Interdependence and Exchange Rates*

Doireann Fitzgerald†

UC-Santa Cruz

December 2003

Abstract

I use a multi-country general equilibrium trade model to illustrate how asymmetric relations between countries induce dependence of bilateral exchange rates on third-country fundamentals. I discuss the implications of asymmetry for standard empirical tests of bilateral models of equilibrium exchange rate determination. I demonstrate that third-country effects are present in real exchange rates from a sample of 25 OECD countries. I show that controlling for third-country fundamentals substantially improves the in-sample fit of a fundamentals-based empirical model of real exchange rates for these countries. At short horizons, it reduces the bias of out-of-sample forecasts of real exchange rates and also reduces the variance of out-of-sample forecast error.

JEL codes F12, F31

Keywords: Exchange rates, trade

1 Introduction

The empirical literature on testing equilibrium models of real and nominal exchange rate determination is vast. The conclusions of this literature have not materially changed since Frankel and Rose wrote in 1995: "We, like much of the profession, are doubtful of the value of further time-series modelling of exchange rates at high or medium frequencies using macroecomomic models." This paper takes the view that progress can still be made in the

*I would like to thank my advisors, Ken Rogoff, Elhanan Helpman and Greg Mankiw. I would also like to thank Manuel Amador, Juan Carlos Hallak, Philip Lane, Marc Melitz, David Papell, James Stock, Silvana Tenreyro and seminar participants at Chicago GSB, Harvard, the New York Fed, the San Francisco Fed, Stanford and UC-Santa Cruz for helpful comments and suggestions. All remaining errors are my own.

†Department of Economics, UC-Santa Cruz, Santa Cruz, CA 95064, dfitzger@ucsc.edu.

empirical modelling of exchange rate behavior by moving beyond the equilibrium models of the 1970s.

The first part of the paper uses a multi-country general equilibrium trade model to illustrate how asymmetric relations between countries induce dependence of bilateral exchange rates on third-country fundamentals. In this model, when trade in goods is costless, bilateral exchange rates (both real and nominal) depend on bilateral fundamentals alone, even when there is asymmetry in country size and bilateral distance. However when trade is costly, asymmetric trade relations and consumption patterns are induced, and bilateral real and nominal exchange rates depend on fundamentals in all countries. Simulations of a three-country version of the model indicate that the importance of third-country effects depends on the degree of asymmetry across countries. I discuss the implications of asymmetry for empirical tests of exchange rate determination, and argue that the standard bilateral approach may lead to inappropriate testing procedures. I argue further that third-country effects could potentially explain a number of features of previous empirical results, such as sensitivity to the choice of numeraire country that have not so far been well understood.

The second part of the paper uses annual data on 25 OECD countries to examine the extent to which third-country effects matter in the data. There are 300 bilateral exchange rates in the sample. In a clear majority of these cases, the productivity of third countries within the sample can explain a significant proportion of the residual variance in real exchange rates after bilateral productivity has been controlled for. This is true both in levels and in differences. This is clear evidence that the interdependence issue should be taken seriously in testing fundamentals-based models of equilibrium exchange rate determination.

The third part of the paper investigates whether taking interdependence into account can mitigate the puzzle referred to by Frankel and Rose: that fundamentals cannot explain or predict the medium-frequency behavior of exchange rates. I focus on real exchange rates. I do not find strong statistical evidence of an equilibrium long-run relationship between real exchange rates and productivity (as predicted by the model), whether or not third-country effects are controlled for. However, for certain pairs of countries where there is a good deal of asymmetry present, there is strong evidence that third-country fundamentals belong in any fundamentals-based model of real exchange rates. Additionally, adding third-country fundamentals to the standard bilateral model can improve forecasts of real exchange rates both in-sample and out of sample. In-sample, while the bilateral model is beaten by a random walk in 91% of the 300 cases investigated, in 51% of cases the model augmented to include third-country fundamentals can beat a random walk. At short horizons, controlling for third-country fundamentals systematically reduces the bias and forecast error variance of out-of-sample forecasts.

I conclude that asymmetric interdependence does not explain the many outstanding exchange rate puzzles. But there is strong evidence that it matters for exchange rate determination, and that it should be taken into account in estimating long-run relationships and in forecasting.

2 A trade model of exchange rate determination

This section presents a multi-country model, where production of goods is specialized due to a desire for variety and increasing returns in production. Equilibrium exchange rates are tied down by trade in goods. First, the case with costless trade is analyzed. In this case, irrespective of asymmetry in size, productivity and bilateral distance, trade and consumption are perfectly symmetric: the share of country i's trade accounted for by country j is the same as the share of country k's trade accounted for by country j for all i, j and k. This model is similar to that used by Anderson and van Wincoop (2003a) to investigate trade between multiple countries in general equilibrium. It is also related to the model presented by Eaton and Kortum (2002).

2.1 Costless trade

There are N countries, indexed $i = 1, \ldots, N$. No restrictions are placed on the distribution of country size or bilateral distances between countries. World labor supply is normalized to one, and country i has share s_i of the world labor force. Each country produces a number of varieties of a traded aggregate consumption good.[1] There is a potentially infinite number of varieties. Because of fixed costs of production of individual varieties, each country specializes in the production of a distinct set of traded goods, the number of which is endogenously determined.

I. Consumers

[1] The model is easily generalized to include a non-traded good, where preferences over the traded and non-traded goods are Cobb-Douglas.

Preferences are identical in each country. They are of the Dixit-Stiglitz form with elasticity of substitution η. Varieties are indexed by x and $C(x)_i$ is consumption of variety x in country i

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

The corresponding utility-consistent price index is

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

Given these preferences, demands for individual traded goods take the constant price-elasticity form

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

II. Producers

Labor is the only factor of production. Within country i, TFP is the same across all varieties. Country i produces v_i varieties, where the number of varieties is determined endogenously. Production functions have a fixed cost component in terms of labor (i.e. the fixed cost will not go to zero as productivity grows):

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

Producers maximize profits. They ignore the externalities from individual firm behavior on the overall price level. Given the constant-elasticity form of demand, this results in price being set equal to 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

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

Together with pricing behavior, this implies the following relationship between output of each variety and productivity:

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

In equilibrium, a country with traded-sector labor force s_i will then produce v_i traded varieties, where

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

III. Law of one price

The law of one price holds for all varieties:

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

and since preferences are identical, Purchasing Power Parity holds for the consumption aggregate:

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

IV. Internal 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

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

This is a static non-stochastic model, so 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

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

V. Money

In this one-period world, money is introduced by assuming a cash-in-advance constraint. Goods for consumption can only be purchased domestically, using domestic currency:

$$P_i C_i = M_i \tag{14}$$

V. Equilibrium

Market clearing for each individual traded good requires that the amount produced of variety x equals total world demand for that variety:

$$Y(x)_i = \sum_{k=1}^{N} \left(\frac{P(x)_k}{P_k} \right)^{-\eta} C_k \tag{15}$$

Substituting in for the firm first order condition and rearranging yields a first relationship between wages, traded sector productivity, and the price of the traded aggregate:

$$W_i^{\eta} A_i^{1-\eta} = \left[\frac{\eta}{\eta - 1} \right]^{1-\eta} \frac{1}{\alpha\eta} \sum_{k=1}^{N} s_k P_k^{\eta-1} W_k E_{ik}^{\eta} \tag{16}$$

This holds for all countries, so it also holds for country j:

$$(E_{ij} W_j)^{\eta} A_j^{1-\eta} = \left[\frac{\eta}{\eta - 1} \right]^{1-\eta} \frac{1}{\alpha\eta} \sum_{k=1}^{N} s_k P_k^{\eta-1} W_k E_{ik}^{\eta} \tag{17}$$

Hence, for all countries i and j relative wages depend on relative traded sector productivity, with an elasticity that depends on the elasticity of demand for a country's traded output:

$$\frac{W_i}{E_{ij} W_j} = \left(\frac{A_i}{A_j} \right)^{\frac{\eta-1}{\eta}} \tag{18}$$

Since PPP holds, the relative price level or real exchange rate between country i and country j is equal to 1.

Using (13) and the cash-in-advance constraint (14), it is possible to solve for the nominal exchange rate:

$$E_{ij} = \frac{M_i/s_i}{M_j/s_j} \left(\frac{A_j}{A_i} \right)^{\frac{\eta-1}{\eta}} \tag{19}$$

Nominal exchange rates depend on size-adjusted relative money supplies and on relative traded-sector productivity between country i and j.

Finally, the share of country j in i's total trade is given by

$$\frac{T_{ij}}{\sum_{\substack{h=1 \\ h \neq i}}^{N} T_{ih}} = \frac{Y_j}{\sum_{\substack{h=1 \\ h \neq i}}^{N} Y_h} \tag{20}$$

That is, the share of country j in i's total trade is the same as the share of country j in k's total trade. Trade relations betwen countries are symmetric. Consumption patterns are also symmetric: the share of country j in country i's consumption is given by

$$\frac{C_{ij}}{C_i} = \frac{Y_j}{\sum_{k-1}^{N} Y_k} \tag{21}$$

2.2 Trade costs and interdependence

Now, per unit trade costs are introduced.

I. Trade cost

There is an iceberg cost of trade, assumed to be increasing in the distance between countries. When this cost is non-zero, the prices of identical goods differ across countries. Different countries end up consuming different baskets of goods, because they face different relative prices. They will tend to trade more with countries that are closer to them. If good x is produced in country i, then the relationship between the price of the good in country i and any other country j is given by:

$$\left(1 + d_{ij}^{\gamma}\right) P\left(x\right)_i = E_{ij} P\left(x\right)_j \tag{22}$$

where d_{ij} is the distance between country i and country j, and γ is the elasticity of trade costs with respect to distance. The distance between a country and itself is always equal to zero, while the distance between any pair of countries is always greater than zero.

II. Consumers

The iceberg trade cost does not affect the consumer's problem. (1) to (3) hold as in the case without trade costs.

III. Producers

Trade costs result in relative prices for varieties differing across countries. However because of the iceberg form of the trade cost and the CES form of demand, the producer's problem is identical to the case without trade costs. (4) to (8) hold as in the case without trade costs.

IV. Internal market clearing and money

(11) to (14) hold as in the case without trade costs.

VI. Equilibrium

When it comes to market clearing for each individual traded variety, the fact that some amount of each variety "melts" must be taken into account. The physical quantity that is exported from the producer country is larger than the total physical quantity imported by all importing countries. The market clearing condition for variety x produced in country i is

$$Y(x)_i = \sum_{k=1}^{N} \left(\frac{P(x)_k}{P_k} \right)^{-\eta} C_k \left(1 + d_{ik}^{\gamma}\right) \tag{23}$$

Substituting in for the firm first order condition, rearranging and making use of transitivity of exchange rates yields an equilibrium relationship between wages, traded sector productivity, and the price of the traded aggregate for country j:

$$\left(E_{ij} W_j\right)^{\eta} A_j^{1-\eta} = \left[\frac{\eta}{\eta - 1}\right]^{1-\eta} \frac{1}{\alpha\eta} \sum_{k=1}^{N} s_k E_{ik} W_k \left(E_{ik} P_k\right)^{\eta-1} \left(1 + d_{jk}^{\gamma}\right)^{1-\eta} \tag{24}$$

Substitution into the traded price index yields a second equilibrium relationship beween wages, traded sector productivity and the price of the traded aggregate for country j

$$\left(E_{ij} P_j\right)^{1-\eta} = \left[\frac{\eta}{\eta - 1}\right]^{1-\eta} \frac{1}{\alpha\eta} \sum_{k=1}^{N} s_k A_k^{\eta-1} \left(E_{ik} W_k\right)^{1-\eta} \left(1 + d_{jk}^{\gamma}\right)^{1-\eta} \tag{25}$$

Using the triangular relationship between exchange rates and substituting (25) into (24) yields a system of equations the solution to which is the vector of relative wages:

$$\begin{aligned}
\left(E_{i1} W_1\right)^{\eta} A_1^{1-\eta} &= \sum_{k=1}^{N} \left[\frac{s_k E_{ik} W_k \left(1 + d_{1k}^{\gamma}\right)^{1-\eta}}{\sum_{h=1}^{N} s_h A_h^{\eta-1} \left(E_{ih} W_h\right)^{1-\eta} \left(1 + d_{kh}^{\gamma}\right)^{1-\eta}} \right] \\
\vdots \quad &= \quad \vdots \\
\left(E_{iN} W_N\right)^{\eta} A_N^{1-\eta} &= \sum_{k=1}^{N} \left[\frac{s_k E_{ik} W_k \left(1 + d_{Mk}^{\gamma}\right)^{1-\eta}}{\sum_{h=1}^{N} s_h A_h^{\eta-1} \left(E_{ih} W_h\right)^{1-\eta} \left(1 + d_{kh}^{\gamma}\right)^{1-\eta}} \right]
\end{aligned} \tag{26}$$

(26) cannot be solved for relative wages in closed form. However, it is clear that if there is asymmetry in bilateral distance, size or productivity, the relative wage between any given pair of countries depends not only on traded sector productivity in that pair of countries, but also on productivity in other countries. The real exchange rate is given by substituting

the solution to (26) into (25), with the result that in general,

$$\frac{\partial \frac{P_i}{E_{ij}P_j}}{\partial A_k} \neq 0$$

Asymmetric interdependence also has implications for nominal exchange rate determination. Appropriate substitution into (26) yields:

$$\begin{aligned}
\left(\frac{M_1}{s_1}\right)^{\eta} A_1^{1-\eta} &= \sum_{k=1}^{N} \left[\frac{E_{ik}M_k\left(1+d_{1k}^{\gamma}\right)^{1-\eta}}{\sum_{h=1}^{N} s_h^{\eta} A_h^{\eta-1} \left(E_{ih}M_h\right)^{1-\eta} \left(1+d_{kh}^{\gamma}\right)^{1-\eta}} \right] \\
\vdots &= \vdots \\
\left(\frac{M_N}{s_N}\right)^{\eta} A_N^{1-\eta} &= \sum_{k=1}^{N} \left[\frac{E_{ik}M_k\left(1+d_{Mk}^{\gamma}\right)^{1-\eta}}{\sum_{h=1}^{N} s_h^{\eta} A_h^{\eta-1} \left(E_{ih}M_h\right)^{1-\eta} \left(1+d_{kh}^{\gamma}\right)^{1-\eta}} \right]
\end{aligned} \quad (27)$$

The solution to this system determines the vector of equilibrium nominal exchange rates. Again, there is no closed-form solution in general. However two points are clear. First, there is a one-for-one relationship between nominal exchange rates and the money supply, just as in the standard case. Second, the nominal exchange rate between any given pair of countries depends on productivity not just in that pair of countries, but in third countries also, analogous to the case for real exchange rates.

This interdependence is related to the asymmetry of trade and consumption patterns. The share of country j in i's total trade is given by

$$\frac{T_{ij}}{\sum_{h\neq i} T_{ih}} = \frac{Y_j\left(1+d_{ij}^{\gamma}\right)^{1-\eta} \left[\left(\frac{W_i}{E_{ij}W_j}\right)^{\eta} \left(\frac{A_i}{A_j}\right)^{1-\eta} + \left(\frac{P_i}{E_{ij}P_j}\right)^{1-\eta} \right]}{\sum_{h\neq i} Y_h\left(1+d_{ih}^{\gamma}\right)^{1-\eta} \left[\left(\frac{W_i}{E_{ih}W_h}\right)^{\eta} \left(\frac{A_i}{A_h}\right)^{1-\eta} + \left(\frac{P_i}{E_{ih}P_h}\right)^{1-\eta} \right]} \quad (28)$$

where the ratios in brackets are given by the solution to (26) and (25). In general, the share of country j in i's total trade will differ from the share of country j in k's total trade. Similarly, the share of country j in i's consumption is given by

$$\frac{C_{ij}}{C_i} = \frac{\frac{Y_j\left(1+d_{ij}^{\gamma}\right)^{1-\eta}}{\left(E_{ij}W_j\right)^{\eta} A_j^{1-\eta}}}{\sum_{k=1}^{N} \left[\frac{Y_k\left(1+d_{ik}^{\gamma}\right)^{1-\eta}}{\left(E_{ik}W_k\right)^{\eta} A_k^{1-\eta}} \right]} \quad (29)$$

Again, in general, the share of country j in i's consumption will differ from the share of country j in k's consumption.

This asymmetry means that changes in fundamentals in third countries need not cancel out in their effect on exchange rates between a given pair of countries. Changes in productivity in a country that is "close" to one member of the pair, but not to the other will affect prices differentially in the two countries, and hence affect exchange rates between them. This phenomenon is related to the phenomenon of "multilateral resistance" in Anderson and van Wincoop (2003a), where bilateral trade between a pair of countries i and j depends not only on bilateral variables, but also on the opportunities faced by countries i and j to trade more easily and cheaply with third countries that may be closer to one of the pair than the other. The next section uses a simulated version of the model to investigate the role of asymmetry.

3 Simulation evidence on third-country effects

To build intuition for the properties of third-country effects, the case of real exchange rates in a three-country world is considered in detail. Asymmetry driven by differences in bilateral distances and asymmetry driven by differences in size are considered separately. In the presence of such asymmetry, the elasticity of real exchange rates with respect to bilateral and third-country fundamentals must be calculated numerically. Values must be chosen for two parameters in order to perform this exercise: η (the elasticity of substitution between goods in demand) and γ (the elasticity of trade cost with respect to distance). In their survey of trade costs, Anderson and van Wincoop (2003b) suggest baseline values for η in the range 5 to 10, and a baseline of 0.3 for γ. Additionally, higher values of γ are considered here. Values of η outside the suggested range are also considered, as values within that range yield small trade shares in GDP, and imply counterfactually small variation in price levels across countries.

To investigate first the effects of asymmetry in distance, consider the case where countries $1, 2$ and 3 are of equal size and have equal productivity, but 1 and 2 are "close" to each other and country 3 is "far" from 1 and 2 (see Figure 1). Initially, $d_{13} = d_{23} = 2d_{12}$. Table 1a reports for several parameter combinations the elasticity of ${}^{P_1}/_{P_3}$ with respect to productivity in country 1 (A_1). It also reports the elasticity of ${}^{P_2}/_{P_3}$ with respect to A_1. Also reported are country 1's share of country 2's trade, and country 1's share of country 2's consumption.

Note that the cases considered are fundamentally asymmetric: 1 and 2 are identical; 3 is different. The symmetric case of the elasticity of $^{P_2}/_{P_1}$ with respect to A_3 is not reported, since it is obviously equal to zero. Table 1b reports the same statistics for the case where $d_{13} = d_{23} = 10d_{12}$.

Under zero trade costs, the elasticity of bilateral real exchange rates with respect to bilateral productivity is zero, as the real exchange rate always equals one. Similarly, the elasticity of bilateral real exchange rates with respect to third-country productivity is zero. And with zero trade costs, trade and consumption are perfectly symmetric, so country 1's share of country 2's trade is exactly equal to country 3's share of country 2's trade, i.e. $^1/_2$, and the corresponding consumption shares are $^1/_3$. However when trade costs are non-zero, the picture is very different. The elasticity of real exchange rates with respect to bilateral productivity is negative. Trade costs induce home bias in consumption, so when domestic productivity increases, the domestic price level falls relative to the foreign price level. The elasticity of real exchange rates with respect to third-country productivity is non-zero. Prices fall in the country that is "close" to the productivity improvement relative to prices in the country that is "far". The absolute value of both elasticities is increasing in the importance of trade costs as measured by γ. When γ is small, trade costs are insensitive to distance, dampening the asymmetry in bilateral distances. when γ is large, trade costs increase close to proportionately with distance, there is stronger asymmetry in trade shares.

The relationship between both elasticities and the elasticity of substitution between goods η is non-linear. In particular, consider the elasticity of relative prices with respect to third-country productivity. When the elasticity of substitution is close to 1, there is a very strong desire to consume the varieties produced in all countries, so consumers in 2 and 3 are relatively symmetric in their consumption of the varieties produced in 1, even though these varieties are much more costly in 3 than in 2. As a result, productivity changes in 1 affect the price level in 2 and 3 symmetrically. Increasing η reduces the desire to consume a varied basket, and has two effects which go in opposite directions. First, it increases the share of country 1 in country 2's trade (country 3's trade is symmetric between 1 and 2, since 1 and 2 are identical). Second, it reduces the share of foreign-produced varieties in country 2's consumption basket (i.e. home bias increases). Initially, the first effect dominates, and the elasticity of $^{P_2}/_{P_3}$ with respect to A_1 increases in absolute value. However at the upper end of the proposed range for η, trade as a share of 2's GDP is small, and changes in productivity in 1 have little effect on prices in 2 and 3.

The effect of asymmetry in size on relative price elasticities is investigated by letting $d_{13} = d_{23} = d_{12}$, but assuming that the labor force in 3 is twice as big as the labor force in 1 and 2: $2s_1 = 2s_2 = s_3$. This implies that twice as many varieties will be produced in 3 as in 1 or 2. The relevant statistics are reported in Table 1c. Table 1d reports the statistic for the case where $10s_1 = 10s_2 = s_3$. For a given value of bilateral distance between all countries, the statistics are invariant to γ. Otherwise, the effects of asymmetry are much as in the case of distance-induced asymmetry. The elasticity of ${}^{P_1}/_{P_3}$ with respect to A_1 is negative. The elasticity of ${}^{P_2}/_{P_3}$ with respect to A_1 is also negative. Both depend nonlinearly on η.

Comparing Table 1a with Table 1b, and Table 1c with Table 1d, it is clear that the absolute value of the elasticity of relative prices with respect to both bilateral and third-country productivity is increasing in the degree of asymmetry, as measured either by distance or size. The actual degree of variation in bilateral distance and relative size in the data is substantially greater than that considered here. It is also likely that the asymmetry of the real world is stronger than can be captured by a model based on CES preferences and per-unit trade costs. Hence, although the elasticities of relative prices with respect to third-country fundamentals reported here may seem small in absolute value, it is likely that in practice, third-country effects are important for asymmetric bilateral pairs.

3.1 Implications for empirical work

The intuition that asymmetry can induce dependence of real exchange rates on third-country fundamentals can easily be tested using linear methods, where log exchange rates are expressed as a linear function of log fundamentals. This approach has the advantage of transparency and direct comparability with the existing empirical literature. Before proceeding to investigate the empirical importance of third-country effects, it is worthwhile to consider how, if they are present, they should affect the way in which theoretical models of exchange rate behavior are tested.

First, and most importantly, if bilateral exchange rates depend on third-country fundamentals in addition to bilateral fundamentals, and they are not controlled for, omitted variable bias may contaminate the estimates of the parameters of interest. Productivity is correlated across countries, making such a bias highly likely for asymmetric pairs of countries (see below for evidence on this). Second, a standard procedure in the literature is to choose a numeraire country, usually the US, and to examine only bilateral exchange rates relative to that country. The simulation demonstrates that if the degree of asymmetry differs across bilateral pairs, omitted variable bias will also differ across bilateral pairs. Choosing a different numeraire country will result in a different pattern of asymmetry across pairs. This means that the results are likely to be dependent on the choice of numeraire country. Another standard procedure is to impose symmetry on the coefficients on bilateral fundamentals, i.e. to impose that the coefficients are equal and opposite in sign. Under asymmetric interdependence, this restriction will be rejected, as asymmetric relations in general equilibrium will induce asymmetry in a log-linear approximation to the true relationship.

Fourth, a panel approach is sometimes taken to the estimation of the relationship between exchange rates and fundamentals. Under asymmetry, the restriction that the coefficients on bilateral fundamentals are the same across bilateral pairs will in general be rejected. Further, omitted variable bias should be a major concern, as the set of independent variables for bilateral pair ij will in be correlated with the error term for pair ik, since fundamentals for j determine the exchange rate between i and j but are omitted from that observation, inducing a correlation between the independent variables and the error term. This problem goes beyond the cross-sectional dependence induced by the use of a common numeraire.[2]

Finally, it is standard to test restrictions on the coefficients on bilateral fundamentals that are derived from a two-country model. For example, it is common to test, or for some purposes impose, the restriction that the coefficient on relative output in an equation explaining nominal exchange rates is equal to -1. In simulations of the model (not presented here), it can be shown that with a moderate amount of asymmetry induced by trade costs, imposing this restriction in a log-linear reduced form would result in a very poor fit.

4 Third-country dependence in the data

Testing for the existence of third-country dependence requires comparable data on a wide cross-section of countries. This effectively dictates the use of annual data rather than data at quarterly or higher frequency, since long series of quarterly data on output and productivity are available for very few countries. In testing the importance of third-country fundamentals in exchange rate determination, I focus on real exchange rates. This requires data on real

[2] This problem is identified by O'Connell (1998).

exchange rates and productivity.[3] The measure of real exchange rates used is the absorbtion PPP from the Penn World Tables 6.1. The sample includes 25 OECD countries from 1953 to 2001 (the countries are listed in Table 5). Output per worker valued at purchasing power parity for these countries and these years also comes from the Penn World Tables 6.1. Aggregate labor productivity is not broken out into traded and non-traded sector productivity. The reasons are as follows: The definition of what is traded and what is non-traded changes over time. Further, calculating productivity in the non-traded sector is particularly difficult, as output itself in non-traded sectors such as government is hard to measure. Finally, evidence in Fitzgerald (2003) suggests that even with careful measurement, using traded and non-traded sector productivity separately may not substantially improve the fit of productivity models of real exchange rates.

First, the degree of collinearity in productivity across countries is investigated. A standard measure of the degree of multicollinearity in a set of variables X is the *condition number* of the matrix $X'X$.[4] The condition number is the square root of the ratio of the largest to the smallest eigenvalue of the matrix $X'X$. A value greater than 20 indicates linear dependence among the columns of X. The condition number for the matrix $A'A$, where column a_i of A is log productivity for country i is 5759, indicating substantial linear dependence in levels. The condition number for the same data first differenced is 24, which is evidence, if less strong, of linear dependence. Table 2 illustrates further the importance of collinearity in productivity. It reports for each country the R^2 from regressing that country's productivity on the productivity of all the other countries in the sample, both in levels and in differences. In all cases, the R^2 is greater than 0.98. This evidence suggests that if real exchange rates do indeed depend on third-country productivity, omission of third-country productivity from the standard bilateral model is likely to lead to substantial omitted variable bias.

Second, the dependence of real exchange rates on third-country fundamentals is investigated by testing whether real exchange rates are correlated with third-country productivity once bilateral productivity has been controlled for. This is implemented by estimating

$$\ln r_{ij,t} = \beta_0 + \beta_i \ln A_{i,t} + \beta_j \ln A_{j,t} + \beta_k \ln A_{k,t} + \varepsilon_{ijk,t} \quad (30)$$

[3] In the flexible-price model presented here, real exchange rates do not depend on monetary variables. With sticky prices, this need not be the case.

[4] See Greene (1997)

for each triple i, j, k, and performing an F-test of the hypothesis that $\beta_k = 0$. Table 3 reports for each pair i and j the number of countries k for which the null hypothesis that $\beta_k = 0$ cannot be rejected at the 5% level. Table 4 reports the same results for (30) estimated in differences. For most bilateral pairs, the null cannot be rejected for a large number of third countries. This indicates that even after controlling for bilateral productivity, there is a significant degree of correlation between bilateral real exchange rates and third-country productivity. This is strong evidence that third-country fundamentals may be part of the story in explaining real exchange rates.

4.1 Selection of "partner countries"

One disadvantage of the log-linear empirical approach is that degrees of freedom constraints require that the number of potential "third countries" included in an estimating equation such as (30) not exceed the number of time periods, less 3. Further, even where a linear model can be estimated, there is likely to be overfitting if fundamentals for a very large number of countries are included as independent variables. There are two possible approaches to this problem, model-based and statistical. One possible statistical approach is suggested by Stock and Watson (1999). They propose a dynamic factor approach to the problem of forecasting inflation using many time series. However the principal components or factor analysis approach assumes that the variable to be forecasted does not depend on idiosyncratic variation in the predictor variables. This is at odds with the intuition that under asymmetry, exchange rates may depend on the fundamentals of particular third countries - not merely on the common variation in the fundamentals of all third countries. The model-based approach is preferred here, as testing the central intuition of the model is the purpose of the exercise.

Although in the model presented, bilateral exchange rates between country i and country j depend on fundamentals in all countries, it should by now be clear that this does not mean, for example, that the real exchange rate between the US and Japan should be highly correlated with fundamentals in Turkey. If trade with country k is a small fraction of the GDP of both i and j, it is likely that fundamentals in country k can safely be ignored when estimating an empirical model of bilateral exchange rates between i and j. Further, if both i and j have roughly the same propensity to trade with country k, i.e., there is symmetry in the relations between i and k and j and k, the correlation between fundamentals in country k and bilateral exchange rates between i and j is likely to be low. This suggests that the relevant "partner countries" for each bilateral pair i and j can be selected from those countries which trade a lot with i or j. In order to implement this model-based selection criterion, bilateral trade data for 1980 to 1992 from the United Nations (as assembled by Statistics Canada and made available by Robert Feenstra) are used to calculate bilateral trade as a share of GDP for all of the country-pairs in the 25 OECD countries in the sample described above. An arbitrary cutoff is chosen: if bilateral trade between i and k is greater than or equal to 5% of i's GDP, k is labelled a potential "partner country" for country i. These partners are reported in Table 5. This cutoff level has the advantage that for only one of the countries in the sample is there a potential partner that is not included in the sample (the criterion selects the USSR/ Russia as a partner for Finland).

5 Asymmetry and the puzzle: Long-run tests

With a set of potentially important third countries in hand, the effect of controlling for third-country fundamentals on the puzzle that fundamentals cannot explain or predict real exchange rates can be investigated. In this section, the effect on tests for the existence of long-run equilibrium relationships between real exchange rates and productivity is examined. The next section investigates the effect on the ability of fundamentals to forecast real exchange rates.

Using conventional single-equation methods, very little evidence has been found to reject the null hypothesis that exchange rates, real and nominal, are a random walk. Researchers using panel methods claim somewhat stronger evidence in favor of mean reversion. However the panel unit root tests used to this date are not robust to the form of interdependence suggested by the model. Similarly, the strongest evidence of a long-run relationship between real exchange rates and productivity comes from panel cointegration tests, which are subject to the same criticism.[5] The approach taken here is to use single-equation methods.

5.1 Unit root tests

The unit root test used is the DF-GLS test of Elliot, Rothenberg and Stock (1996), with critical values taken from ERS. GLS detrending is carried out under the assumption of a

[5] See Banerjee, Marcellino and Osbat (2001), (2002) for more on this point.

constant and trend. Lag length is chosen using the MAIC criterion of Ng and Perron (2001). This test is implemented for all 300 log bilateral real exchange rates between pairs chosen from the 25 sample countries. Results are reported in Table 6. Test statistics in bold indicate that the null hypothesis is rejected at the 5% level. Excluding rejections for Turkey (where hyperinflation is an important source of identification), the null hypothesis is rejected in 13% of cases. The test is also implemented for all 300 log bilateral relative productivities and all 25 log productivities. The results are reported in Table 7. For bilateral productivities, the unit root null is rejected at the 5% level in 6% of cases, about what one would expect if the test were properly sized. The same is true for individual productivity series.

5.2 Cointegration tests

For the remainder of this section, rejections of the unit root null for real exchange rates are treated as type I errors. Single equation cointegration tests are implemented to investigate whether there is stronger evidence of a long run relationship between bilateral real exchange rates, bilateral productivity and third-country productivity than between bilateral real exchange rates and bilateral fundamentals alone. The cointegration test used is the ADF-GLS test of Perron and Rodriguez (2001). Lag length is chosen using the MAIC criterion. First, the test is implemented on bilateral real exchange rates and bilateral relative productivity alone.

$$\ln r_{ij,t} = \beta_0 + \beta_i \ln A_{i,t} + \beta_j \ln A_{j,t} + \varepsilon_{ij,t} \tag{31}$$

The results of this test for all 300 bilateral pairs are reported in Table 8. The null hypothesis of no cointegration can be rejected in 11% of cases. In some cases (e.g. Turkey) this rejection seems to be correlated with rejection of the unit root null for real exchange rates. Second, the test is implemented on bilateral real exchange rates, bilateral relative productivity and third-country productivity, where the third countries are chosen using the model-based criterion described in the previous section.

$$\ln r_{ij,t} = \beta_0 + \beta_i \ln A_{i,t} + \beta_j \ln A_{j,t} + \sum_{k \in K_{ij}} \beta_{ijk} \ln A_{k,t} + \varepsilon_{ij,t} \tag{32}$$

The results of this test for all bilateral pairs are reported in Table 9. The null of no cointegration is rejected in only 6% of cases, about what one would expect if the test were correctly sized.[6] There is thus no evidence that third-country productivity is the "missing link" whose omission can explain the failure to observe a long run relationship between real exchange rates and bilateral fundamentals. A Monte Carlo experiment for a subset of bilateral pairs (results available on request) suggests that this failure is not due to low power of the test alone.

5.3 Estimated long-run relationships

Although the evidence in favor of cointegration is weak, for the subset of bilateral pairs, the relationship between real exchange rates and bilateral productivity is estimated using a number of methods, both excluding and including third-country productivity. The methods used are simple OLS, OLS with Newey-West standard errors, OLS with the Prais-Winston correction for AR(1) in the error term, dynamic OLS (DOLS) and OLS in first differences. The results are reported in Table 10.

There are several points to note about these results. First, in four out of the six cases, relaxing the restriction that bilateral productivities enter with equal and opposite sign leads to an appreciable increase in the explanatory power of OLS. In the case of the bilateral pairs US-Germany and US-UK, this increase is very substantial. In these cases, an F-test of the equal and opposite sign restriction is strongly rejected. Second, in three cases, Japan-Germany, US-Germany and US-UK, controlling for third-country productivity leads to a significant increase in explanatory power over and above the increase from relaxing the restriction on bilateral productivity. In these cases, the restriction that the coefficients on third-country productivity are zero is rejected at the 5% level. Third, there are significant changes in the coefficients on bilateral productivity once third-country productivity is controlled for in OLS and OLS with Newey-West standard errors in all cases except UK-Germany and US-Japan. Fourth, in a number of bilateral pairs, there is systematic evidence across specifications of significant coefficients on the productivity of certain third countries. For Japan-Germany, US productivity enters significantly in all specifications. For UK-Japan, US productivity enters significantly in all specifications except DOLS. For US-Japan, the coefficient on oil is significantly different from zero both in levels and in first differences. Finally, there is no clear evidence that the coefficient on bilateral productivity is the same across bilateral

[6] The results from repeating the exercise imposing that the coefficient on bilateral productivity be equal and opposite in sign are roughly similar.

pairs and across specifications. Taken together, all of this evidence suggests that omission of third-country fundamentals from the standard bilateral model is an important misspecification. In particular, it is interesting to note that the effects are greatest for the bilateral pairs US-Germany and US-UK, where asymmetries in openness, size and trade relations are large, and smallest for the bilateral pairs UK-Germany and US-Japan, where asymmetries are smallest. A related finding is Honohan and Lane (2003) who show that differences in trade-weighted exchange rates play a substantial role in explaining inflation differentials in Europe since EMU.

6 Asymmetry and the puzzle: Forecasting

This section investigates the effect of controlling for dependence on third-country fundamentals on the ability of fundamentals to forecast real exchange rates.There are two approaches to forecasting in the literature. The first is agnostic about the time-series properties of the data. The second assumes that there is a long-run cointegrating relationship between exchange rates and fundamentals, and estimates the ability of deviations from the long-run relationship to forecast movements in exchange rates. Since the evidence on the existence of a long-run relationship between real exchange rates and aggregate productivity is so weak, this approach is set aside. I investigate the ability of a simple model, augmented to include third-country fundamentals to predict real exchange rates in-sample and out-of-sample.

6.1 In-sample forecasts

The conventional measure of in-sample forecast performance is the root mean squared error (RMSE). This measure has the advantage that it can be used to compare models for which a conventional R^2 cannot be calculated (e.g. a random walk without drift). It has the disadvantage that it does not penalize the addition of explanatory variables. When the RMSE comes from the estimation of a model by OLS, the addition of explanatory variables cannot increase the RMSE. It should also be noted (more on this later) that there is a potential trade-off between bias and root mean squared error. In-sample, it is not possible to measure bias. But it is possible that estimators with lower RMSE may produce systematically more biased forecasts than estimators with higher RMSE.

Table 11a reports the ratio of the RMSE from estimating the bilateral model

$$\ln r_{ij,t} = \beta_0 + \beta_i \ln A_{i,t} + \beta_j \ln A_{j,t} + \varepsilon_{ij,t} \tag{33}$$

to the RMSE from a random walk model without drift

$$\ln r_{ij,t} = \ln r_{ij,t-1} + \varepsilon_{ij,t} \tag{34}$$

Table 11b reports the ratio of the RMSE from estimating the bilateral model augmented with third-country productivity

$$\ln r_{ij,t} = \beta_0 + \beta_i \ln A_{i,t} + \beta_j \ln A_{j,t} + \sum_{k \in K_{ij}} \beta_{ijk} \ln A_{k,t} + \varepsilon_{ij,t} \tag{35}$$

to the RMSE from a random walk model. In only 9% of the 300 bilateral pairs considered is the RMSE of the bilateral model lower than the RMSE of a random walk. However when third-country fundamentals are added to the model, the fundamentals-based model has a lower RMSE than a random walk in 51% of cases. In-sample, the third-country-augmented model outperforms a random walk (if only barely) and does considerably better than the bilateral model.

6.2 Out-of-sample forecasts

The usefulness of a forecast is usually judged by the extent to which it is biased (the average size of the forecast error), and by the variance of the forecast error. So far, the literature on exchange rates and fundamentals has not paid much attention to the issue of bias. It is assumed that the bilateral fundamentals model is not badly misspecified, and hence bias is not of interest. However this paper puts forward the hypothesis that the bilateral model is misspecified: third-country fundamentals should also be included. Hence, the issue of bias is of great interest. Analogous to the in-sample case, omitted independent variables (if they are correlated with included independent variables) can lead to biased forecasts. However, there is no clear prediction on whether omission of variables increases or decreases the variance of forecast error.[7] Accordingly, care should be taken in interpreting the effect of including third-country fundamentals on the estimated variance of forecast error in what follows. An increase in the variance of forecast error does not mean that third-country fundamentals do not determine exchange rates. It means only that if the forecaster wants a forecast with low variance, using third-country fundamentals as part of the information set may not be optimal.

The method for calculating mean forecast error (bias) and the RMSE (variance) of forecasts is as follows. A model $y_t = x_t'\beta + \varepsilon_t$ is estimated on a sub-period $t = 1, \ldots, T_1$ of the total sample yielding estimate $\hat{\beta}^{T_1}$ of the parameter vector. The desired k-step ahead forecasts are calculated using $\hat{\beta}^{T_1}$ and the realized values of the independent variables x'_{T_1+k}: $\hat{y}^1_{T_1+k} = x'_{T_1+k}\hat{\beta}^{T_1}$. Then the sample for estimation is shifted forward one period $(t = 2, \ldots, T_2 = T_1 + 1)$ and the procedure is repeated until the last k-step ahead forecast is at the end of the sample. The mean forecast error is the mean of the errors $y_{T_s+k} - x'_{T_s+k}\hat{\beta}^{T}$ and the RMSE is the square root of the sum of squared errors. This approach is standard in the literature. In this case, the mean percentage error: $\left(y_{T_s+k} - x'_{T_s+k}\hat{\beta}^{T_s}\right)/y_{T_s+k}$ is used to report summary statistics on the bias of forecasts.

Mean error, mean percentage error and RMSE are calculated for the following three models:

$$\ln r_{ij,t} = \ln r_{ij,t-1} + \varepsilon_{ij,t} \quad (36)$$

$$\ln r_{ij,t} = \beta_0 + \beta_i \ln A_{i,t} + \beta_j \ln A_{j,t} + \varepsilon_{ij,t} \quad (37)$$

$$\ln r_{ij,t} = \beta_0 + \beta_i \ln A_{i,t} + \beta_j \ln A_{j,t} + \sum_{k \in K_{ij}} \beta_{ijk} \ln A_{k,t} + \varepsilon_{ij,t} \quad (38)$$

The period on which the initial forecast is based is 1953-1974. Statistics are calculated for 1-year ahead, 2-year ahead and 5-year ahead forecast horizons. At each frequency, 22 forecasts are calculated, before the end of the sample is reached. This exercise is repeated for all 300 bilateral pairs in the sample.

Table 12 reports some results for the out-of-sample forecasting exercise. Panel A reports for each bilateral pair the ratio of the mean percentage error for the 1-year ahead forecast

[7] The sign of the effect on the RMSE of the forecast depends on the variances and covariances of the included and omitted variables. Stock and Watosn (1999) find that including many forecasting variables adversely affects the RMSE of inflation forecasts.

calculated using (37) to the mean percentage error for the 1-year ahead forecast calculated using (38). Panel B reports the ratio of the RMSE for (37) to the RMSE for (38), again for the 1-year ahead forecast. Table 13 reports summary statistics for analogous tables comparing different models at different forecast frequencies.

The first point to note about these results is that at short horizons, the predictions of the bilateral model are biased relative to those of the model augmented with third-country fundamentals. In 64% of bilateral pairs, the mean percentage error is higher for the bilateral model than for (38), and the average ratio of these errors is large. This is exactly what would be expected if omitted variable bias were a problem when third-country fundamentals are excluded. At a 1-year horizon, the variance of forecast error is roughly similar for (37) and (38). That is, at short horizons, the augmented model performs unambiguously better than the bilateral model. However at a 5-year forecasting horizon, on average, the bilateral model is no more likely to be biased than the augmented model (though the average bias is larger), and the variance of forecast error is smaller. As already noted, this does not mean that third-country fundamentals are not determinants of real exchange rates. It means that using third-country fundamentals to forecast real exchange rates using the approach taken here may lead to forecasts which have a high variance of forecast error.

The second point to note about these results comes from examining the lower panel of Table 12. This panel reports summary statistics for comparisons of (37) and a random walk and (38) and a random walk. From this, it is evident that neither (37) or (38) can beat a random walk in terms of bias or forecast error variance. At short horizons, the augmented models do relatively better in terms of bias compared with the bilateral model. At long horizons, the bilateral model does better than the augmented model.

To sum up, controlling for third-country fundamentals unambiguously improves the in-sample forecast performance of a simple fundamentals model of real exchange rates. Out-of-sample at short horizons, controlling for third country fundamentals improves the forecast performance of the same model, particularly in terms of bias. At long horizons, there is no clear advantage in controlling for third-country fundamentals.

7 Conclusion

This paper uses a multi-country model where trade costs induce asymmetry in trade relations across countries to illustrate the point that under asymmetry, the simple relationship betweeen bilateral exchange rates and bilateral fundamentals that is used as a baseline throughout the empirical literature on exchange rates breaks down. Evidence that interdependence of the type suggested by the model is in fact present in real exchange rate data for a sample of 25 OECD countries is presented. Support for an equilibrium long-run relationship between real exchange rates and fundamentals (aggregate productivity) in this sample can at best be described as weak, whether or not third-country fundamentals are included. Nevertheless, taking account of third-country fundamentals is shown to be particularly salient for cases where there is a good deal of asymmetry across the country-pair in question. Controlling for third-country fundamentals is shown to unambiguously improve on the in-sample forecast performance of a simple bilateral model of real exchange rates. At short horizons, it also improves on out-of-sample performance. I conclude that asymmetric interdependence does not explain the many outstanding exchange rate puzzles. But there is strong evidence that it matters for exchange rate determination, and that it should be taken into account in estimating long-run relationships and in forecasting.

References

[1] Anderson, J. and E. van Wincoop (2003a) "Gravity with Gravitas: A Solution to the Border Puzzle," *American Economic Review*, 93, 170-192

[2] Anderson, J and E. van Wincoop (2003b) "Trade Costs," mimeo

[3] Banerjee, A., M. Marcellino and C. Osbat (2001), "Testing for PPP: Should We Use Panel Methods?" mimeo, European University Institute.

[4] Banerjee, A., M. Marcellino and C. Osbat (2002), "Some Cautions on the Use of Panel Methods for Integrated Series of Macro-Economic Data," mimeo, European University Institute.

[5] Eaton, J. and S. Kortum (2002), "Technology, Geography and Trade," *Econometrica* 70 (5), 1741-1779

[6] Elliott, G., T. Rothenberg and J. Stock (1996), "Efficient Tests for an Autoregressive Unit Root," *Econometrica* 64 (4), 813-836.

[7] Fitzgerald, D. (2003), "Terms-of-Trade Effects, Interdependence and Real Exchange Rates," mimeo.

[8] Frankel, J. and A. Rose (1995), "Empirical Research on Nominal Exchange Rates," in Grossman, G. and K. Rogoff (eds.) *Handbook of International Economics*, Vol. 3. Elsevier, Amsterdam, 1647-1688.

[9] Greene, W. (1997), *Econometric Analysis*, 3rd Edition.

[10] Honohan, P. and P. Lane (2003), "Divergent Inflation Rates in EMU," *Economic Policy* 37, 357-394.

[11] Ng, S. and P. Perron (2001), "Lag Length Selection and the Construction of Unit Root Tests With Good Size and Power," *Econometrica* 69, 1519-1554.

[12] O'Connell, P. (1998), "The Overvaluation of Purchasing Power Parity," *Journal of International Economics* 44, 1-19

[13] Perron, P. and G. Rodríguez (2001), "Residual Based Tests for Cointegration with GLS Detrended Data," mimeo, Boston University.

[14] Stock, J. and M. Watson (1999), "Forecasting Inflation," *Journal of Monetary Economics* 44, 293-335.

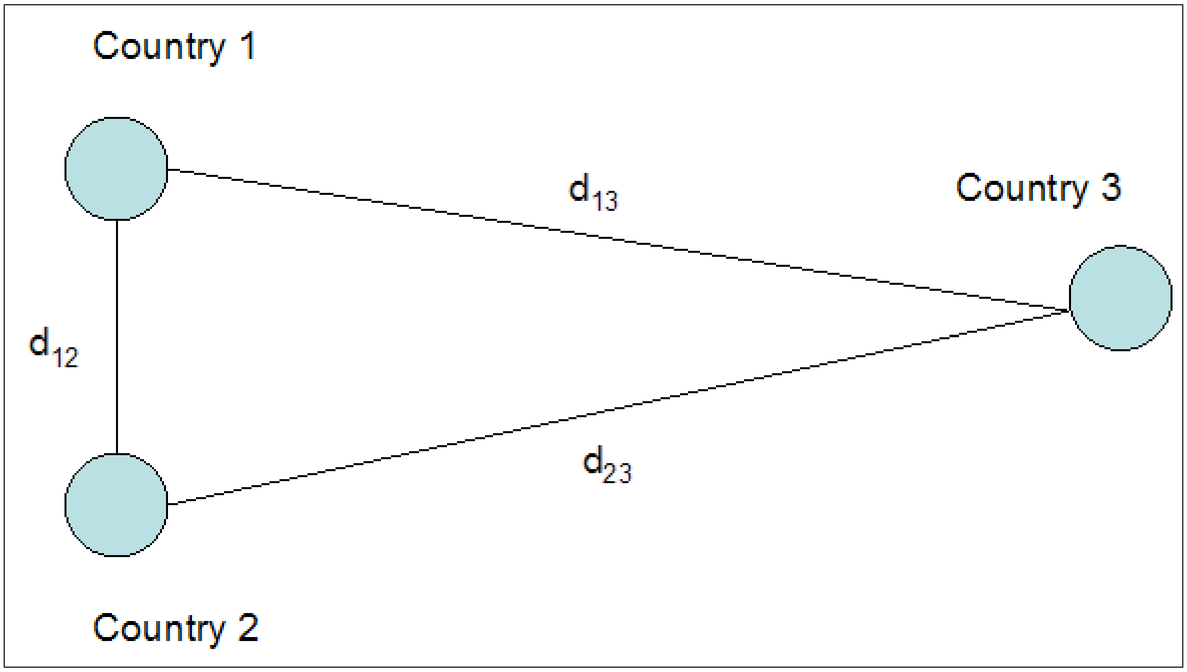

Figure 1: Asymmetry in distance

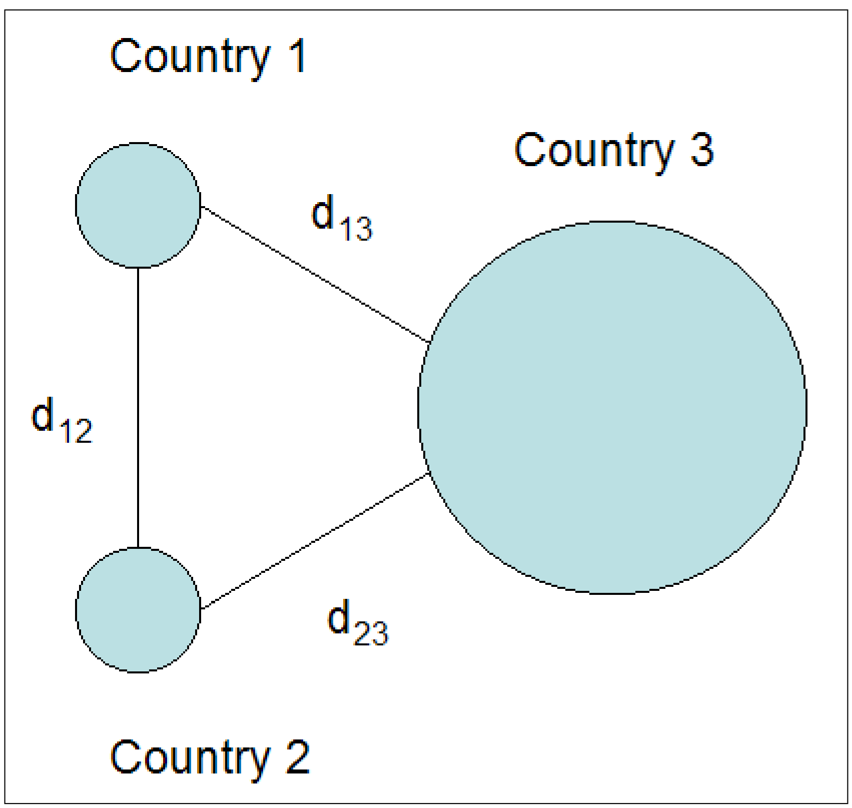

Figure 2: Asymmetry in size

Table 1a: Asymmetric distance I

	$d_{13} = d_{23} = 2.d_{12}$ and $s_1 = s_2 = s_3$				$d_{13} = d_{23} = 2.d_{12}$ and $s_1 = s_2 = s_3$				$d_{13} = d_{23} = 2.d_{12}$ and $s_1 = s_2 = s_3$				$d_{13} = d_{23} = 2.d_{12}$ and $s_1 = s_2 = s_3$			
	Elasticity of P_1/P_3 with respect to A_1				Elasticity of P_2/P_3 with respect to A_1				1's share in 2's trade				1's share in 2's consumption			
gamma\eta	1.5	3	5	8	1.5	3	5	8	1.5	3	5	8	1.5	3	5	8
0.3	-0.090	-0.182	-0.174	-0.123	-0.008	-0.010	-0.004	-0.001	0.512	0.550	0.605	0.682	0.298	0.172	0.057	0.008
0.6	-0.099	-0.197	-0.179	-0.124	-0.016	-0.019	-0.007	-0.001	0.525	0.605	0.711	0.832	0.303	0.178	0.058	0.008
0.9	-0.110	-0.211	-0.183	-0.124	-0.025	-0.028	-0.009	-0.001	0.538	0.661	0.805	0.925	0.308	0.182	0.058	0.008
no trade cost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.500	0.500	0.333	0.333	0.333	0.333

Table 1b: Asymmetric distance II

	$d_{13} = d_{23} = 10.d_{12}$ and $s_1 = s_2 = s_3$				$d_{13} = d_{23} = 10.d_{12}$ and $s_1 = s_2 = s_3$				$d_{13} = d_{23} = 10.d_{12}$ and $s_1 = s_2 = s_3$				$d_{13} = d_{23} = 10.d_{12}$ and $s_1 = s_2 = s_3$			
	Elasticity of P_1/P_3 with respect to A_1				Elasticity of P_2/P_3 with respect to A_1				1's share in 2's trade				1's share in 2's consumption			
gamma\eta	1.5	3	5	8	1.5	3	5	8	1.5	3	5	8	1.5	3	5	8
0.3	-0.113	-0.215	-0.184	-0.124	-0.028	-0.031	-0.009	-0.001	0.543	0.680	0.831	0.944	0.310	0.184	0.058	0.008
0.6	-0.152	-0.246	-0.188	-0.124	-0.061	-0.052	-0.012	-0.001	0.596	0.850	0.974	0.998	0.328	0.194	0.059	0.008
0.9	-0.193	-0.260	-0.188	-0.124	-0.097	-0.062	-0.012	-0.001	0.655	0.947	0.997	1.000	0.346	0.198	0.059	0.008
no trade cost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.500	0.500	0.333	0.333	0.333	0.333

Table 1c: Asymmetric size I

	$d_{13} = d_{23} = d_{12}$ and $2.s_1 = 2.s_2 = s_3$				$d_{13} = d_{23} = d_{12}$ and $2.s_1 = 2.s_2 = s_3$				$d_{13} = d_{23} = d_{12}$ and $2.s_1 = 2.s_2 = s_3$				$d_{13} = d_{23} = d_{12}$ and $2.s_1 = 2.s_2 = s_3$			
	Elasticity of P_1/P_3 with respect to A_1				Elasticity of P_2/P_3 with respect to A_1				1's share in 2's trade				1's share in 2's consumption			
gamma\eta	1.5	3	5	8	1.5	3	5	8	1.5	3	5	8	1.5	3	5	8
no trade cost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.333	0.333	0.333	0.250	0.250	0.250	0.250
trade cost	-0.076	-0.157	-0.163	-0.122	-0.013	-0.014	-0.005	-0.001	0.343	0.370	0.391	0.399	0.227	0.143	0.053	0.008

Table 1d: Asymmetric size II

	$d_{13} = d_{23} = d_{12}$ and $10.s_1 = 10.s_2 = s_3$				$d_{13} = d_{23} = d_{12}$ and $10.s_1 = 10.s_2 = s_3$				$d_{13} = d_{23} = d_{12}$ and $10.s_1 = 10.s_2 = s_3$				$d_{13} = d_{23} = d_{12}$ and $10.s_1 = 10.s_2 = s_3$			
	Elasticity of P_1/P_3 with respect to A_1				Elasticity of P_2/P_3 with respect to A_1				1's share in 2's trade				1's share in 2's consumption			
gamma\eta	1.5	3	5	8	1.5	3	5	8	1.5	3	5	8	1.5	3	5	8
no trade cost	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.091	0.091	0.091	0.091	0.083	0.083	0.083	0.083
trade cost	-0.035	-0.081	-0.118	-0.115	-0.012	-0.014	-0.006	-0.001	0.102	0.128	0.146	0.153	0.081	0.067	0.037	0.007

Table 2: R-squared from regressing log productivity for one country on log productivity for all other countries

Country	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
level	0.997	0.999	0.999	0.998	0.998	0.999	1.000	0.995	0.998	0.990	0.999	0.999	1.000	0.999	0.996	0.998	0.998	0.983	0.999	0.999	0.998	0.995	0.996	0.999	0.999
difference	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.999	1.000	1.000	1.000	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.999	1.000	1.000

Table 3: Number of countries for which F-test does not reject inclusion in regression of bilateral exchange rates on bilateral productivity (levels)

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US	Avg
Aus																										15
Aut	16																									12
Bel	18	15																								11
Can	16	16	12																							13
Dnk	11	20	6	11																						14
Fin	19	16	4	18	13																					10
Fra	15	15	13	13	2	8																				10
Ger	1	21	7	10	23	12	8																			11
Grc	11	16	8	15	1	13	6	20																		12
Ice	22	2	20	18	14	10	3	18	19																	13
Irl	17	10	7	0	19	10	8	6	4	18																11
Ita	15	5	15	15	9	5	7	6	5	6	10															9
Jap	16	15	16	15	17	14	17	15	2	9	12	10														13
Kor	21	6	6	17	13	4	13	19	20	4	23	10	11													10
Mex	18	11	9	6	23	7	10	1	14	19	14	7	6	20												13
Nth	19	8	9	2	4	18	4	4	9	18	18	8	10	22	13											12
Nzl	3	21	20	11	22	6	20	7	19	11	10	15	20	6	11	6										13
Nor	15	1	11	4	14	1	5	5	20	5	2	2	13	2	22	16	18									10
Prt	20	13	16	20	18	14	5	7	13	8	17	5	16	11	9	17	14	15								14
Spa	18	13	4	18	21	17	9	20	19	16	10	10	4	5	17	10	22	5	12							13
Swe	4	21	15	8	19	14	19	5	19	18	11	17	18	0	10	5	16	13	20	22						13
Swi	18	12	13	19	23	15	11	23	5	20	19	14	15	4	24	13	18	24	17	1	21					15
Tur	17	10	1	14	5	1	9	15	19	8	17	12	12	2	18	17	10	7	7	13	2	8				10
UK	19	6	3	15	14	4	7	6	3	13	4	5	9	0	8	18	6	3	13	12	12	14	8			9
US	18	10	10	14	15	6	9	11	11	18	5	8	10	5	4	16	11	11	18	10	14	18	11	6		11

Table 4: Number of countries for which F-test does not reject inclusion in regression of bilateral exchange rates on bilateral productivity (differences)

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US	Avg
Aus																										1
Aut	1																									1
Bel	0	3																								2
Can	0	0	0																							1
Dnk	0	1	0	0																						1
Fin	1	1	4	1	1																					2
Fra	0	2	0	0	1	3																				1
Ger	1	0	1	1	2	0	1																			1
Grc	0	0	0	0	0	2	0	2																		1
Ice	4	1	5	4	3	0	3	4	5																	3
Irl	0	2	2	0	2	0	2	1	3	3																1
Ita	0	0	0	0	1	1	1	1	0	3	0															1
Jap	2	1	0	0	0	4	1	1	1	1	2	0														2
Kor	4	0	1	1	0	1	3	3	0	1	0	0	1													1
Mex	3	0	2	6	2	1	1	2	3	0	2	2	3	0												2
Nth	0	0	1	0	0	1	0	1	1	5	0	0	1	1	3											1
Nzl	0	3	6	0	3	3	0	1	0	3	4	0	2	1	2	1										2
Nor	2	0	0	1	0	0	1	0	1	0	1	0	3	0	2	0	0									1
Prt	0	1	2	0	1	1	1	1	1	4	0	0	3	1	1	2	2	0								1
Spa	1	2	1	1	0	1	4	2	6	1	4	2	1	0	1	0	2	0	1							2
Swe	1	1	1	0	1	6	0	1	1	4	0	0	2	3	1	2	2	0	3	3						2
Swi	0	3	0	1	0	3	0	0	0	5	4	1	1	0	2	1	1	0	1	2	1					1
Tur	2	2	3	0	0	1	3	0	1	1	0	0	1	1	0	0	7	0	1	2	2	0				1
UK	1	4	4	0	4	1	5	2	2	3	0	0	4	1	4	1	1	2	0	4	3	1	0			2
US	4	1	0	6	1	3	0	2	5	3	0	0	1	0	2	3	1	1	1	1	0	4	0	1		2

Table 5: Partner countries selected by trade>= 5% of GDP rule

Country	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Partners	US Jap	Ger Ita	Fra Ger Ita Nth UK US	US	Ger Swe UK	Rus* Ger Swe UK	Ger Ita	Fra Ita Nth UK	Ger Ita	Dnk Ger UK US	Fra Ger Nth UK US	Fra Ger	US	Jap US	US	Bel Fra Ger Ita UK US	Jap UK US	Ger Swe UK US	Fra Ger Spa UK US	Fra Ger	Dnk Ger Nor UK US	Fra Ger Ita UK US	Ger	Fra Ger US	

* Data on Russia is not available, so results for bilateral pairs including Finland should be treated with caution

Table 6 DF-GLS unit root tests on bilateral real exchange rates*

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Aus																									
Aut	-2.93																								
Bel	**-3.40**	-1.93																							
Can	-1.86	-1.95	**-2.82**																						
Dnk	**-2.75**	-1.73	-1.70	-2.71																					
Fin	-2.04	-2.44	-2.31	-2.63	-2.05																				
Fra	-2.69	-1.95	-1.75	-2.20	-1.69	-2.08																			
Ger	-1.93	-1.84	-2.30	-2.62	**-3.65**	-1.80	-2.04																		
Grc	-1.42	-1.46	-1.78	-2.10	-1.88	-1.89	-2.40	-2.13																	
Ice	-0.80	**-3.05**	-1.44	-1.46	-1.15	**-3.60**	**-3.14**	-1.06	-1.78																
Irl	-2.65	-1.97	-2.62	-2.14	-1.95	-2.96	-2.54	-1.72	-2.03	-1.30															
Ita	-1.60	**-2.84**	**-2.80**	-3.00	-2.12	-2.35	-2.59	-2.06	-2.38	-1.91	**-3.45**														
Jap	-2.97	-2.15	-2.53	**-3.81**	-2.19	-2.73	-2.36	-2.30	-1.79	**-3.21**	-1.75	-1.97													
Kor	-1.09	-2.40	-2.09	-2.26	-2.15	-3.08	-2.30	-2.07	-2.49	-1.58	-2.17	-2.52	-1.49												
Mex	-1.83	-2.30	-2.83	-2.58	-2.71	-2.71	-2.67	-2.63	-3.16	-1.55	-2.42	-2.32	**-3.40**	-1.93											
Nth	**-3.46**	-2.13	-2.32	-2.16	**-2.74**	-1.72	-2.18	-2.52	-1.76	-0.97	-2.16	-2.22	-1.37	-2.05	-2.48										
Nzl	-2.25	-2.36	-1.65	-2.11	-1.27	-1.73	-1.46	-1.73	-1.73	-1.39	-1.51	-1.80	-1.68	-1.84	-2.27	-1.89									
Nor	-1.71	-2.19	-2.01	**-3.19**	-2.07	-2.80	-2.29	-2.06	-1.91	**-3.53**	-2.61	-2.57	-2.29	-2.32	-1.91	-1.82	-1.66								
Prt	-1.72	-2.41	-1.86	-1.91	-2.06	-2.09	-2.19	-1.94	-2.60	-2.37	**-3.07**	-2.09	**-2.80**	-2.56	-2.48	-2.31	-2.18	-2.52							
Spa	-2.53	**-3.74**	-2.02	**-3.43**	-2.14	**-4.17**	-2.05	-2.26	-1.89	-1.77	-2.90	-2.26	**-3.88**	-2.31	-2.24	-1.96	-1.60	**-3.54**	-1.84						
Swe	-2.61	-1.76	-1.94	**-3.73**	-2.40	-1.76	-1.54	**-3.12**	-1.69	-1.18	-2.16	-1.59	-2.19	-2.21	-2.87	-2.84	-1.81	-1.98	-1.33	-2.00					
Swi	**-3.25**	-2.03	-2.07	-2.09	-1.83	-2.10	-1.56	-2.36	-1.72	-2.46	-1.86	-1.93	-2.00	-2.30	-2.25	-2.28	-2.37	-1.95	-2.49	-2.87	-1.88				
Tur	**-3.09**	**-4.09**	**-4.38**	**-3.94**	**-3.97**	**-3.85**	**-4.53**	**-3.87**	**-4.86**	-2.50	**-4.51**	**-2.97**	**-3.96**	-1.71	**-3.55**	**-3.74**	**-3.16**	**-3.52**	**-4.08**	-2.78	**-3.78**	**-3.41**			
UK	-1.97	-2.36	**-2.88**	**-3.55**	-2.02	**-3.18**	**-2.73**	-1.93	**-3.30**	-1.78	-2.05	-2.69	-2.00	-2.13	-2.26	-2.22	-1.73	-2.68	**-3.53**	-2.13	-1.90	-1.96	**-3.01**		
US	-1.81	-2.22	-2.62	-1.96	-2.62	-2.82	-2.42	-2.02	**-3.41**	-2.08	-2.32	-2.96	-2.23	-2.57	-2.52	-2.36	-2.16	-2.26	**-2.83**	-2.07	-2.76	-2.08	**-3.18**	-2.72	

*GLS demeaning and detrending, c= -13.5, MAIC selection of lag length, test statistics significant at 5% level in bold

Table 7: DF-GLS unit root tests on productivity and bilateral relative productivity*

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Prod.	-1.818	-2.304	-2.278	-1.43	-2.317	-1.574	-2.493	-2.155	-2.584	-1.155	-2.908	-1.841	-1.698	-1.921	-2.026	-1.565	-1.772	-1.348	-1.769	-1.504	-1.56	-1.516	-1.437	-1.317	-2.175
Bilateral Prod.																									
Aus																									
Aut	-1.21																								
Bel	-1.43	-1.35																							
Can	-2.00	-1.23	-1.37																						
Dnk	-1.59	-1.35	-1.83	-1.79																					
Fin	-1.54	-1.56	**-2.83**	-0.95	**-2.84**																				
Fra	-1.33	-1.91	-2.53	-1.53	-1.63	-1.57																			
Ger	-1.81	-2.02	-1.37	-1.60	-2.45	-1.38	-1.30																		
Grc	-2.30	-2.72	-2.96	-1.85	-2.13	-1.72	-2.50	-2.15																	
Ice	-1.97	-1.45	-2.66	-2.43	-2.74	**-3.00**	-1.59	-1.82	-1.57																
Irl	-1.63	-1.42	-1.48	-1.83	-1.91	-1.23	-1.69	-1.35	-2.27	-1.50															
Ita	-0.85	-1.53	-1.30	-1.68	-1.11	-2.30	-2.44	-2.20	**-3.06**	**-2.96**	-1.50														
Jap	-1.35	-2.59	-1.60	-1.29	-1.27	-1.75	-1.87	-2.41	**-2.97**	-1.76	-1.31	-2.00													
Kor	-1.83	**-2.86**	-2.06	-1.79	-1.83	-1.54	-2.18	-1.42	**-2.84**	-1.42	-2.37	-1.95	-2.23												
Mex	-1.78	-2.53	-2.20	-1.56	-1.46	-2.25	-2.37	**-2.85**	-1.86	-1.86	-1.77	-2.77	-2.51	-1.83											
Nth	-1.69	-1.53	-1.59	-2.49	-1.99	-1.19	-1.34	-1.57	-1.97	-1.07	-1.64	-1.19	-1.60	-2.09	-1.91										
Nzl	-1.05	-1.93	-1.27	-1.32	-2.24	-1.77	-2.71	-1.34	**-3.06**	-1.97	-1.39	-2.44	-1.59	-1.98	-2.88	-1.17									
Nor	-0.98	-1.90	-2.63	-2.03	**-4.05**	-1.99	-1.35	-1.34	-1.59	-1.83	-1.76	-2.14	-1.60	-1.56	-1.94	-1.23	**-3.22**								
Prt	-1.47	-1.48	-2.16	-1.68	-2.19	**-2.90**	-2.47	-1.68	-2.10	-2.18	-1.13	-2.23	-1.32	-2.15	-1.95	-1.78	**-2.73**	-2.48							
Spa	-1.40	-2.24	-1.33	-1.76	-1.37	-1.29	-1.42	-2.02	-2.02	-1.81	-1.51	-1.77	-1.75	-2.67	-2.45	-1.37	-1.41	-1.23	-1.06						
Swe	-1.76	-0.98	-2.40	-1.20	-2.16	-2.35	-1.10	-1.78	-1.96	-2.29	-1.21	-1.70	-1.57	-1.63	-2.01	-1.23	-1.30	-1.34	-2.22	-1.95					
Swi	-1.23	-1.75	-2.09	-1.07	-1.53	-2.28	-2.48	-1.70	-2.60	-2.44	-1.23	-1.73	-1.86	-1.63	-1.96	-1.28	-2.36	-2.49	**-3.56**	-1.63	-2.70				
Tur	-3.04	-1.49	**-3.42**	-2.24	-2.04	-1.74	-2.16	-1.46	-2.05	-2.32	-2.73	-1.44	-1.25	-1.70	-1.50	-1.87	-1.18	-1.68	-1.61	-1.64	-2.15	-1.38			
UK	-1.96	-2.19	-1.96	-2.36	-2.44	-1.66	-1.93	-1.80	**-2.76**	-1.76	-1.97	-1.18	-1.69	-1.24	-1.70	-2.08	-2.30	-1.79	-1.84	-2.07	-1.26	-1.37	-3.00		
US	-1.25	-1.39	-1.35	-1.53	-1.76	-1.09	-1.10	-1.30	-2.09	-1.40	-2.06	-1.03	-1.36	-1.89	-1.63	**-2.83**	-1.54	-0.89	-1.60	-1.96	-2.03	-1.18	-3.17	**-2.74**	

*GLS demeaning and detrending, c= -13.5, MAIC selection of lag length, test statistics significant at 5% level in bold

Table 8: ADF-GLS cointegration test - bilateral real exchange rates and bilateral productivity

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Aus																									
Aut	-2.60																								
Bel	-2.35	-2.13																							
Can	-1.97	-2.50	-2.72																						
Dnk	-2.17	-2.18	-2.69	-2.96																					
Fin	-3.28	-2.78	-2.27	-3.01	-2.46																				
Fra	-2.58	-2.82	-2.55	-3.00	-2.76	-2.37																			
Ger	-2.65	-2.55	-2.45	-2.90	-2.91	-1.94	**-4.00**																		
Grc	-2.64	-2.13	-2.39	-2.98	-3.00	-1.90	-3.31	-3.72																	
Ice	-2.88	-3.52	-3.08	-1.84	-2.00	-3.08	**-4.56**	**-5.75**	-2.96																
Irl	-3.34	-2.34	-2.91	-2.51	-2.39	-3.34	-2.64	-2.31	-2.73	-3.30															
Ita	-2.53	-2.87	-3.54	-3.11	-2.93	-2.27	-2.96	-3.06	-2.67	-2.62	-3.59														
Jap	-3.00	-2.23	-2.21	-2.31	-2.50	-2.37	-2.31	-2.82	-1.79	-2.45	-2.12	-1.94													
Kor	-2.94	**-4.33**	-3.33	-2.25	-3.45	**-5.28**	-3.46	-3.59	-3.50	-2.23	-3.39	-3.59	-3.38												
Mex	-2.69	-2.19	-2.50	-2.59	-3.37	-2.31	-2.64	-3.62	**-3.87**	-1.93	-3.33	-1.91	-2.52	-2.34											
Nth	-3.20	-2.80	-2.68	-2.38	-3.01	-3.14	**-3.88**	-2.49	-3.09	-2.97	-2.33	-3.31	-2.41	**-3.82**	-2.55										
Nzl	-2.94	-2.82	-1.76	-2.46	-2.69	-2.44	-2.18	-2.20	-2.66	-3.02	-2.24	-2.79	-2.58	**-4.10**	-3.28	-2.38									
Nor	-1.61	-2.97	-2.70	-2.63	-1.85	-3.07	-2.37	-2.75	-2.35	-2.37	-2.57	-3.25	-2.66	-3.64	-2.52	-2.80	-2.86								
Prt	-1.99	-2.21	-3.26	-2.16	-2.28	-2.15	-1.84	-3.05	-2.36	-2.07	-3.42	-2.55	-2.09	-2.95	-3.12	-2.51	-2.03	-2.33							
Spa	-3.23	**-5.28**	-3.60	-2.22	-3.12	-2.72	-2.23	-3.57	-1.91	**-4.45**	-2.43	-2.01	**-3.90**	-3.44	-2.16	-2.78	**-4.18**	-2.59	-1.68						
Swe	-2.96	-3.03	-2.35	-2.78	-2.80	-2.45	-2.92	-3.48	**-4.09**	-3.06	-2.06	-2.87	-2.31	**-4.80**	-2.59	-3.24	-2.81	-2.52	-1.86	**-4.48**					
Swi	-2.38	-2.30	-2.06	-2.11	-3.46	-2.40	-1.39	-2.28	-2.04	-1.65	-2.38	-1.88	-2.21	**-4.68**	-2.18	-2.34	-1.65	-2.17	-2.23	**-4.02**	-2.85				
Tur	-3.61	**-3.83**	**-3.97**	**-3.97**	-3.58	-3.62	**-4.18**	**-4.50**	**-5.20**	-2.80	**-5.13**	-3.65	-3.43	-2.40	**-4.38**	**-3.97**	**-4.18**	-3.15	**-4.51**	-2.65	**-4.15**	-2.98			
UK	-2.42	-2.36	-2.98	**-4.65**	-2.23	-3.21	-2.51	-2.68	-3.09	-3.35	-2.48	-2.88	-1.71	-3.78	-2.21	-2.40	-2.30	-2.61	-3.32	-2.37	-2.25	-2.09	**-4.57**		
US	-1.88	-2.21	-2.66	-1.85	-2.81	-2.87	-2.42	-2.49	-3.48	-2.17	-2.47	-2.88	-2.16	-2.93	-2.35	-2.47	-2.27	-2.31	-2.86	-2.10	-3.26	-2.08	-2.69	-3.35	

*GLS demeaning and detrending, c= -13.5, MAIC selection of lag length, test statistics significant at 5% level in bold

Table 9: ADF-GLS cointegration test - bilateral real exchange rates, bilateral productivity and third-country productivity

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Aus																									
Aut	-2.58																								
Bel	-2.93	-3.29																							
Can	-2.64	-3.25	-2.73																						
Dnk	-2.83	-2.77	-3.67	-2.51																					
Fin	-3.10	-2.57	-3.86	-3.62	-2.90																				
Fra	-2.74	-3.18	-2.78	-2.70	-2.19	-2.51																			
Ger	-3.14	-3.69	-3.94	-2.04	**-5.72**	-3.33	-3.56																		
Grc	-3.20	-2.80	-2.82	-2.77	-2.20	-3.44	-2.16	-2.20																	
Ice	-2.69	**-5.17**	-4.07	-2.65	-4.15	-3.38	**-5.58**	-4.52	-4.38																
Irl	-2.55	-2.82	-3.34	-2.86	-2.95	-2.37	-2.48	-3.41	-2.34	-4.69															
Ita	-2.75	-2.19	-3.11	-3.27	-2.48	-2.60	-2.92	-3.26	-2.64	-3.67	-2.98														
Jap	-2.61	-2.66	-3.62	-2.52	-2.72	-2.57	-3.02	-2.96	-2.53	-3.73	-2.26	-2.21													
Kor	-2.36	-4.28	-3.05	-2.93	**-5.97**	**-4.84**	-4.41	-4.44	**-5.77**	-3.98	-3.59	-4.12	-3.16												
Mex	-2.95	-3.66	-3.18	-2.12	**-6.10**	-3.88	-3.77	-3.22	-3.24	**-5.68**	-3.36	-2.34	-3.03	-3.79											
Nth	-2.86	-2.22	-3.19	-2.30	-2.92	-3.20	-3.71	-3.69	-3.39	-4.50	-2.37	-2.76	-2.25	-4.74	-2.73										
Nzl	-3.18	-2.42	-2.56	-3.35	-3.01	-2.47	-2.05	-2.48	-2.97	-4.85	-2.69	-2.73	-2.61	-4.19	-3.11	-3.59									
Nor	-3.59	-3.38	-2.99	-2.02	-2.57	-2.29	-2.37	-2.95	-3.84	-3.09	-2.37	-2.62	-2.83	-3.64	-2.29	-3.27	-2.85								
Prt	-2.68	**-4.74**	-4.32	-2.97	-3.49	-2.20	-2.60	**-4.80**	-3.76	**-6.32**	-2.83	-2.41	-1.85	-3.55	-2.95	-2.32	-3.52	-2.87							
Spa	-3.69	-4.41	-3.45	-3.90	-3.98	-3.82	-4.26	-4.04	-2.25	-3.08	-3.80	-3.00	-4.15	-2.62	-4.00	-3.58	-3.84	-3.33	-3.21						
Swe	-2.59	-2.31	-1.93	-2.44	-2.40	-2.54	-3.83	-2.58	-3.62	-4.27	-3.54	-2.32	-2.72	-4.17	-2.35	-3.04	-2.45	-2.79	-2.54	**-4.78**					
Swi	-3.07	-4.09	-2.37	-4.36	-2.33	-2.60	-1.97	-2.65	-2.13	-3.66	-2.39	-2.21	-2.36	-4.63	-3.04	-3.07	-2.24	-2.95	-1.70	-2.31	-2.36				
Tur	-4.23	-4.46	-3.23	-4.01	-3.86	-3.37	-3.37	-3.19	-4.02	-3.87	-4.48	-2.93	-3.44	-2.87	-4.38	-3.68	**-7.33**	-3.03	**-4.92**	-2.35	-3.81	-2.90			
UK	-2.66	-2.85	-2.44	-2.54	-2.16	-2.87	-2.45	-2.29	-2.13	-3.73	-2.27	-2.27	-2.05	-3.76	-3.42	-1.83	-2.56	-3.19	-2.37	-2.64	-2.66	-2.09	**-4.78**		
US	-3.40	-2.83	-2.34	-2.21	-2.82	-2.61	-2.65	-2.34	-3.55	-3.14	-2.05	-2.86	-2.85	**-6.17**	-2.24	-2.28	-3.12	-3.82	-2.27	-2.41	-3.68	-2.11	**-4.80**	-2.21	

*GLS demeaning and detrending, c= -13.5, MAIC selection of lag length, test statistics significant at 5% level in bold

Table 10: Panel A. Models of the Japan-Germany real exchange rate

	Dep var: ln real ex. rate OLS				Dep var: ln real ex. rate Prais-Winston				Dep var: ln real ex. rate OLS, Newey-West std. errors				Dep var: ln real ex. rate Dynamic OLS (1 lag)				Dep var: 1st dif ln real ex.rate OLS			
Const.	0.26	-11.82	0.26	-11.64	0.21	-13.45	-6.29	-12.83	0.26	-11.82	0.26	-11.64	0.24	-10.92	1.75	-9.95	0.03	0.03	0.03	0.03
	7.19***	4.68***	0.25	4.22***	2.38**	4.52***	3.41***	3.94***	5.69***	3.86***	0.21	3.22***	6.98***	3.04***	1.51	2.28**	2.75***	1.67	1.57	1.45
a_bilat	0.74	-0.42			0.66	-0.35			0.74	-0.42			-0.46	-0.82			-0.46	-0.50		
	15.43***	2.37**			5.69***	1.71*			13.35***	2.59**			0.89	2.15**			1.96*	2.00*		
a_ger			-0.75	0.44			0.51	0.42			-0.75	0.44			0.16	0.77			0.49	0.57
			3.91***	1.94*			1.89*	1.72*			3.37***	2.34**			0.27	1.68			1.83*	2.07**
a_jap			0.75	-0.37			0.08	-0.16			0.75	-0.37			-1.58	-1.11			-0.41	-0.22
			7.43***	1.06			0.43	0.39			6.55***	1.14			1.31	1.15			1.21	0.45
oil		0.01		0.01		0.01		0.02		0.01		0.01		-0.05		-0.05		-0.03		-0.02
		0.6		0.62		0.47		0.6		0.5		0.54		0.75		0.82		0.68		0.35
a_fra		-0.54		-0.62		-0.69		-0.94		-0.54		-0.62		-0.65		-0.67		-0.86		-1.05
		0.77		0.73		0.94		1.08		0.93		0.85		0.53		0.5		1.11		1.25
a_us		1.45		1.43		1.55		1.56		1.45		1.43		1.57		1.54		1.35		1.38
		2.71***		2.64**		2.91***		2.91***		3.45***		3.31***		2.06**		1.90*		2.69**		2.72***
a_uk		0.57		0.61		0.52		0.57		0.57		0.61		0.53		0.73		-0.59		-0.59
		1.14		1.11		0.96		1.03		1.24		1.3		0.47		0.56		0.87		0.87
a_ita		1.02		0.99		0.81		0.65		1.02		0.99		0.85		0.81		0.36		0.18
		2.17**		1.92*		1.55		1.11		2.35**		2.42**		0.93		0.82		0.64		0.29
a_nth		-1.42		-1.42		-0.96		-0.93		-1.42		-1.42		-0.07		-0.12		-0.03		-0.03
		3.97***		3.92***		2.45**		2.35**		4.39***		4.34***		0.09		0.15		0.07		0.07
Obs	51	51	51	51	51	51	51	51	51	51	51	51	49	49	49	49	50	50	50	50
Rsq-adj.	0.83	0.94	0.82	0.93	0.44	0.85	0.19	0.84	N.A.	N.A.	N.A.	N.A.	0.84	0.94	0.84	0.93	0.05	0.11	0.04	0.1

Absolute value of t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 10: Panel B. Models of the UK-Germany real exchange rate

	Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: 1st dif ln real ex.rate			
	OLS				Prais-Winston				OLS, Newey-West std. errors				Dynamic OLS (1 lag)				OLS			
Const.	-0.18	0.00	-0.73	0.28	-0.21	-0.92	1.65	1.84	-0.18	0.00	-0.73	0.28	-0.16	-0.23	0.27	0.36	0.00	0.02	0.03	0.03
	7.32***	0	1.12	0.08	2.17**	0.31	0.67	0.54	6.00***	0	0.94	0.06	5.79***	0.05	0.3	0.08	0.45	1.13	2.28**	1.85*
a_bilat	0.34	0.09			-0.14	-0.21			0.34	0.09			-0.10	-0.20			-0.21	-0.25		
	3.15***	0.3			0.68	0.84			2.10**	0.31			0.19	0.32			0.89	1		
a_ger			-0.38	-0.18			0.19	0.13			-0.38	-0.18			-0.26	0.08			0.05	0.09
			3.23***	0.51			0.88	0.53			2.16**	0.55			0.43	0.11			0.23	0.36
a_uk			0.43	-0.27			-0.37	-1.37			0.43	-0.27			-1.94	-1.23			-1.30	-1.72
			2.81***	0.33			1.11	2.23**			1.95*	0.31			1.52	0.67			2.85***	2.79***
oil		0.01		0.01		0.05		0.03		0.01		0.01		-0.02		-0.06		0.05		0.02
		0.3		0.24		1.34		0.72		0.24		0.21		0.19		0.57		1.43		0.62
a_fra		-1.64		-1.73		0.12		0.31		-1.64		-1.73		0.80		-0.01		-0.16		-0.11
		1.66		1.70*		0.17		0.46		1.79*		1.76*		0.41		0		0.23		0.16
a_us		0.69		0.95		0.05		0.34		0.69		0.95		0.30		0.05		-0.16		0.23
		1.1		1.14		0.11		0.72		0.92		0.98		0.25		0.04		0.35		0.51
a_ita		1.07		1.21		-0.20		-0.04		1.07		1.21		0.48		0.46		-0.37		-0.25
		1.5		1.55		0.37		0.08		1.62		1.58		0.33		0.3		0.69		0.49
a_nth		-0.17		-0.06		0.09		0.41		-0.17		-0.06		-0.37		-0.11		0.17		0.59
		0.34		0.11		0.22		0.99		0.27		0.09		0.34		0.09		0.43		1.45
Obs	51	51	51	51	51	51	51	51	51	51	51	51	49	49	49	49	50	50	50	50
Rsq-adj.	0.15	0.15	0.15	0.13	0.02	-0.05	0.01	0.01					0.16	0.23	0.15	0.23	0	-0.04	0.11	0.08

Absolute value of t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 10: Panel C. Models of the US-Germany real exchange rate

	Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: 1st dif ln real ex.rate			
	OLS				Prais-Winston				OLS, Newey-West std. errors				Dynamic OLS (1 lag)				OLS			
Const.	-0.14	5.30	7.51	1.99	0.12	4.26	4.82	1.69	-0.14	5.30	7.51	1.99	-0.12	4.15	7.42	3.18	-0.01	0.03	-0.01	0.03
	2.70***	1.68*	8.00***	0.55	0.67	1.33	1.97*	0.48	2.59**	1.14	6.30***	0.36	2.29**	0.95	6.41***	0.62	0.59	1.55	0.44	1.34
a_bilat	0.76	-0.27			-0.06	-0.13			0.76	-0.27			-0.13	-0.33			-0.18	-0.20		
	4.20***	0.77			0.25	0.52			5.03***	0.95			0.16	0.62			0.73	0.77		
a_ger			-0.24	0.60			-0.04	0.46			-0.24	0.60			-0.08	0.73			0.19	0.49
			1.80*	1.54			0.17	1.48			1.27	1.45			0.11	0.95			0.64	1.57
a_us			-0.47	1.18			-0.41	0.81			-0.47	1.18			0.03	0.67			-0.17	0.63
			2.44**	1.28			1.22	1.35			1.72*	1.04			0.02	0.49			0.35	1.09
oil		-0.08		-0.08		0.01		0.02		-0.08		-0.08		-0.06		-0.06		0.01		0.02
		2.15**		2.16**		0.16		0.41		1.58		1.56		0.54		0.54		0.13		0.35
a_fra		-0.45		-0.91		-0.15		-0.33		-0.45		-0.91		0.84		0.69		-0.57		-0.66
		0.41		0.81		0.18		0.39		0.49		0.79		0.4		0.31		0.65		0.77
a_uk		0.27		-0.72		-0.35		-0.99		0.27		-0.72		-0.13		0.17		-1.08		-1.57
		0.38		0.79		0.53		1.35		0.43		0.85		0.07		0.08		1.48		2.02*
a_ita		0.01		0.01		-0.26		-0.45		0.01		0.01		0.05		-0.24		-0.50		-0.63
		0.01		0.01		0.39		0.69		0.01		0.01		0.03		0.14		0.76		0.97
a_nth		-0.31		-0.37		0.34		0.29		-0.31		-0.37		0.20		-0.01		0.62		0.55
		0.5		0.62		0.67		0.59		0.4		0.47		0.17		0		1.19		1.08
Obs	51	51	51	51	51	51	51	51	51	51	51	51	49	49	49	49	50	50	50	50
Rsq-adj.	0.25	0.72	0.68	0.73	-0.01	0.05	0.05	0.08					0.36	0.79	0.73	0.77	-0.01	0.01	-0.03	0.05

Absolute value of t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 10: Panel D. Models of the UK-Japan real exchange rate

	Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: 1st dif ln real ex.rate			
	OLS				Prais-Winston				OLS, Newey-West std. errors				Dynamic OLS (1 lag)				OLS			
Const.	-0.31	7.88	8.37	0.21	-0.29	12.54	9.99	9.13	-0.31	7.88	8.37	0.21	-0.32	4.32	6.04	-7.49	-0.03	-0.01	0.01	0.00
	10.24***	2.45**	4.49***	0.06	3.89***	3.02***	3.42***	2.08**	6.70***	2.25**	2.93***	0.07	11.83***	0.84	2.71***	1.26	1.6	0.3	0.27	0.01
a_bilat	0.62	0.68			0.57	0.12			0.62	0.68			-1.91	-1.09			-0.42	-0.22		
	13.48***	1.92*			5.36***	0.29			11.91***	2.20**			1.54	0.8			1.03	0.48		
a_jap			-0.11	-1.65			0.00	-0.62			-0.11	-1.65			0.47	0.35			0.14	-0.11
			0.99	3.76***			0.01	1.28			0.72	4.04***			0.34	0.26			0.33	0.19
a_uk			-0.71	-1.41			-0.98	-0.66			-0.71	-1.41			-2.09	-2.16			-1.51	-0.82
			2.46**	1.96*			2.17**	0.95			1.66	2.23**			1.54	1.38			2.22**	1.02
oil		-0.03		-0.06		0.03		0.00		-0.03		-0.06		0.02		0.05		0.05		0.04
		0.91		1.80*		0.54		0.07		0.69		1.76*		0.2		0.52		1.03		0.64
a_fra		1.41		3.47		0.81		1.77		1.41		3.47		1.16		1.33		0.78		1.27
		1.86*		3.70***		1.16		1.95*		2.11**		3.71***		0.62		0.75		0.97		1.31
a_us		-1.85976		-0.02231		-1.49413		-0.93665		-1.85976		-0.022309		-1.616601		-0.5587		-1.33984		-1.117988
		3.39***		0.03		2.79***		1.42		4.17***		0.04		1.36		0.53		2.26**		1.74*
a_ger		-0.27		-0.48		-0.49		-0.44		-0.27		-0.48		-0.43		-0.34		-0.53		-0.45
		0.95		1.77*		1.65		1.52		0.8		1.53		0.58		0.53		1.61		1.31
Obs	51	51	51	51	51	51	51	51	51	51	51	51	49	49	49	49	50	50	50	50
Rsq-adj.	0.78	0.85	0.85	0.88	0.35	0.5	0.56	0.58					0.83	0.84	0.85	0.88	0	0.12	0.06	0.12

Table 10: Panel E. Models of the US-Japan real exchange rate

	Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: ln real ex. rate				Dep var: 1st dif ln real ex.rate			
	OLS				Prais-Winston				OLS, Newey-West std. errors				Dynamic OLS (1 lag)				OLS			
Const.	-0.61	-0.35	18.20	19.54	-0.19	-0.25	14.22	14.15	-0.61	-0.35	18.20	19.54	-0.59	-0.42	18.88	22.70	-0.04	-0.04	-0.01	-0.01
	9.97***	1.80*	7.07***	8.17***	0.58	0.64	4.43***	4.33***	7.21***	1.13	4.87***	5.45***	10.02***	2.03**	6.05***	7.08***	2.35**	2.48**	0.35	0.53
a_bilat	1.00	0.94			0.49	0.45			1.00	0.94			-0.85	-0.84			-0.28	-0.31		
	15.97***	11.86***			2.06**	1.80*			13.91***	8.73***			0.64	0.6			0.82	0.93		
a_jap			-0.08	0.06			-0.23	-0.24			-0.08	0.06			0.37	0.41			-0.06	0.00
			0.62	0.49			1.27	1.28			0.47	0.38			0.25	0.29			0.15	0
a_us			-1.61	-1.85			-1.11	-1.10			-1.61	-1.85			-1.54	-1.10			-1.01	-0.98
			4.48***	5.46***			2.49**	2.43**			3.16***	3.79***			1.37	1			1.99*	1.93*
oil		-0.08		-0.11		0.04		0.02		-0.08		-0.11		0.05		0.02		0.06		0.05
		1.41		3.21***		0.73		0.51		0.92		2.62**		0.34		0.22		1.22		0.97
Obs	51	51	51	51	51	51	51	51	51	51	51	51	49	49	49	49	50	50	50	50
Rsq-adj.	0.84	0.84	0.92	0.93	0.08	0.04	0.65	0.61					0.85	0.85	0.92	0.93	-0.01	0	0.05	0.04

Absolute value of t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 10: Panel F. Models of the US-UK real exchange rate

	Dep var: ln real ex. rate OLS				Dep var: ln real ex. rate Prais-Winston				Dep var: ln real ex. rate OLS, Newey-West std. errors				Dep var: ln real ex. rate Dynamic OLS (1 lag)				Dep var: 1st dif ln real ex.rate OLS			
Const.	-1.46	2.37	7.79	4.53	0.21	3.68	6.74	3.65	-1.46	2.37	7.79	4.53	-1.87	1.41	7.83	5.15	-0.01	0.00	-0.02	0.00
	4.60***	3.17***	7.57***	2.46**	0.9	3.78***	4.69***	1.82*	4.68***	2.79***	7.04***	2.25**	5.32***	1.46	6.56***	1.97*	1.07	0.03	1.13	0.25
a_bilat	4.43	0.73			0.18	0.30			4.43	0.73			0.81	0.46			0.07	0.23		
	5.45***	1.23			0.36	0.61			5.66***	1.19			0.57	0.59			0.14	0.48		
a_uk			-0.45	-0.86			-0.54	-0.30			-0.45	-0.86			0.29	1.48			0.13	0.11
			0.68	1.44			1.11	0.52			0.64	1.33			0.24	1.25			0.22	0.16
a_us			-0.28	0.41			-0.09	0.31			-0.28	0.41			0.14	0.89			0.16	0.38
			0.39	0.65			0.16	0.58			0.36	0.6			0.16	1.07			0.32	0.72
oil		-0.08		-0.09		-0.03		-0.03		-0.08		-0.09		-0.07		-0.01		-0.02		-0.01
		3.20***		3.46***		0.86		0.8		1.88*		2.15**		0.93		0.2		0.43		0.22
a_ger		0.79		0.58		0.45		0.45		0.79		0.58		0.76		0.65		0.37		0.36
		5.00***		2.60**		1.99*		1.90*		4.62***		2.30**		1.46		1.28		1.37		1.3
a_fra		-1.01		-0.55		-0.79		-0.80		-1.01		-0.55		0.24		0.23		-0.71		-0.89
		7.23***		1.43		3.68***		1.96*		7.58***		1.36		0.18		0.17		1.33		1.53
Obs	51	51	51	51	51	51	51	51	51	51	51	51	49	49	49	49	50	50	50	50
Rsq-adj.	0.36	0.83	0.76	0.83	0.05	0.51	0.4	0.5					0.42	0.84	0.8	0.87	-0.02	-0.01	-0.04	-0.01

Absolute value of t statistics in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 11a: Ratio of RMSE from regressing log real ex. rate on log bilateral productivity to RMSE of random walk

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Aus																									
Aut	1.46																								
Bel	1.32	2.74																							
Can	1.58	1.54	1.44																						
Dnk	1.26	2.04	1.54	1.40																					
Fin	1.76	1.15	1.37	1.52	1.33																				
Fra	1.24	1.23	1.50	1.36	0.94	1.12																			
Ger	1.04	2.88	1.48	1.27	2.32	1.36	1.17																		
Grc	1.23	1.44	1.19	1.56	1.16	1.74	0.89	1.77																	
Ice	1.49	0.88	1.02	1.39	1.07	0.96	0.79	0.98	1.17																
Irl	1.34	1.59	1.91	1.11	1.99	1.43	1.38	1.63	1.17	1.23															
Ita	1.60	1.72	2.26	1.34	1.96	1.23	1.69	1.73	1.48	0.96	1.52														
Jap	1.82	1.06	1.68	1.61	1.45	1.17	1.28	1.47	1.11	0.96	1.13	1.13													
Kor	1.07	0.87	0.87	1.01	0.88	0.92	0.92	1.03	1.10	0.82	1.11	1.02	1.01												
Mex	1.41	1.16	1.07	1.26	1.36	1.22	1.04	0.89	1.00	1.02	1.13	1.07	1.17	1.15											
Nth	1.13	1.11	1.56	1.27	1.12	1.66	1.10	1.19	1.40	1.38	1.78	1.83	1.11	1.05	1.19										
Nzl	1.05	3.11	1.67	1.37	2.13	1.31	1.62	1.51	1.25	1.04	1.76	2.23	1.67	0.86	1.13	1.30									
Nor	1.58	0.93	1.36	1.31	1.32	1.06	1.03	1.18	1.33	0.99	0.97	1.10	1.20	0.82	1.38	1.33	1.27								
Prt	2.13	1.94	1.70	1.81	2.39	1.80	1.31	1.18	1.24	0.98	2.17	1.71	1.33	1.04	0.87	2.94	2.02	1.54							
Spa	1.62	1.29	1.52	1.59	1.63	1.29	1.25	1.94	1.74	1.05	1.82	1.79	1.06	0.84	1.43	1.47	2.11	0.92	2.00						
Swe	1.25	1.94	1.26	1.27	1.58	1.56	1.52	1.08	1.42	1.09	1.56	2.38	1.70	0.85	1.14	1.20	1.24	1.37	2.61	2.32					
Swi	1.38	1.48	2.13	1.61	2.27	1.32	1.55	2.96	1.59	1.22	1.96	1.67	1.25	0.86	1.74	1.25	2.67	1.98	2.39	1.21	1.82				
Tur	1.31	1.22	1.02	1.33	1.17	1.16	1.11	1.20	1.31	1.03	1.31	1.22	1.25	0.94	1.15	1.26	1.17	1.23	1.14	1.27	1.04	1.25			
UK	1.75	1.48	1.76	1.48	1.85	1.55	1.49	1.58	1.29	1.18	1.17	1.50	1.15	0.82	1.16	2.02	1.63	1.25	2.08	1.70	1.88	1.76	1.20		
US	2.17	1.65	1.63	2.11	1.78	1.63	1.53	1.56	1.55	1.38	1.27	1.33	1.49	0.90	1.22	1.97	1.61	1.40	1.68	1.77	1.69	1.91	1.34	1.41	

Table 11b: Ratio of RMSE from regressing log real ex. rate on log bilateral productivity and log third-country productivity to RMSE of random walk

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Aus																									
Aut	1.00																								
Bel	1.06	1.40																							
Can	0.96	1.14	1.22																						
Dnk	0.93	1.11	0.96	1.07																					
Fin	0.95	0.84	1.13	1.12	0.95																				
Fra	0.95	1.05	1.21	1.11	0.85	0.99																			
Ger	0.90	1.27	1.26	1.11	0.99	1.20	1.01																		
Grc	0.98	1.20	0.95	1.17	1.09	1.45	0.87	1.04																	
Ice	0.77	0.69	0.63	0.85	0.80	0.85	0.63	0.67	0.63																
Irl	0.90	1.27	1.60	1.03	1.43	1.05	1.32	1.50	1.07	0.86															
Ita	0.95	1.38	1.77	0.95	1.33	0.91	1.54	1.69	1.43	0.78	1.03														
Jap	1.14	0.81	1.07	1.12	1.03	0.84	0.98	0.99	0.88	0.87	0.87	0.95													
Kor	0.77	0.76	0.73	0.73	0.75	0.79	0.76	0.71	0.71	0.64	0.64	0.74	0.82												
Mex	1.14	0.85	0.83	1.23	0.79	0.96	0.87	0.79	0.80	0.73	0.78	0.94	1.04	0.85											
Nth	0.84	0.94	1.40	1.01	0.90	0.99	0.96	1.08	1.18	0.65	1.12	1.11	0.84	0.71	0.81										
Nzl	0.98	1.09	0.83	1.16	0.70	1.03	0.80	0.99	0.93	0.67	1.43	1.62	0.90	0.76	0.93	1.22									
Nor	0.98	0.91	1.13	1.07	1.13	0.89	1.00	1.06	1.13	0.91	0.73	0.76	0.99	0.74	0.96	0.91	0.96								
Prt	0.97	1.00	0.97	1.09	0.83	1.25	1.01	0.94	0.86	0.71	1.16	1.49	0.85	0.68	0.75	1.01	0.92	1.03							
Spa	1.12	0.99	1.21	1.12	0.83	0.92	1.01	1.21	1.40	0.73	1.23	1.22	0.90	0.73	1.04	1.05	1.20	0.78	1.33						
Swe	0.89	0.84	0.78	1.14	0.83	1.07	0.89	0.82	0.88	0.80	1.25	1.40	1.03	0.72	0.82	0.83	0.73	1.04	1.06	0.77					
Swi	0.77	0.76	1.53	1.01	1.02	0.67	1.14	1.19	1.27	0.70	0.92	1.03	0.79	0.76	0.88	0.88	0.95	0.88	1.21	0.95	0.89				
Tur	0.92	0.94	0.86	1.11	1.12	1.11	0.94	0.96	0.91	0.88	0.95	1.03	1.09	0.80	0.98	0.95	0.85	1.14	0.96	1.10	1.02	1.04			
UK	1.19	1.44	1.54	1.23	1.52	1.49	1.47	1.48	1.14	1.00	1.12	1.38	1.00	0.74	0.97	1.38	1.40	1.06	1.33	1.46	1.60	1.36	1.08		
US	1.20	1.38	1.37	2.01	1.41	1.37	1.37	1.29	1.22	0.98	1.03	1.20	1.36	0.77	1.22	1.22	1.37	1.16	1.12	1.35	1.49	1.32	1.20	1.11	

Table 12: A. Ratio of absolute value of mean percent error in model without third country productivity to absolute value of mean percent error in model with third country prod.

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Aus																									
Aut	4.25																								
Bel	0.75	0.28																							
Can	0.29	1.60	0.28																						
Dnk	0.24	2.29	0.28	0.37																					
Fin	3.90	3.48	0.44	0.25	1.20																				
Fra	1.42	1.13	0.37	9.72	1.18	1.58																			
Ger	1.20	29.2	7.84	3.04	0.76	0.72	1.97																		
Grc	0.82	1.16	3.88	1.17	5.88	10.6	0.92	16.8																	
Ice	0.44	0.70	1.64	1.32	87.2	1.14	0.44	0.85	2.37																
Irl	3.05	5.28	0.27	0.01	1.88	0.34	2.21	0.94	0.72	0.29															
Ita	1.09	9.83	0.69	0.08	193	1.69	1.48	0.60	1.29	1.48	0.13														
Jap	1.87	2.10	0.38	2.00	1.45	0.41	0.29	3.80	3.59	2.06	0.94	1.20													
Kor	1.16	1.89	3.26	0.49	9.47	1.73	0.23	1.15	14.56	0.56	10.83	2.32	0.39												
Mex	0.44	49.9	1.53	0.78	0.86	3.44	5.61	0.41	3.22	0.52	3.80	1.36	0.46	17.9											
Nth	1.09	1.88	1.30	3.32	9.81	1.35	0.85	1.63	1.16	209	0.58	2.84	2.30	1.40	3.19										
Nzl	1.13	0.83	2.29	3.71	4.15	6.50	1.31	4.26	10.3	0.73	0.91	2.34	17.8	0.74	0.02	0.94									
Nor	2.53	1.14	1.45	0.67	0.51	0.11	2.55	3.10	1.97	0.99	0.82	0.65	0.40	0.49	0.75	1.23	23.8								
Prt	1.63	1.99	0.53	1.29	1.75	0.28	0.18	2.45	3.19	0.51	25.5	1.54	4.56	6.25	0.82	2.96	1.00	1.21							
Spa	0.36	9.10	1.27	0.20	3.31	8.00	10.9	3.01	0.12	1.47	1.42	1.00	1.75	1.09	0.07	1.56	8.75	0.20	1.34						
Swe	0.53	0.94	3.95	3.10	1.06	1.37	2.89	0.94	3.22	1.27	5.54	3.37	0.38	0.06	0.77	0.12	11.2	5.40	1.33	14.8					
Swi	12.3	1.20	1.49	1.35	4.85	0.80	1.07	64.1	5.32	2.17	2.03	3.95	2.11	0.43	6.69	0.38	3.08	44.4	1.59	0.07	1.53				
Tur	0.50	1.43	2.79	1.34	1.20	0.20	1.44	1.17	0.85	0.42	34.0	0.75	69.5	0.77	0.88	34.2	1.46	2.28	0.38	1.01	0.39	1.20			
UK	1.01	0.68	0.65	0.73	1.53	1.09	1.94	2.13	5.17	0.81	2.20	1.29	2.04	0.63	2.17	1.00	3.48	1.81	2.19	8.96	2.91	1.50	0.64		
US	0.76	12.3	0.97	1.27	0.48	0.30	5.57	0.65	1.62	1.21	1.53	0.41	1.84	0.23	1.28	1.53	0.61	0.62	1.49	8.49	0.90	1.80	3.18	1.13	

Table 12: B. Ratio of absolute value of mean percent error in model without third country productivity to absolute value of mean percent error in model with third country prod.

	Aus	Aut	Bel	Can	Dnk	Fin	Fra	Ger	Grc	Ice	Irl	Ita	Jap	Kor	Mex	Nth	Nzl	Nor	Prt	Spa	Swe	Swi	Tur	UK	US
Aus																									
Aut	0.79																								
Bel	0.66	1.80																							
Can	2.12	0.94	0.89																						
Dnk	0.66	1.06	1.62	1.05																					
Fin	1.00	0.95	0.96	0.87	1.35																				
Fra	0.69	0.90	0.92	0.88	0.94	0.87																			
Ger	0.69	2.26	0.98	0.79	1.25	1.15	0.82																		
Grc	0.73	0.99	1.07	1.10	1.00	1.31	0.88	1.06																	
Ice	0.87	0.62	0.53	0.94	1.03	0.49	0.54	0.74	1.14																
Irl	0.83	1.12	1.18	0.77	0.74	0.83	0.83	1.20	0.82	1.01															
Ita	1.13	1.56	1.25	0.90	1.25	1.20	1.11	1.19	1.07	0.87	1.08														
Jap	1.24	0.87	0.92	1.20	0.85	1.01	0.94	1.38	1.15	0.85	1.01	1.08													
Kor	0.66	0.68	0.64	1.13	0.59	0.79	0.61	0.65	0.74	0.99	1.00	0.88	1.02												
Mex	0.96	1.14	0.94	0.94	1.14	1.03	1.04	0.82	0.99	0.88	0.91	1.01	1.15	0.96											
Nth	0.63	0.88	0.92	0.99	0.77	1.27	0.73	0.86	1.07	1.04	0.80	1.35	0.96	0.86	1.08										
Nzl	0.93	2.02	1.42	1.17	1.45	1.45	1.38	0.76	1.18	0.64	1.04	1.44	1.36	0.84	1.07	0.83									
Nor	1.12	0.58	1.01	1.05	0.96	0.84	0.64	0.65	0.76	0.78	0.63	1.11	0.96	0.99	1.19	0.73	0.66								
Prt	1.04	1.28	0.87	0.84	1.69	0.99	0.68	0.77	0.94	0.75	1.22	1.05	1.16	1.15	0.99	1.71	0.88	1.18							
Spa	0.77	1.10	1.17	0.94	1.17	1.04	1.07	1.47	0.87	0.94	1.17	1.89	0.97	0.94	1.23	1.07	1.44	0.80	1.25						
Swe	0.95	1.08	1.11	0.93	1.25	1.14	1.02	0.90	1.25	0.61	0.75	0.87	1.06	0.63	0.97	1.09	1.58	0.95	1.20	1.46					
Swi	0.86	1.45	1.36	1.16	1.28	1.14	1.22	2.50	1.15	1.31	1.21	1.47	1.04	0.71	1.48	0.73	1.60	1.32	1.72	1.21	1.40				
Tur	0.58	0.90	0.85	0.99	0.99	0.82	0.88	0.87	1.08	1.02	1.63	1.00	0.79	0.71	0.99	1.17	0.72	1.09	0.71	1.19	0.68	0.89			
UK	0.92	1.27	1.28	1.01	0.95	1.06	1.02	1.04	0.93	0.80	0.87	1.13	0.98	1.04	1.09	1.24	1.09	0.86	1.33	1.30	0.82	1.14	0.77		
US	1.30	1.10	1.03	0.96	1.11	0.99	0.91	0.97	1.13	0.96	0.79	0.90	1.13	1.23	0.96	1.40	1.22	0.96	1.09	1.32	0.95	1.10	1.03	1.04	

Table 13: Summary statistics of comparisons of forecast errors for different models at different horizons

Numerator	Denominator	Forecast horizon / Variable	1 year ahead Percent. bias	RMSE	2 years ahead Percent. bias	RMSE	5 years ahead Percent. bias	RMSE
OLS regression of log real ex. rate on log bilateral productivity	OLS regression of log real ex. rate on log bilateral productivity & 3rd country prod.	average ratio	5.12	1.03	4.07	0.91	5.2	0.81
		% of cases where ratio > 1	64	50	55	30	47	20
OLS regression of log real ex. rate on log bilateral productivity	random walk	average ratio	6.64	1.62	4.25	1.28	3.03	1.18
		% of cases where ratio > 1	79	97	70	77	56	63
OLS regression of log real ex. rate on log bilateral productivity & 3rd country prod.	random walk	average ratio	3.82	1.6	3.37	1.44	3.27	1.56
		% of cases where ratio > 1	71	98	62	89	61	91