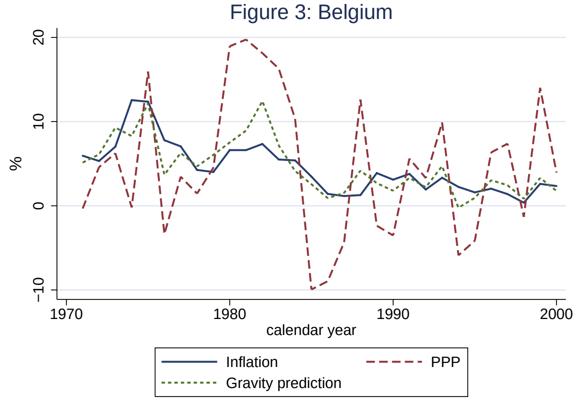


Figure 4: Canada

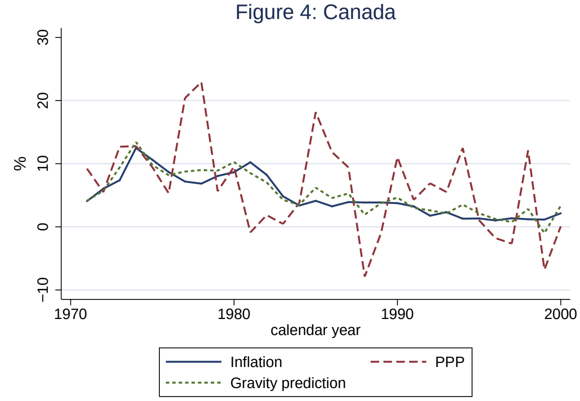


Figure 5: Denmark

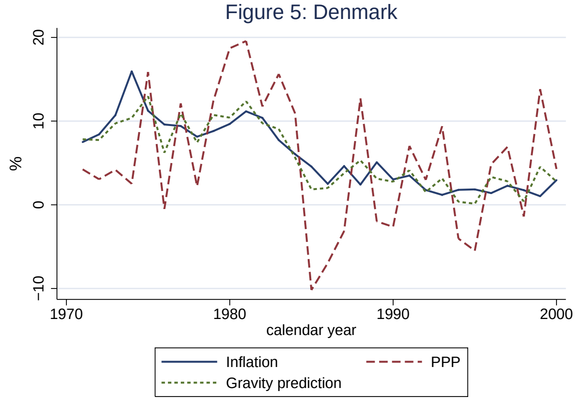


Figure 6: Finland

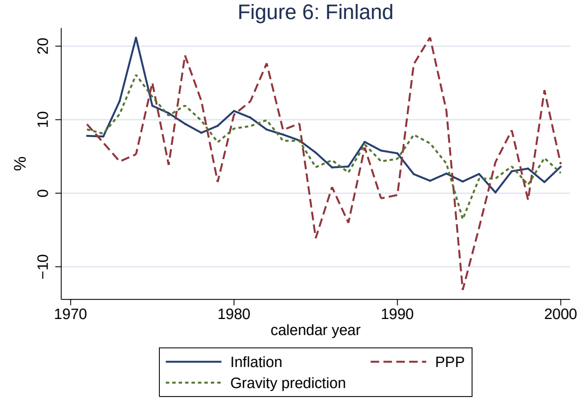


Figure 7: France

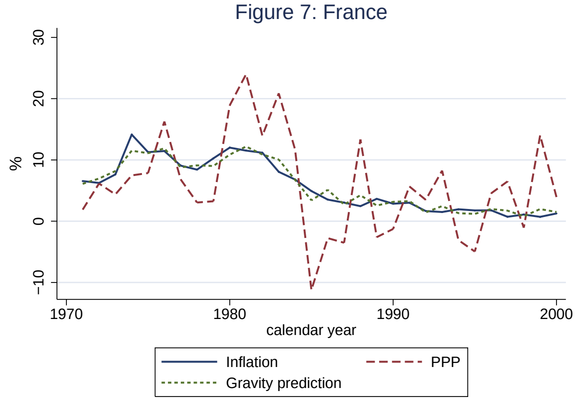


Figure 8: Germany

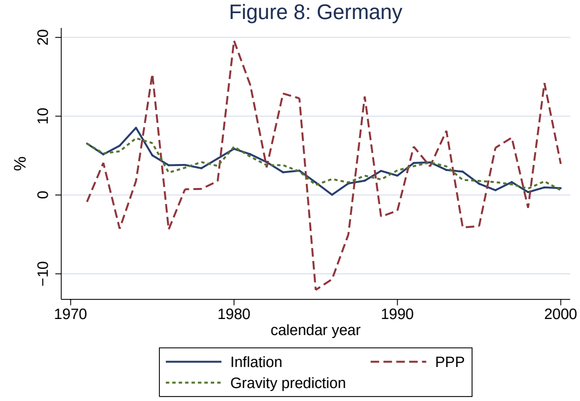


Figure 9: Greece

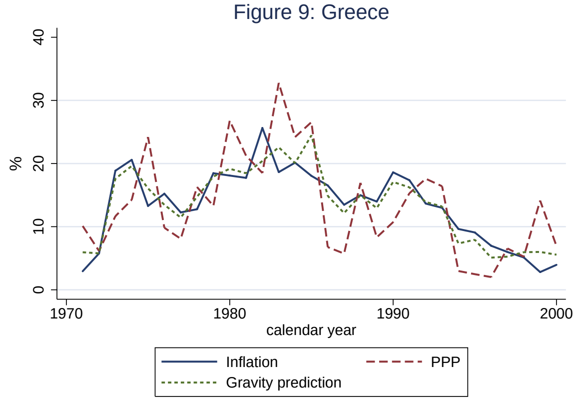


Figure 10: Iceland

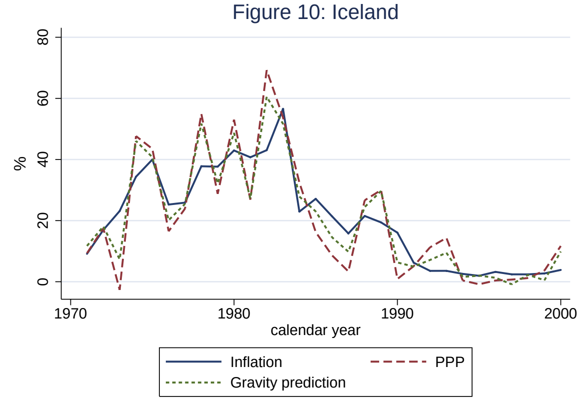


Figure 11: Ireland

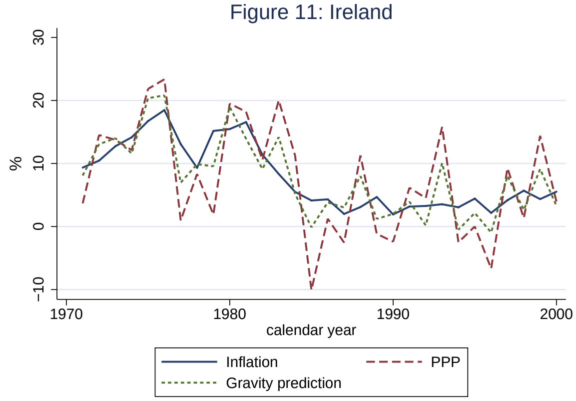


Figure 12: Italy

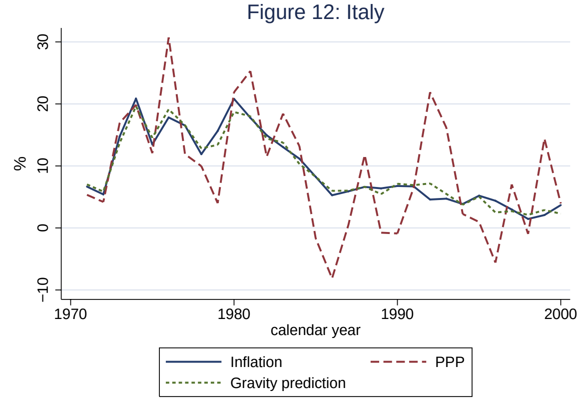


Figure 13: Japan

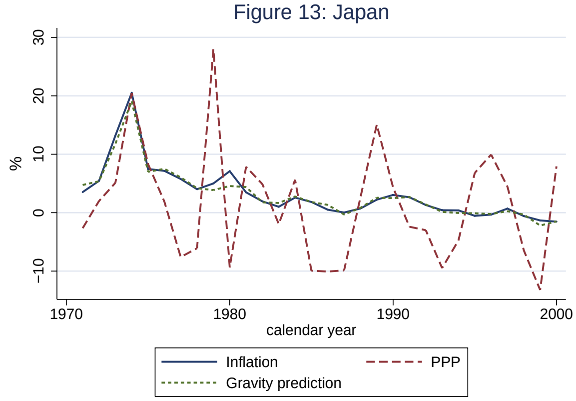


Figure 14: Korea

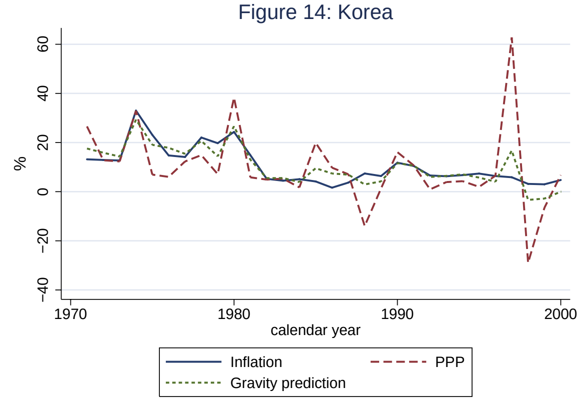


Figure 15: Mexico

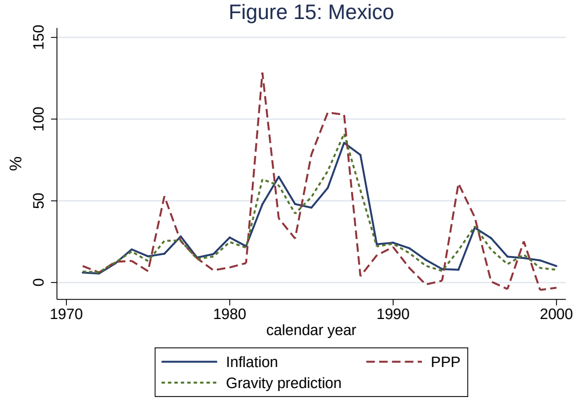


Figure 16: Netherlands

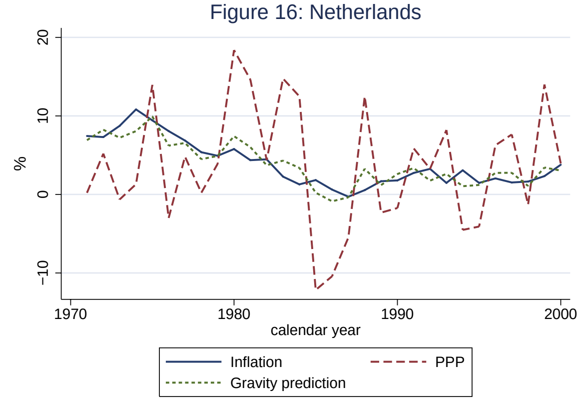


Figure 17: New Zealand

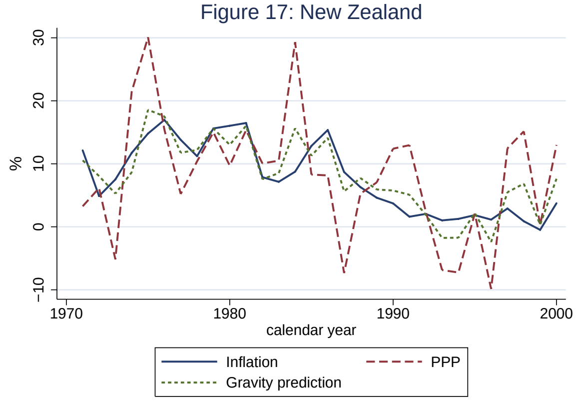


Figure 18: Norway

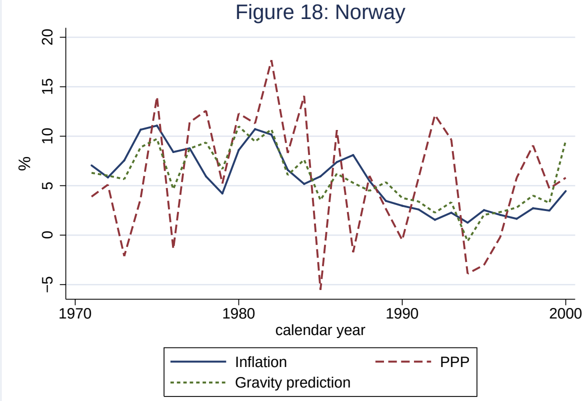


Figure 19: Portugal

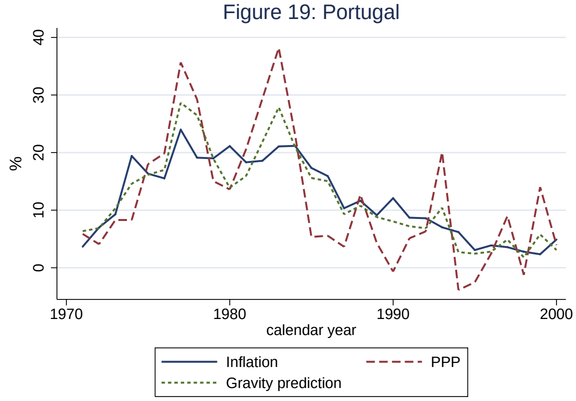


Figure 20: Spain

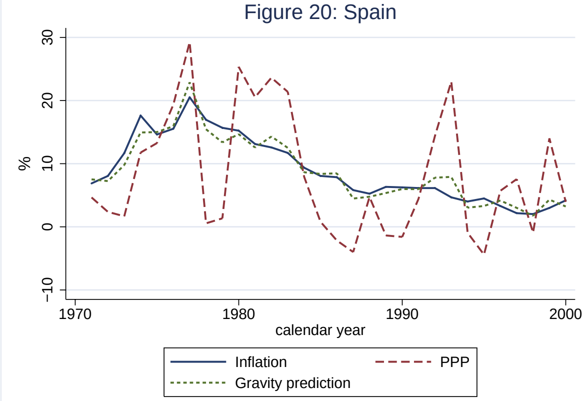


Figure 21: Sweden

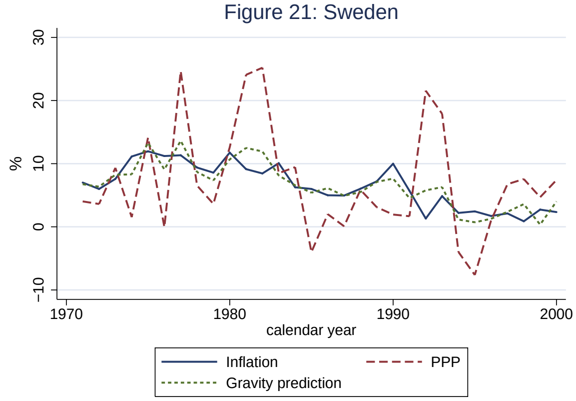


Figure 22: Switzerland

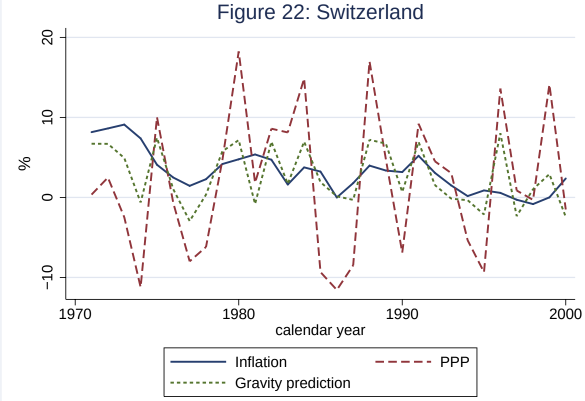


Figure 23: Turkey

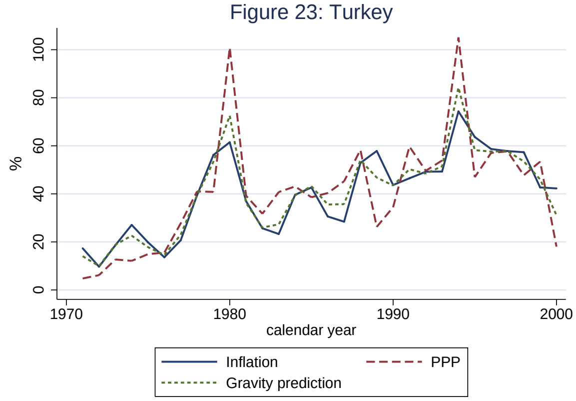
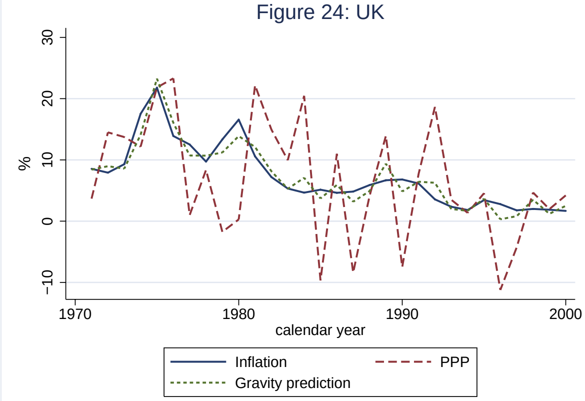


Figure 24: UK



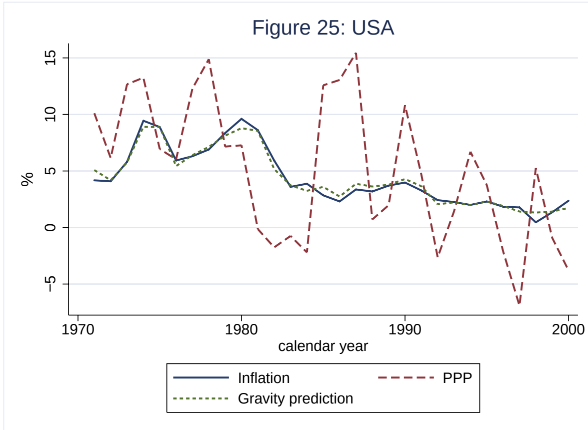


Figure 25: USA
%
calendar year
Inflation
PPP
Gravity prediction

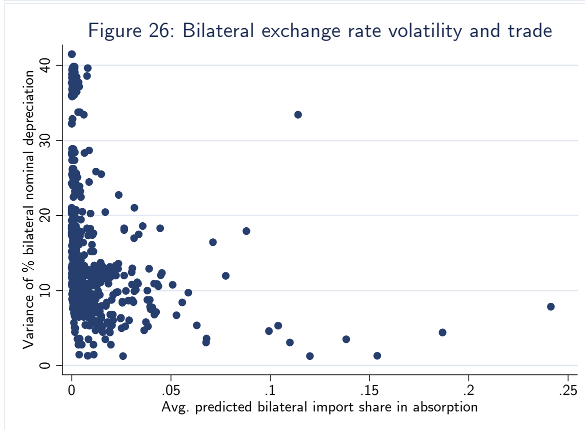


Figure 26: Bilateral exchange rate volatility and trade
Variance of % bilateral nominal depreciation
Avg. predicted bilateral import share in absorption

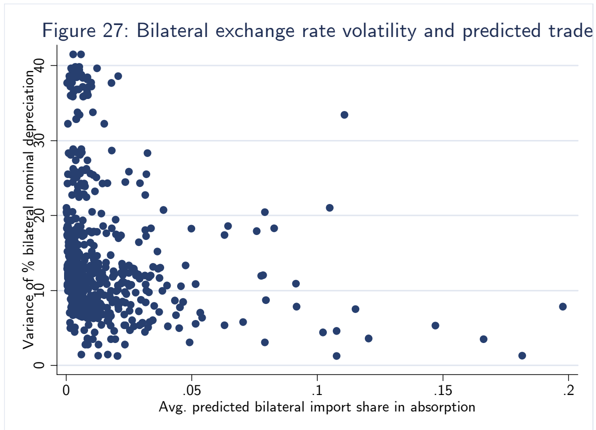


Figure 27: Bilateral exchange rate volatility and predicted trade
Variance of % bilateral nominal depreciation
Avg. predicted bilateral import share in absorption

Table 1: Estimates of the gravity equation

Year	Ln(1+distance)		Not contiguous		No common lang.		Not former colony		Not same country		Constant		Pseudo-R2
1971	-0.42	(0.08)**	-0.86	(0.19)**	-0.55	(0.14)**	-0.77	(0.23)**	0.33	(0.58)	10.46	(0.03)**	0.99
1972	-0.41	(0.08)**	-0.88	(0.20)**	-0.53	(0.14)**	-0.65	(0.23)**	0.18	(0.58)	10.51	(0.03)**	0.99
1973	-0.44	(0.08)**	-0.80	(0.19)**	-0.53	(0.15)**	-0.54	(0.24)*	0.26	(0.57)	10.75	(0.03)**	0.99
1974	-0.46	(0.08)**	-0.75	(0.18)**	-0.52	(0.15)**	-0.44	(0.24)	0.47	(0.57)	11.12	(0.03)**	0.99
1975	-0.47	(0.08)**	-0.75	(0.19)**	-0.51	(0.15)**	-0.42	(0.28)	0.36	(0.60)	11.12	(0.03)**	0.99
1976	-0.48	(0.08)**	-0.77	(0.18)**	-0.51	(0.15)**	-0.33	(0.25)	0.39	(0.58)	11.15	(0.04)**	0.99
1977	-0.48	(0.08)**	-0.75	(0.18)**	-0.52	(0.14)**	-0.26	(0.25)	0.37	(0.57)	11.24	(0.03)**	0.99
1978	-0.46	(0.08)**	-0.75	(0.18)**	-0.51	(0.14)**	-0.18	(0.26)	0.14	(0.57)	11.31	(0.03)**	0.99
1979	-0.49	(0.08)**	-0.68	(0.18)**	-0.51	(0.15)**	-0.10	(0.25)	0.32	(0.57)	11.42	(0.03)**	0.99
1980	-0.48	(0.08)**	-0.68	(0.16)**	-0.49	(0.13)**	0.02	(0.23)	0.15	(0.54)	11.59	(0.03)**	0.99
1981	-0.47	(0.07)**	-0.71	(0.16)**	-0.52	(0.13)**	0.19	(0.20)	-0.04	(0.53)	11.74	(0.03)**	0.99
1982	-0.49	(0.07)**	-0.69	(0.15)**	-0.48	(0.13)**	0.22	(0.22)	0.01	(0.53)	11.82	(0.03)**	0.99
1983	-0.49	(0.08)**	-0.68	(0.16)**	-0.49	(0.14)**	0.37	(0.21)	-0.09	(0.54)	11.64	(0.03)**	0.99
1984	-0.47	(0.08)**	-0.67	(0.17)**	-0.54	(0.14)**	0.44	(0.22)*	-0.12	(0.55)	11.67	(0.04)**	0.99
1985	-0.50	(0.08)**	-0.65	(0.16)**	-0.53	(0.14)**	0.34	(0.21)	0.14	(0.55)	11.64	(0.04)**	0.99
1986	-0.47	(0.08)**	-0.70	(0.17)**	-0.47	(0.14)**	0.30	(0.21)	-0.16	(0.55)	11.69	(0.04)**	0.99
1987	-0.48	(0.08)**	-0.65	(0.16)**	-0.46	(0.13)**	0.28	(0.22)	-0.09	(0.53)	11.84	(0.04)**	0.99
1988	-0.47	(0.07)**	-0.67	(0.15)**	-0.46	(0.13)**	0.36	(0.21)	-0.19	(0.52)	12.05	(0.04)**	0.99
1989	-0.49	(0.07)**	-0.67	(0.15)**	-0.45	(0.13)**	0.39	(0.22)	-0.07	(0.52)	12.24	(0.04)**	0.99
1990	-0.49	(0.07)**	-0.65	(0.14)**	-0.46	(0.13)**	0.38	(0.21)	-0.08	(0.51)	12.25	(0.04)**	0.99
1991	-0.49	(0.07)**	-0.68	(0.15)**	-0.43	(0.14)**	0.46	(0.22)*	-0.18	(0.52)	12.22	(0.04)**	0.99
1992	-0.49	(0.07)**	-0.70	(0.15)**	-0.45	(0.14)**	0.44	(0.22)	-0.16	(0.52)	12.18	(0.04)**	0.99
1993	-0.42	(0.08)**	-0.79	(0.17)**	-0.50	(0.15)**	0.49	(0.23)*	-0.64	(0.53)	12.18	(0.04)**	0.99
1994	-0.43	(0.08)**	-0.79	(0.18)**	-0.50	(0.16)**	0.50	(0.25)*	-0.53	(0.53)	12.26	(0.04)**	0.99
1995	-0.43	(0.08)**	-0.80	(0.19)**	-0.45	(0.16)**	0.46	(0.24)	-0.42	(0.52)	12.40	(0.05)**	0.99
1996	-0.42	(0.08)**	-0.84	(0.20)**	-0.45	(0.17)**	0.45	(0.25)	-0.42	(0.52)	12.50	(0.05)**	0.99
1997	-0.42	(0.07)**	-0.88	(0.19)**	-0.47	(0.17)**	0.54	(0.23)*	-0.40	(0.49)	12.41	(0.05)**	0.99
1998	-0.41	(0.07)**	-0.92	(0.19)**	-0.45	(0.17)**	0.59	(0.21)**	-0.48	(0.47)	12.39	(0.06)**	0.99
1999	-0.44	(0.07)**	-0.92	(0.19)**	-0.48	(0.17)**	0.55	(0.21)**	-0.19	(0.46)	12.41	(0.06)**	0.99
2000	-0.47	(0.07)**	-0.90	(0.18)**	-0.50	(0.17)**	0.39	(0.22)	0.37	(0.45)	12.37	(0.07)**	0.99

Dependent variable is bilateral imports. Estimation method is pseudo-maximum likelihood (Poisson regression)

Robust standard errors in parentheses; * significant at 5%; ** significant at 1%

Table 2A: Mean and Standard Deviation of Inflation and Inflation Predictions

	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
	Australia		Austria		Belgium		Canada		Denmark	
Absorption inflation	6.38	4.37	4.00	2.34	4.46	3.05	4.87	3.23	5.88	4.00
Gravity share pred.	6.42	4.41	3.61	2.43	4.45	3.32	5.09	3.46	5.59	3.95
Multilateral PPP pred.	7.16	9.87	3.10	7.47	4.46	8.30	6.18	7.43	5.12	7.83
PPP with US pred.	6.70	10.32	2.50	12.34	3.91	13.31	5.68	5.09	4.59	12.56
PPP with Ger. pred.	7.47	15.23	3.27	2.13	4.68	4.38	6.45	13.49	5.36	4.65
PPP with Japan pred.	9.37	13.34	5.18	11.57	6.59	11.73	8.36	14.18	7.27	11.34
Home Bias pred.	6.60	4.27	3.63	4.41	4.62	5.16	5.25	3.47	5.75	4.74
Avg. gravity share pred.	6.36	4.38	3.52	2.43	4.41	3.35	5.08	3.46	5.52	3.92
Actual share pred.	6.42	4.36	3.66	2.13	4.52	3.51	5.12	3.34	5.60	3.80
CPI inflation	6.63	3.97	3.94	2.25	4.53	3.10	5.15	3.29	5.75	3.65
	Finland		France		Germany		Greece		Iceland	
Absorption inflation	6.59	4.45	5.68	4.16	3.30	2.04	13.45	5.93	20.34	15.73
Gravity share pred.	6.33	4.17	5.56	4.00	3.25	1.89	13.11	6.17	19.86	17.99
Multilateral PPP pred.	6.27	8.03	5.67	8.10	3.13	7.77	12.97	8.23	19.63	20.04
PPP with US pred.	5.78	11.97	5.16	12.81	2.53	12.77	12.70	11.24	19.58	22.47
PPP with Ger. pred.	6.55	7.74	5.93	5.99	n.a.	n.a.	13.47	8.22	20.36	19.17
PPP with Japan pred.	8.46	12.96	7.84	12.19	5.20	11.43	15.38	13.01	22.26	21.61
Home Bias pred.	6.55	4.48	5.71	4.20	3.34	2.18	13.47	5.97	20.34	18.39
Avg. gravity share pred.	6.27	4.17	5.53	4.00	3.20	1.91	13.10	6.12	19.76	18.18
Actual share pred.	6.30	4.18	5.52	3.97	3.24	1.88	13.11	6.17	19.75	16.05
CPI inflation	6.33	4.45	5.67	4.05	3.31	1.96	12.83	6.89	20.20	16.51
	Ireland		Italy		Japan		Korea		Mexico	
Absorption inflation	7.87	5.23	9.32	5.83	3.26	4.57	10.51	7.59	27.66	21.17
Gravity share pred.	7.47	6.24	8.97	5.77	3.02	4.22	10.07	8.03	26.40	21.79
Multilateral PPP pred.	7.18	8.80	8.79	9.56	1.24	9.47	9.37	15.82	26.33	34.67
PPP with US pred.	6.72	12.63	8.39	13.20	0.58	13.07	8.98	17.11	26.50	33.17
PPP with Ger. pred.	7.49	7.97	9.16	9.81	1.35	12.50	9.75	18.23	27.27	39.17
PPP with Japan pred.	9.40	13.51	11.06	14.39	n.a.	n.a.	11.66	19.02	29.18	37.80
Home Bias pred.	7.51	7.20	9.24	5.71	3.11	4.23	10.26	7.82	27.28	21.63
Avg. gravity share pred.	7.44	6.23	8.97	5.78	3.00	4.22	10.00	7.95	26.52	21.85
Actual share pred.	7.58	6.19	8.94	5.73	2.97	4.18	9.95	8.04	26.16	21.05
CPI inflation	7.57	5.84	8.60	5.43	3.82	4.58	8.70	6.70	27.43	21.62

Table 2B: Mean and Standard Deviation of Inflation and Inflation Predictions

	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
	Netherlands		New Zealand		Norway		Portugal		Spain	
Absorption inflation	3.89	2.96	7.75	5.69	5.59	3.06	12.04	6.81	8.97	5.21
Gravity share pred.	3.76	2.80	7.84	5.85	5.55	3.08	11.66	7.91	8.60	5.32
Multilateral PPP pred.	3.56	7.60	7.90	9.75	5.59	6.11	11.40	11.16	7.94	9.81
PPP with US pred.	2.97	12.61	7.47	12.78	5.08	10.19	11.08	14.07	7.51	13.74
PPP with Ger. pred.	3.74	2.56	8.24	11.01	5.85	6.83	11.85	10.91	8.28	9.05
PPP with Japan pred.	5.65	11.26	10.14	11.49	7.76	11.10	13.76	15.22	10.18	14.86
Home Bias pred.	3.86	3.71	8.07	5.76	5.67	3.60	11.91	8.15	8.87	5.33
Avg. gravity share pred.	3.68	2.76	7.66	5.80	5.53	3.14	11.69	7.95	8.56	5.32
Actual share pred.	3.78	2.85	7.74	5.71	5.59	3.15	11.60	7.36	8.65	5.28
CPI inflation	4.01	2.80	7.91	5.37	5.91	3.23	12.40	7.48	8.97	5.34
	Sweden		Switzerland		Turkey		UK		USA	
Absorption inflation	6.51	3.48	3.20	2.66	40.24	17.03	7.34	5.21	4.37	2.60
Gravity share pred.	6.40	3.71	2.60	3.64	39.10	18.94	7.06	5.27	4.24	2.54
Multilateral PPP pred.	6.88	8.49	1.77	8.63	39.47	24.18	6.43	9.64	4.90	6.26
PPP with US pred.	6.41	12.39	1.13	13.48	40.09	24.88	5.94	12.94	n.a.	n.a.
PPP with Ger. pred.	7.18	8.84	1.90	5.19	40.86	22.03	6.71	11.75	5.14	12.68
PPP with Japan pred.	9.08	12.97	3.81	11.35	42.76	26.48	8.62	12.83	7.04	12.98
Home Bias pred.	6.57	3.86	2.69	5.10	40.34	17.88	7.26	5.23	4.39	2.46
Avg. gravity share pred.	6.34	3.79	2.50	3.58	39.12	18.94	7.06	5.25	4.24	2.54
Actual share pred.	6.34	3.70	2.93	2.72	38.84	18.28	7.01	5.33	4.26	2.54
CPI inflation	6.13	3.69	3.37	2.51	40.40	18.26	7.39	5.14	4.96	2.91

Data is annual. Sample period is 1971-2000. All inflation rates and predictions are calculated as log changes. Absorption inflation is inflation in the absorption (C+I+G) deflator. Predictions of inflation are weighted averages of changes in bilateral exchange rates with and the GDP deflator in all 25 sample countries. The gravity share prediction uses import shares predicted by estimating a gravity equation as weights. The multilateral PPP prediction uses shares of within-sample GDP as weights. Bilateral PPP predictions have a weight of 1 on the US, Germany and Japan respectively, and a weight of zero on all other countries. PPP is relative to these countries' absorption inflation. The home bias prediction weights the own country with the own-import share predicted by the gravity equation and all other countries with shares of within-sample GDP (less own country GDP) multiplied by 1 minus home bias. The average gravity share prediction uses the average across 1971-2000 of the import shares predicted by the gravity equation as weights. The actual share prediction uses actual within-sample import shares as weights. Note that throughout, account is taken of countries imports from themselves. For details on data sources and construction, see the text.

Table 3A: Bias and RMSE of Inflation Predictions Compared to Absorption Inflation

	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE
	Australia		Austria		Belgium		Canada		Denmark	
Gravity share pred.	-0.26	1.31	0.28	1.98	-0.14	1.89	-0.39	1.28	0.11	1.88
Multilateral PPP pred.	-1.02	9.28	0.80	7.78	-0.16	7.77	-1.51	7.26	0.59	7.33
PPP with US pred.	-0.32	9.92	1.50	12.54	0.54	12.67	-0.81	4.66	1.29	12.12
PPP with Ger. pred.	-1.09	14.32	0.73	1.67	-0.23	3.60	-1.58	13.20	0.52	3.19
PPP with Japan pred.	-2.99	12.95	-1.18	11.41	-2.13	11.27	-3.48	14.25	-1.39	10.92
Home Bias pred.	-0.22	1.27	0.37	4.40	-0.16	4.26	-0.38	1.44	0.14	3.37
Avg. gravity share pred.	-0.19	1.16	0.36	2.04	-0.10	1.99	-0.37	1.24	0.18	1.92
Actual share pred.	-0.26	1.13	0.22	1.03	-0.22	2.25	-0.41	1.18	0.10	1.31
	Finland		France		Germany		Greece		Iceland	
Gravity share pred.	0.05	2.35	-0.06	1.00	-0.06	0.78	-0.09	2.21	-0.18	7.38
Multilateral PPP pred.	0.11	8.33	-0.18	6.99	0.07	7.59	0.05	6.61	0.06	10.73
PPP with US pred.	0.81	12.15	0.52	11.84	0.77	12.44	0.75	10.17	0.76	14.15
PPP with Ger. pred.	0.04	7.70	-0.25	4.44	n.a.	n.a.	-0.02	6.27	-0.01	10.78
PPP with Japan pred.	-1.87	13.08	-2.15	11.49	-1.91	11.22	-1.92	12.35	-1.92	13.49
Home Bias pred.	0.04	3.18	-0.03	1.75	-0.04	1.39	-0.02	2.69	0.00	8.15
Avg. gravity share pred.	0.11	2.34	-0.03	0.97	-0.01	0.81	-0.09	2.26	-0.08	7.71
Actual share pred.	0.08	1.28	-0.02	0.91	-0.05	0.85	-0.09	0.99	-0.07	2.90
	Ireland		Italy		Japan		Korea		Mexico	
Gravity share pred.	0.15	3.42	0.04	1.05	0.14	0.77	0.10	3.81	0.38	6.60
Multilateral PPP pred.	0.45	6.85	0.23	7.32	1.98	8.94	0.82	14.47	0.46	28.01
PPP with US pred.	1.15	10.87	0.93	11.33	2.68	12.95	1.53	15.90	1.16	26.51
PPP with Ger. pred.	0.38	6.06	0.16	7.84	1.91	11.22	0.75	16.90	0.39	33.28
PPP with Japan pred.	-1.52	12.30	-1.74	12.84	n.a.	n.a.	-1.15	17.72	-1.52	31.08
Home Bias pred.	0.36	4.75	0.08	1.38	0.15	0.77	0.24	3.62	0.38	6.71
Avg. gravity share pred.	0.19	3.37	0.04	1.05	0.16	0.76	0.17	3.73	0.25	6.59
Actual share pred.	0.04	3.31	0.08	1.03	0.19	0.81	0.23	3.96	0.63	4.30

Table 3B: Bias and RMSE of Inflation Predictions Compared to Absorption Inflation

	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE
	Netherlands		New Zealand		Norway		Portugal		Spain	
Gravity share pred.	0.01	1.36	-0.35	2.75	-0.14	1.92	-0.01	3.13	0.08	1.33
Multilateral PPP pred.	0.21	7.78	-0.42	8.77	-0.19	5.82	0.26	7.91	0.77	8.49
PPP with US pred.	0.92	12.62	0.28	12.36	0.51	10.07	0.96	11.66	1.47	12.90
PPP with Ger. pred.	0.14	1.86	-0.49	9.42	-0.26	6.43	0.19	7.94	0.70	7.21
PPP with Japan pred.	-1.76	11.14	-2.39	10.33	-2.17	10.55	-1.72	12.52	-1.21	13.52
Home Bias pred.	0.03	2.92	-0.32	2.88	-0.08	2.90	0.13	3.95	0.10	1.93
Avg. gravity share pred.	0.08	1.38	-0.17	2.55	-0.12	2.04	-0.04	3.17	0.13	1.43
Actual share pred.	-0.02	1.78	-0.25	1.82	-0.19	1.98	0.05	1.90	0.03	0.99
	Sweden		Switzerland		Turkey		UK		USA	
Gravity share pred.	-0.10	1.84	0.51	3.33	-0.17	4.80	0.05	1.65	-0.01	0.45
Multilateral PPP pred.	-0.60	8.20	1.37	8.89	-0.55	14.59	0.70	9.08	-0.70	5.84
PPP with US pred.	0.11	12.17	2.07	13.55	0.15	15.47	1.40	12.56	n.a.	n.a.
PPP with Ger. pred.	-0.67	8.60	1.30	5.06	-0.62	14.05	0.63	11.25	-0.77	12.44
PPP with Japan pred.	-2.57	12.62	-0.60	11.38	-2.53	21.19	-1.27	12.22	-2.68	12.95
Home Bias pred.	-0.06	2.44	0.52	4.93	-0.11	4.91	0.08	1.87	-0.02	0.57
Avg. gravity share pred.	-0.04	1.85	0.62	3.35	-0.19	4.46	0.05	1.62	-0.01	0.43
Actual share pred.	-0.04	1.69	0.18	1.96	0.10	2.26	0.10	1.96	-0.04	0.54

Data is annual. Sample period is 1971-2000. All inflation rates and predictions are calculated as log changes. Absorption inflation is inflation in the absorption (C+I+G) deflator. Predictions of inflation are weighted averages of changes in bilateral exchange rates with and the GDP deflator in all 25 sample countries. The gravity share prediction uses import shares predicted by estimating a gravity equation as weights. The multilateral PPP prediction uses shares of within-sample GDP as weights. Bilateral PPP predictions have a weight of 1 on the US, Germany and Japan respectively, and a weight of zero on all other countries. PPP is relative to these countries' absorption inflation. The home bias prediction weights the own country with the own-import share predicted by the gravity equation and all other countries with shares of within-sample GDP (less own country GDP) multiplied by 1 minus home bias. The average gravity share prediction uses the average across 1971-2000 of the import shares predicted by the gravity equation as weights. The actual share prediction uses actual within-sample import shares as weights. Note that throughout, account is taken of countries imports from themselves. For details on data sources and construction, see the text. Bias is mean prediction error. Root mean squared error (RMSE) is square root of the mean squared prediction error.

Table 4A: Bias and RMSE of Inflation Predictions Compared to CPI Inflation

	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE
	Australia		Austria		Belgium		Canada		Denmark	
Gravity share pred.	-0.01	1.95	0.22	1.92	-0.07	1.91	-0.11	1.69	-0.03	1.76
Multilateral PPP pred.	-0.77	9.17	0.74	7.45	-0.09	7.75	-1.23	7.42	0.45	7.00
PPP with US pred.	-0.67	10.03	0.84	12.28	0.01	12.79	-1.13	4.83	0.55	12.02
PPP with Ger. pred.	-0.85	14.25	0.67	1.87	-0.16	3.80	-1.30	13.35	0.38	3.42
PPP with Japan pred.	-3.31	13.23	-1.79	11.75	-2.62	11.68	-3.76	14.66	-2.08	11.08
Home Bias pred.	0.03	1.96	0.32	4.12	-0.09	4.28	-0.10	1.85	0.00	3.16
Avg. gravity share pred.	0.06	1.80	0.30	1.95	-0.03	2.00	-0.09	1.65	0.04	1.77
Actual share pred.	-0.01	1.79	0.17	1.09	-0.14	2.25	-0.13	1.54	-0.04	1.34
	Finland		France		Germany		Greece		Iceland	
Gravity share pred.	-0.21	2.17	-0.07	1.12	-0.05	0.96	-0.71	3.47	-0.32	7.54
Multilateral PPP pred.	-0.15	7.77	-0.19	6.83	0.08	7.50	-0.57	7.14	-0.08	10.59
PPP with US pred.	-0.05	11.70	-0.09	11.71	0.18	12.46	-0.47	11.09	0.02	13.84
PPP with Ger. pred.	-0.22	7.58	-0.27	4.89	n.a.	n.a.	-0.64	6.77	-0.16	11.14
PPP with Japan pred.	-2.68	13.05	-2.73	11.86	-2.46	11.68	-3.10	12.74	-2.62	13.75
Home Bias pred.	-0.21	2.89	-0.04	1.65	-0.04	1.39	-0.64	3.95	-0.14	8.10
Avg. gravity share pred.	-0.15	2.11	-0.04	1.10	-0.01	0.96	-0.71	3.53	-0.22	7.87
Actual share pred.	-0.17	1.52	-0.03	1.04	-0.04	1.00	-0.71	2.90	-0.21	3.66
	Ireland		Italy		Japan		Korea		Mexico	
Gravity share pred.	-0.15	4.06	-0.67	1.38	0.70	1.28	-1.71	5.19	0.15	7.20
Multilateral PPP pred.	0.15	7.07	-0.48	7.61	2.54	9.32	-0.99	15.18	0.23	28.38
PPP with US pred.	0.25	10.78	-0.38	11.50	2.64	13.26	-0.88	16.17	0.33	26.62
PPP with Ger. pred.	0.08	6.71	-0.56	8.36	2.46	11.68	-1.06	17.78	0.15	33.77
PPP with Japan pred.	-2.38	12.80	-3.02	13.43	n.a.	n.a.	-3.52	18.68	-2.31	31.55
Home Bias pred.	0.06	5.08	-0.63	1.58	0.71	1.27	-1.57	4.90	0.15	7.31
Avg. gravity share pred.	-0.11	3.99	-0.67	1.41	0.72	1.28	-1.64	5.06	0.02	7.29
Actual share pred.	-0.26	4.00	-0.63	1.27	0.75	1.33	-1.58	5.15	0.40	5.15

Table 4B: Bias and RMSE of Inflation Predictions Compared to CPI Inflation

	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE	Bias	RMSE
	Netherlands		New Zealand		Norway		Portugal		Spain	
Gravity share pred.	0.12	1.12	-0.19	3.88	0.17	1.98	0.35	3.39	0.08	1.24
Multilateral PPP pred.	0.33	7.39	-0.26	9.58	0.12	5.57	0.62	7.96	0.77	8.47
PPP with US pred.	0.43	12.41	-0.16	13.23	0.23	9.92	0.72	11.58	0.87	12.97
PPP with Ger. pred.	0.26	1.79	-0.33	9.81	0.05	6.67	0.55	7.71	0.69	7.41
PPP with Japan pred.	-2.20	11.26	-2.79	11.38	-2.41	10.78	-1.91	13.45	-1.77	13.93
Home Bias pred.	0.15	2.56	-0.16	3.97	0.24	2.78	0.50	4.30	0.10	1.86
Avg. gravity share pred.	0.20	1.15	-0.01	3.68	0.19	2.11	0.32	3.40	0.13	1.32
Actual share pred.	0.10	1.52	-0.09	3.01	0.13	2.12	0.42	2.63	0.04	0.78
	Sweden		Switzerland		Turkey		UK		USA	
Gravity share pred.	-0.48	2.08	0.68	3.66	-0.01	4.85	0.09	1.82	0.59	1.14
Multilateral PPP pred.	-0.97	8.12	1.54	9.07	-0.39	12.20	0.75	9.18	-0.10	6.00
PPP with US pred.	-0.87	12.19	1.64	13.76	-0.29	13.06	0.85	12.32	n.a.	n.a.
PPP with Ger. pred.	-1.05	8.83	1.46	5.57	-0.47	12.88	0.67	11.38	-0.18	12.46
PPP with Japan pred.	-3.51	12.94	-1.00	11.81	-2.93	18.64	-1.79	12.58	-2.64	13.26
Home Bias pred.	-0.44	2.55	0.68	5.13	0.06	4.56	0.13	2.02	0.58	1.24
Avg. gravity share pred.	-0.42	2.03	0.79	3.68	-0.03	4.33	0.10	1.79	0.59	1.14
Actual share pred.	-0.42	1.92	0.34	2.27	0.26	4.57	0.14	2.10	0.56	1.19

Data is annual. Sample period is 1971-2000. All inflation rates and predictions are calculated as log changes. Absorption inflation is inflation in the absorption (C+I+G) deflator. Predictions of inflation are weighted averages of changes in bilateral exchange rates with and the GDP deflator in all 25 sample countries. The gravity share prediction uses import shares predicted by estimating a gravity equation as weights. The multilateral PPP prediction uses shares of within-sample GDP as weights. Bilateral PPP predictions have a weight of 1 on the US, Germany and Japan respectively, and a weight of zero on all other countries. PPP is relative to these countries' consumer pric inflation. The home bias prediction weights the own country with the own-import share predicted by the gravity equation and all other countries with shares of within-sample GDP (less own country GDP) multiplied by 1 minus home bias. The average gravity share prediction uses the average across 1971-2000 of the import shares predicted by the gravity equation as weights. The actual share prediction uses actual within-sample import shares as weights. Note that throughout, account is taken of countries imports from themselves. For details on data sources and construction, see the text. Bias is mean prediction error. Root mean squared error (RMSE) is square root of the mean squared prediction error.

Table 5: Decomposition of Variance of the Gravity Inflation Prediction

	Foreign % of variance	Covariance % of variance	Home % of variance	Avg. predicted home bias	Avg. actual home bias
Australia	14	6	79	0.85	0.82
Austria	59	17	25	0.45	0.63
Belgium	50	27	23	0.44	0.35
Canada	17	8	75	0.79	0.71
Denmark	28	33	39	0.56	0.67
Finland	32	14	54	0.61	0.72
France	7	27	66	0.79	0.79
Germany	15	5	80	0.82	0.76
Greece	26	35	39	0.59	0.76
Iceland	69	27	4	0.20	0.64
Ireland	55	33	12	0.35	0.41
Italy	7	25	68	0.82	0.78
Japan	1	7	92	0.96	0.90
Korea	29	24	50	0.77	0.68
Mexico	14	33	53	0.77	0.83
Netherlands	19	18	63	0.64	0.48
New Zealand	33	16	51	0.66	0.71
Norway	38	4	58	0.58	0.63
Portugal	38	43	19	0.51	0.68
Spain	11	26	63	0.75	0.80
Sweden	30	13	57	0.69	0.69
Switzerland	81	5	14	0.45	0.66
Turkey	19	43	38	0.70	0.84
UK	12	16	72	0.81	0.73
USA	2	5	93	0.95	0.90

As described in the text, the gravity inflation prediction is the sum of domestic and foreign contributions. The variance of the prediction is the sum of the variance of the foreign contribution, the variance of the domestic contribution and twice the covariance of the domestic and foreign contributions. This decomposition is reported in percentages of the total variance. The sample period is 1971-2000. Columns may not sum to 100 due to rounding. Predicted home bias is the prediction from the gravity results in Table 1. Home bias averages are averages over 1971-2000.