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A MULTIPLE-HORIZON SEARCH FOR THE ROLE OF TRADE AND FINANCIAL FACTORS IN BILATERAL REAL EXCHANGE RATE VOLATILITY

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A Multiple-Horizon Search for the Role of Trade and Financial Factors in Bilateral Real Exchange Rate Volatility

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Abstract

This study investigates the sources of bilateral real exchange rate (RER) volatility in industrial countries. Going beyond traditional macroeconomic determinants, we identify the role of both trade- and finance-related factors in explaining RER volatility at different time horizons. The results suggest that RER volatility tends to increase with financial openness and with transport costs but decrease with trade openness and with financial depth. Moreover, the time horizon matters. Financial factors (financial openness and financial depth) are found to influence RER volatility at primarily short horizons, while trade-related factors (trade openness and transport costs) contribute significantly also to RER volatility at much longer horizons. The relative importance of traditional macroeconomic fundamentals and these trade- and finance-related factors can vary considerably across horizons.

Keywords: Exchange Rate Volatility, Time Horizons, Trade Openness, Financial Openness, Financial Depth

JEL Classification: F15, F31, F41

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1. Introduction

A longstanding issue in international monetary economics is what determines real exchange rate (RER) variability. Volatile RER fluctuations are often attributed to significant monetary disturbances operating under nominal rigidities. However, traditional monetary models of exchange rates do not fare too well with the modern float data. Building on a pricing-to-market paradigm, new open economy macroeconomics models have gained popularity for explaining RER dynamics (witness the burgeoning literature surveyed by Lane, 2001 and Sarno, 2001). In addition to such non-monetary factors as government spending and productivity growth, Obstfeld and Rogoff (2000) and Hau (2002) highlight an important role of trade in explaining RER volatility. Greater trade flows may provide a channel that facilitates faster aggregate price adjustment to economic shocks. Changes in exchange rates are shown to depend not only on the size of economic shocks but also on the size of the tradables sector. For given volatilities of economic shocks, RER volatility would decrease with openness to trade.[1]

Direct evidence for the volatility-openness linkage has been limited thus far. In examining the volatility of three-year changes of effective RERs over the period 1980-1998, Hau (2002) finds that trade openness can explain a significant portion of the cross-country variation in RER volatility. Using panel analysis of cross-country data from 1974-2003, Calderón (2004) analyzes the volatility of one-year changes of effective RERs and reports also that greater trade openness reduces RER volatility. In both studies, the negative relation detected between trade openness and RER volatility is more evident in the data from only industrial countries than in the data from both developing and industrial countries. As Hau (2002) observes, it is not too surprising to find stronger results in the data from industrial countries alone than in the blended data. There is great dissimilarity in economic experience between developing and industrial countries and even among developing countries themselves. Indeed, some developing countries might have experienced such extreme situations as runaway inflation, political instability, and financial crises, which would confound the data and make it difficult to detect volatility-openness linkage.

In this study we examine the empirical determinants of bilateral RER volatility among industrial countries. These countries comprise a relatively homogeneous group of economies with comparable growth experience. While a broad range of potential determinants are considered, special attention is given to the role of trade (trade openness and transport costs) and financial factors (financial openness and financial depth) in determining RER volatility. Changes in financial openness often take place in tandem with changes in trade openness. Lane and Milesi-Ferretti (2003) point out that greater financial openness can help reduce costs of trade-related financial services, thereby enhancing trade growth. Increasing openness to trade, in return, promotes capital flows by creating an economic environment conducive to foreign investment. Aizenman (2004) also notes that greater trade openness helps erode the

[1] The predicted inverse relation between volatility and trade openness is in line with Mundell's (1961) optimal currency area hypothesis of a stabilizing effect of trade flows on RER fluctuations.

effectiveness of restrictions on capital mobility. Aizenman and Noy (forthcoming) confirm the significance of a two-way dynamic relation between trade openness and financial openness: More openness to trade tends to be followed by greater financial openness, and the reverse is also evident. Given the complementary connection between trade and financial openness, it is important to consider both trade and financial variables together. [2]

Moreover, this study adopts a multiple-horizon approach and explores the sources of bilateral RER volatility over different time horizons. An efficient multiple-grid estimator of volatility proposed by Zhang *et al*. (2005) is employed to measure the volatilities of both RERs and their fundamentals at multiple time scales. The important point is that an economic factor may have quite different effects at long as opposed to short horizons. In comparison to single-horizon analysis, multiple-horizon analysis provides a fuller and more comprehensive evaluation of the underlying linkage.

In the case of trade openness, Hau (2002) points out that the influence of tradables on aggregate price adjustment may be limited in the short run because of incomplete exchange rate pass-through. As a result, the linkage between RER volatility and trade openness is expected to be more significant over long than over short horizons. Lower transport costs, on the other hand, are known to decrease short-term RER volatility by reducing deviations from the law of one price (Engel and Rogers, 1996; Parsley and Wei, 2001). A recent study by Bravo-Ortega and di Giovanni (2004) further suggests that lower trade costs would also decrease long-term RER volatility through two separate channels. Lower trade costs tend to expand the share of tradables in consumption over time. Lower trade costs may also induce more similar consumption baskets between countries, thus lessening their relative price variability in the long run. If such long-term effects prevail, there would be a positive relation between RER volatility and transport costs at long horizons, in addition to their expected linkage at short horizons.

New open economy macroeconomics models have not yet offered any clear predictions about the impact of financial openness on RER volatility. While greater financial openness may make an economy more prone to external shocks, it may also facilitate faster macroeconomic adjustment to disturbances in general. [3] Based on the early model of Obstfeld and Rogoff (1995), Sutherland (1996) shows that the effects of financial openness on the short-term volatility of macroeconomic variables (including output, consumption, and exchange rates) can vary vastly depending on the nature of shocks. The role of financial openness in determining RER volatility remains an open empirical issue. Does greater financial openness – like greater trade openness – lead to lower RER volatility? We seek to find out if trade openness and financial openness have similar or dissimilar effects on RER volatility.

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2 In addition to analyzing trade openness, the recent study by Calderón (2004) also explores the implications of financial openness for RER volatility. While finding RER volatility to have a significantly negative relation with trade openness, the study fails to uncover any systematic relation with financial openness.

3 With the increasing liberalization of global financial flows, there is a growing interest in analyzing the effects of financial openness on macroeconomic stability in general. For example, Edwards (2004) examines the implication of financial

Two basic types of exchange rate measurements are bilateral and effective rates. Following most studies of purchasing power parity deviations, our analysis focuses on bilateral RER volatility. The bilateral approach is common in nominal exchange rate volatility analysis (Bayoumi and Eichengreen, 1998; Devereux and Lane, 2003). Hitherto, the key evidence linking RER volatility to trade openness has been based on analysis of effective RERs (Hau, 2002; Calderón, 2004). Constructed as a trade-weighted average of bilateral RERs, the effective RER is a useful aggregate measure of a country's competitiveness in multilateral trade. Since changes in bilateral RERs may partly offset one another through averaging, the effective RER measure tends to understate the observed bilateral RER volatility at the disaggregate level. To explain bilateral RER volatility thus presents a new challenging task. It is interesting to see whether the earlier finding of the volatility-openness linkage can be extended to bilateral RERs. If a similar relation can be established for bilateral RERs, it will expand the existing evidence and further strengthen the empirical support for the stabilizing role of trade openness.

There is also a practical reason for us to adopt the bilateral approach. Analyzing bilateral RERs permits us to explore more fully the cross-country variation existed in the data. Data availability limits the number of industrial countries included in our analysis. For a sample of n countries, in general, there would be only n series of effective RERs plus their respective country data. In contrast, we would have $n(n - 1)/2$ series of bilateral RERs and other economic data from corresponding country pairs. The bilateral data thus contain more information on cross-country variation that can be exploited in statistical analysis. Models of RER determination are typically two-country models with a home country facing either a foreign country or the rest of the world (ROW). In analysis of effective exchange rates, the sources of RER volatility to be considered are often limited to economic changes in the home country with other changes in the empirical counterpart of the ROW ignored. In analysis of bilateral rates, the sources of RER volatility include economic changes in both the home and the foreign country.

This paper is organized as follows: Section 2 discusses a multiple-grid estimator for the volatility of changes over different time horizons. Section 3 reports the results from cross-country analysis and evaluates the relative importance of different factors in explaining bilateral RER volatility. Section 4 extends our analysis to explain nominal exchange rate volatility. Section 5 investigates additional issues concerning the exchange rate regime effect and the numeraire currency effect. Section 6 concludes.

2. An Efficient Multiple-Grid Estimator of Volatility

Empirically, volatility is often measured as the standard deviation of period-to-period changes in the relevant variable. To analyze volatility over multiple horizons, Zhang *et al*. (2005) recently explored the notion of data grids or subgrids. A data grid is a set of data points recorded at regular time intervals. The

openness for current-account reversals. Other studies include Kose *et al*. (2003), Prasad *et al*. (2003), and Buch *et al*. (2005), which investigate the impact of financial openness on output volatility.

full grid (denoted by Ψ) contains all the data points available over the sample period. When data are sampled from Ψ less frequently, it generates different possible subgrids of data. Like the full grid, these subgrids also contain uniformly spaced data points, though with a longer sampling horizon. More formally, given a sampling frequency, the full grid can be partitioned into a number of disjoint subgrids:

$$\Psi = \bigcup_{r=1}^{h} \Psi_r \text{ and } \Psi_r \cap \Psi_s = \varnothing \text{ for } r \neq s \tag{1}$$

where $\Psi = \{X_t, t = 1, 2, 3, \ldots, n\}$, h indicates the sampling horizon, and Ψ_r is the rth data subgrid given by $\{X_t, t = r, r + h, r + 2h, \ldots, r + \lambda_r h\}$ with λ_r being the integer part of $(n - h - r)/h$. Note that Ψ_r has $\lambda_r + 1$ data points. While the sample sizes of different data subgrids need not be equal, their total size should be the same as the size of the full grid so that $\lambda_1 + \lambda_2 + \ldots + \lambda_h + h = n$.

Let $\Phi_h(X_t)$ be the volatility of h-period changes of X_t. In the simplest case of one-period volatility (i.e., of $h = 1$), we have $\Psi_1 = \Psi$ and

$$V(X_t) = \sqrt{\underset{X_t \in \Psi}{Var}(X_{t+1} - X_t)} \tag{2}$$

where $Var(\cdot)$ is the standard variance estimator. To estimate the volatility of longer-horizon changes, researchers may sample data more sparsely and look at non-overlapping sample data from only a subgrid of Ψ. In the general case of h-period volatility, data would be sequentially sampled at every hth observation (starting, say, with the first observation X_1) until the end of the sample period. Accordingly, the h-period volatility of the variable changes can be specified as follows:

$$V(X_t; h) = \sqrt{\underset{X_t \in \Psi_1}{Var}(X_{t+h} - X_t)} \quad \text{for } \Psi_1 \subset \Psi \tag{3}$$

where $\Psi_1 = \{X_t, t = 1, 1 + h, 1 + 2h, \ldots, 1 + \lambda_1 h\}$ with λ_1 being the integer part of the $(n - h - 1)/h$ value.

There are two problems with the foregoing approach. First, there is no necessary reason why other available subgrids with different starting data points should not be used. The choice of which observation to include and which to drop seems arbitrary. This also raises questions about the potential bias of the volatility measure and its sensitivity with respect to the start date of the sample period. Second, Ψ_1 can be a very small subset of Ψ, especially when measuring long-horizon volatility. With a substantial portion of data being ignored, the multi-period volatility estimator in (3) is far from efficient.

In this study we use a new estimator of multi-period volatility based on a multiple-grid approach. The new volatility estimator fully utilizes the data information available, and it is more robust and more efficient than the conventional single-grid estimator. In a recent statistical study of realized volatility of asset returns, Zhang *et al*. (2005) point out the deficiency in the conventional volatility estimator and propose a more efficient method of volatility estimation with noisy data. Instead of using only a single, arbitrarily chosen subgrid of data, as the conventional method does, the new method includes all the data subgrids and is based on the average of the variances for all individual subgrids. The multiple-grid approach is shown to provide an unbiased and efficient estimator for multi-period volatility.

Following the multiple-grid approach of Zhang *et al*. (2005), an efficient estimator for *h*-period volatility in terms of standard deviation is given by

$$V_m(X_t;\, h) = \sqrt{\frac{1}{h}\sum_{r=1}^{h} \underset{X_t \in \Psi_r}{Var}\,(X_{t+h} - X_t)} \quad \text{for } \bigcup_{r=1}^{h} \Psi_r = \Psi \tag{4}$$

Differing from the single-grid estimator, the multiple-grid estimator for the standard deviation of multi-period changes makes full use of all the data information available. By utilizing the whole set of subgrids rather than just one single subgrid, the new estimator also averts the issue concerning any arbitrariness in data subgrid selection. As *h* increases, the *Var* estimate for each subgrid has a lesser degree of freedom but the overall estimation efficiency can still be maintained through averaging of more subgrid estimates.

3. Empirical Determinants of Bilateral RER Volatility

To understand what drives bilateral RER volatility across countries, we seek to identify its principal determinants based on data from a cross section of developed economies. Unless indicated otherwise, quarterly data for exchange rates, consumer prices, and other series used to construct relevant structural variables were obtained from the International Monetary Fund's IFS database. The empirical analysis focuses on data from 19 industrial countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States. Compared to developing countries, these developed countries have relatively efficient goods and capital markets – conditions that underlie most equilibrium models of RERs. The sample choice is dictated by the data availability of structural economic variables. Except for European Union (EU) countries, which have a shorter sample period ended in 1998 Q4, the cross-country data mostly cover the period from 1973 Q3 through 2004 Q4.[4] Bilateral RERs (expressed in logarithms) are constructed based on end-of-period nominal exchange rates and consumer price indices from individual country pairs, for a total of 171 country pairs. Using the multiple-grid standard

[4] In January 1999, all the currencies of the EU countries were completely fixed against the euro at irrevocable conversion rates. There would be no changes in the values of these currencies against one another, and their changes against non-EU currencies could take place only through the fluctuating euro value. National currencies then ceased to be legal tender in all EU member countries by the end of February 2002.

deviation estimator, the volatility of RER changes over a range of time horizons (h = 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 quarters) is measured for each country pair.

We first evaluate the role of trade-related factors in explaining RER volatility, as in Hau (2002). This allows a direct comparison of our results with previous results. Financial factors will be added to the model subsequently. The sequential modeling strategy helps illustrate the robustness of the estimated empirical relation and evaluate the relative importance of trade-related and financial factors.

3.1 RER Volatility and Trade-Related Factors

In specifying the empirical model, the potential determinants of RER volatility to be considered can be classified into several groups. The first group contains variables representing volatilities of traditional macroeconomic factors such as relative money growth, relative productivity growth, and relative changes in government spending between countries.[5] For each country pair, the h-quarter volatility of relative money growth is measured as the standard deviation of h-quarter changes in the logarithms of the relative M2 money supply between the respective countries. The corresponding volatility of relative productivity growth is given by the standard deviation of h-quarter changes of the logarithmic difference in per-capita output between the countries. The volatility of relative government spending is computed as the standard deviation of h-quarter changes in the relative ratio of government spending (as a share in GDP) between the countries. To capture the possible impact of other unspecified real shocks, we include also the volatility of relative real output growth, calculated as the standard deviation of h-quarter changes of the logarithmic difference in real GDP between the countries.

The second group consists of trade-related determinants. It includes transport costs and openness to trade. Central to the gravity model literature on international trade is the vital role geography plays in determining trade costs. Transport costs tend to increase with distance. Other things being equal, countries are likely to trade more with proximate countries than with distant countries. Thus, distance is often used as a proxy for transport costs. Our data on bilateral distance are compiled from the CEPII dataset, with the distance being calculated as the population-weighted average distance between the major cities in the two countries (Head and Mayer, 2002).[6] By taking proper account of the geographic distribution of population within each country, the weighted distance measure indirectly incorporates the possible impact of population size on trade flows between countries.

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5 In our preliminary analysis we included the volatility of interest rate differentials as a possible explanatory variable. Adding the interest rate variable, which was found to be very much insignificant, produced little change in our statistical results.

6 We also considered three other distance measures given in the CEPII dataset, including one calculated as the simple distance between the capital cities and another as the distance between the most populated cities of the two countries. The empirical results reported later in this paper are not sensitive to the choice of the distance measure.

The degree of trade openness of each country is measured as the average of the total trade (import plus export) as a share of GDP over the sample period. For country pairs, the trade openness estimates are averaged between the two countries. In addition to the average degree of trade openness, this study further investigates whether the variability of the over-time changes in trade openness matters. Since the pace of change in trade openness can vary considerably over time and across countries, the average openness measure may not capture the full impact of the change in trade openness on RER dynamics. Indeed, the models of Obstfeld and Rogoff (2000) and Hau (2002) show that, all else being equal, an increase in the share of traded goods would result in a decrease in the RER level. These models yield a similar reduced-form relation as follows:

$$\text{Change in RER} = (1 - \text{Trade Openness}) \times \text{Structural Shock} \qquad (5)$$

Given the variability of the structural shock, economies with greater trade openness would have lower RER volatility. This testable implication is central to the analysis of Hau (2002). Going further, we notice another implication of the same equation: RER volatility would depend also on the variability of trade openness. Changes in trade openness can take place in varying degrees over time. All else the same, large abrupt changes in trade openness are expected to add volatility to RER changes.[7] This leads to a new testable hypothesis: Countries with greater variability in trade openness changes would tend to have higher RER volatility than would countries with less variability in trade openness changes.

The third set of variables to be considered includes two control variables. The first variable is the size of the two economies, which is measured as the mean of the logarithm of GDP (in US$) of the home and the foreign country. The country size variable, which acts as a general control for macroeconomic heterogeneity of countries, has often been identified in the optimum currency area literature as a possible determinant of exchange rate volatility. The second variable is a dummy variable for countries that are contiguous and have a common border. This contiguity variable has been widely used in the gravity model literature on international trade.

The empirical model of bilateral RER volatility is given by

$$\begin{aligned} VRER_{jk} = {} & \beta_0 + \beta_1 VMS_{jk} + \beta_2 VGOVT_{jk} + \beta_3 VPROD_{jk} + \beta_4 VRGDP_{jk} + \beta_5 LDIST_{jk} \\ & + \beta_6 ATOPEN_{jk} + \beta_7 VTOPEN_{jk} + \beta_8 CONTIG_{jk} + \beta_9 LSIZE_{jk} + \varepsilon_{jk} \end{aligned} \qquad (6)$$

where $j \neq k$ and $j < k$ are country indicators; $VRER_{jk}$ is the volatility of bilateral RER changes; VMS_{jk} is the volatility of relative money supply changes between country j and country k; $VGOVT_{jk}$ is the volatility of relative government spending changes; $VPROD_{jk}$ is the volatility of relative productivity changes;

[7] A recent study by Li (2004) finds that trade liberalizations can have an appreciable short-term impact on RERs. It is reported that RERs can depreciate considerably subsequent to trade liberalizations.

$VRGDP_{jk}$ is the volatility of relative output changes; LDIST is the logarithm of the distance between countries; $ATOPEN_{jk}$ is the average trade openness and $VTOPEN_{jk}$ is the volatility of trade openness changes; $CONTIG_{jk}$ is a border dummy variable that takes a value of one for countries that are contiguous with a common border and a value of zero otherwise; $LSIZE_{jk}$ is the average size of the economies; and ε_{jk} is the random error term.

A few remarks are in order. First, note that for each sampling horizon *h*, (6) is a cross-sectional regression covering country pairs in the sample. For different sampling horizons, the regression equations give the relationship between real exchange rate volatility and its determinants at different data frequencies. Thus, the usual GARCH type specification considered in the time series framework is not applicable to the current exercise. Second, the dependent variable $VRER_{jk}$ is an efficient estimate of the volatility of bilateral RER changes constructed using equation (4). It is known that if an independent variable is an estimated quantity, then the resulting estimator could be asymptotically biased. Nonetheless, a constructed dependent would *not* lead to an asymptotically biased estimator. Third, robust standard errors are reported in our subsequent analysis to control for the effect of heteroskedastic error terms. Fourth, without any *a priori* information, we consider only linear specifications, which can be viewed as a first order approximation of the true unknown functional form.

Table 1 reports the results from estimating the RER volatility equation in (6) over different time horizons. These multiple-horizon results can display varying patterns depending on the variable being considered. The money supply variable (VMS) is statistically significant with a positive sign for all the horizons examined. This indicates that a positive relation between RER volatility and money growth volatility exists not just over short horizons of less than two years, but also over much longer horizons. The coefficient estimate for the government spending variable (VGOVT) is significantly positive at short horizons only. At horizons of two years or longer, no significant relation can be detected between RER volatility and government spending. For the productivity variable (VPROD) and the output growth variable (VRGDP) alike, their coefficient estimates are statistically insignificant at all the horizons and may even have an incorrect sign.[8] Hence, among all the traditional macroeconomic fundamentals, it is the money growth volatility that is the main contributor to RER volatility at different horizons.

On the other hand, the significance of trade-related factors is generally evident from Table 1. There is strong evidence to support the presence of a positive relation between RER volatility and transport costs proxied by distance (LDIST). The invariably positive and significant LDIST coefficient estimates suggest that greater transport costs tends to raise RER volatility over not just short but also long horizons. The short-horizon results mirror those found in research on the deviations from the law of one price (Engel and Rogers, 1996; Parsley and Wei, 2001), while the results for longer horizons support the RER analysis

[8] For the productivity variable, we also experimented with two different measures: one is per capita real GDP and the other is per capita industrial output. Our reported results are not sensitive to the use of either measure.

by Brava-Ortega and di Giovanni (2004).[9] Regarding trade openness (ATOPEN), our results affirm the prediction of the open economy macroeconomics models of Obstfeld and Rogoff (2000) and Hau (2002) that greater trade openness tends to induce lower RER volatility. While the negative relation between RER volatility and the level of trade openness seems weak at short horizons, it becomes significant at horizons of one year or longer. By contrast, greater variability of trade openness tends to add RER volatility. The estimated coefficients on VTOPEN are all positive and significant at horizons of four quarters or longer. It follows that countries with more variable changes in trade openness tend to have higher RER volatility than do countries with less variable changes in trade openness. In other words, the pace of transition in trade openness matters. In regard to the finding of insignificant impact at short horizons, Hau (2002) suggests that the relation between RER volatility and trade openness can be tenuous when exchange rate pass-through is rather limited over short horizons. We will reexamine the empirical evidence related to trade openness when considering a more general RER volatility model that incorporates financial factors as well.

The two control variables seem able to pick up additional systematic effects on RER volatility. The geographic contiguity variable (CONTIG) has consistently a negative coefficient and is significant at all the time horizons beyond one quarter. It follows that contiguous countries tend to share lower RER volatility than noncontiguous countries do. To the extent that countries are likely to trade more with contiguous countries than with distant countries, the CONTIG variable may capture some effects of trade intensity on RER volatility (beyond those through the distance and trade openness variables). In contrast, the coefficient on the country size variable (LSIZE) is significantly positive for horizons longer than one quarter, suggesting that larger economies tend to have greater RER volatility. Nonetheless, this positive relation with country size fails to hold up when financial factors are included in our extended analysis.

3.2 The Contributing Role of Financial Factors

Since a country's trade growth and its financial growth often go together, our RER analysis is extended to include both trade- and finance-related factors. Different financial factors are considered as potential determinants of bilateral RER volatility. These include the depth of financial development within countries (an internal measure) and the financial openness of countries (an external measure). The degree of financial deepening is measured as total credit to the private sector in percent of GDP. An alternative measure of financial depth is the ratio of total domestic credit to GDP. Total domestic credit includes funds available to both private and government sectors. Because this measure can be sensitive to the budgetary conditions of the government sector, the total credit/GDP ratio may not show the true extent to which credit is available to the private sector. We choose not to use this alternative measure. In our data

9 In a related study, Broda and Romalis (2004) examine the relation between bilateral trade and short-term RER volatility. They find that trade expansion reduces RER volatility even after allowing for simultaneity in estimation.

construction, the average of the two countries' private credit/GDP ratios over the sample period is computed for each country pair.

As for financial openness, two measures are used. The first one comes from Chinn and Ito's (2006) index of capital account openness. To capture both the intensity and the scope of capital controls, this openness index is constructed as the first principle component of four IMF binary classifications that codify the regulatory restrictions on cross-border financial transactions. The index takes on larger values for countries that are financially more open. The second measure is the indicator of financial openness derived from the data of Lane and Milesi-Ferretti (2001), who observe that many of the benefits of international financial integration are tied to gross holdings of foreign assets and liabilities. Being constructed as the ratio of net foreign assets (NFA) – including foreign direct investment, portfolio investment, and bank lending – to GDP, this measure provides a broad indicator of financial openness. The NFA reflects essentially the accumulation of realized capital flows into an economy.[10] While the Chinn-Ito index represents a *de jure* measure on financial openness, the NFA indicator gives a *de facto* measure of financial integration. For either measure, the average degree of financial openness is computed for each country pair over the sample period. The relevance of both *de jure* and *de facto* measures of financial openness will be investigated.

Augmenting the empirical model of RER volatility to include financial variables, we have

$$\begin{aligned} \text{VRER}_{jk} = \; & \beta_0 + \beta_1\text{VMS}_{jk} + \beta_2\text{VGOVT}_{jk} + \beta_3\text{VPROD}_{jk} + \beta_4\text{VRGDP}_{jk} + \beta_5\text{LDIST}_{jk} \\ & + \beta_6\text{ATOPEN}_{jk} + \beta_7\text{VTOPEN}_{jk} + \beta_8\text{AFDEPTH}_{jk} + \beta_9\text{ANFA}_{jk} + \beta_{10}\text{AKOPEN}_{jk} \\ & + \beta_{11}\text{CONTIG}_{jk} + \beta_{12}\text{LSIZE}_{jk} + \varepsilon_{jk} \end{aligned} \quad (7)$$

where $j \neq k$ and $j < k$ are country indicators; AFDEPTH_{jk} is the average financial depth between countries j and k; ANFA_{jk} is the *de facto* level of financial openness measured by the average NFA; AKOPEN_{jk} is the average value of the Chinn-Ito index of capital account openness; and the rest of the variables are defined in equation (6). In our preliminary analysis, we also experimented with a model that contained two additional explanatory variables: one for the variability of financial openness changes (VNFA) over the sample period, and another for the variability of financial depth changes (VFDEPTH) within the sample period. These two variables were consistently found to be insignificant and were thus omitted from our final estimated model.

Table 2 contains the results from estimating the RER volatility equation in (7) over different time horizons. Among all the traditional fundamental variables, the money growth variable remains to be an important source of RER volatility. Similar to that reported earlier in Table 1, RER volatility is found to increase with

[10] Standard intertemporal open-economy models suggest a long-term positive relation between the RER and the NFA of the country. In analyzing a sample of 20 OECD countries, Lane and Milesi-Ferreti (2002) find that growth in NFA (as a ratio of GDP), through its impact on the trade balance, tend to be associated with RER appreciation in the long run.

the volatility of money supply changes at all the time horizons considered. On the other hand, the variability in government spending changes is no longer a significant contributor to RER volatility at any horizons. The government spending variable may even have an ambiguous sign. Similar negative results are obtained for the productivity growth and the output growth variable alike.

Among the trade-related factors, the distance variable – the transport cost proxy – is strongly significant and has a positive sign at every horizon. In accord with the earlier results from Table 1, the positive relation between RER volatility and transport costs again prevails at not only short horizons but also at much longer horizons. Regarding the two trade openness variables, RER volatility is still found to be negatively related to the average level of trade openness but positively related to the variability of trade openness changes. While greater trade openness tends to reduce RER volatility, larger and more variable changes in trade openness raise RER volatility. Unlike the results from Table 1, these effects of trade openness are now shown to be significant not just at relatively long horizons but also at short horizons of two quarters or less. Evidently, the inclusion of financial factors into the empirical model can help detect stronger effects of trade-related factors on RER volatility, particularly at short horizons. It is therefore useful to analyze both trade- and finance-related factors at the same time.

Financial factors are also significant contributors to RER volatility. As shown in Table 2, the financial depth variable (AFDEPTH) is significantly negative at short horizons of one year or less, though not at longer horizons. This suggests that economies with greater financial depth are associated with significantly lower RER volatility over short horizons. For financial openness, the *de facto* variable (ANFA) and the *de jure* variable (AKOPEN) appear to yield comparable but somewhat different results across horizons. Both variables have consistently a positive coefficient for all the horizons examined. However, while the *de jure* variable of financial openness is significant at both short and long horizons, the *de facto* variable is significant at horizons shorter than three years only.[11] Despite some differences in statistical significance at longer horizons, the overall results suggest that greater financial openness tends to induce higher RER volatility over short horizons.[12]

The results on the two control variables seem different from those reported in Table 1. The country size variable now has a negative coefficient at every horizon, with the coefficient being significant at primarily short horizons. Hence, after accounting for the inter-country differences in financial factors, short-horizon RER volatility is found to increase rather than decrease with the size of economies. The geographic contiguity variable has a negative coefficient but it is significant at long horizons only.

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11 As an alternative measure to NFA, we tried another de facto measure of financial openness, constructed based on the sum of the banking system's total foreign assets and foreign liabilities as a ratio to GDP. Compared to the NFA variable, this alternative variable was also significant but at even shorter horizons of one year or less only.

3.3 Relative Importance of Trade-Related and Financial Factors

The results reported in sections 3.1 and 3.2 shows the statistical significance of both trade-related and financial factors. To gain deeper insight into these different sources of RER volatility, it is useful to quantify their relative importance. Two questions of interest are: How much more can the trade-related factors explain RER volatility than the traditional fundamentals variables? How much more can the financial factors explain RER volatility than the traditional fundamentals variables? In the absence of any exact way to measure their relative importance, we consider a ratio measure based on regression estimates of the incremental explanatory power attributable to individual groups of variables. Starting with the general model given in equation (7), which contains all the three main groups of potential determinants (namely, traditional fundamental variables, trade-related variables, and financial variables), we check how much the adjusted R^2 value would fall if any one of the groups of these determinants was not included. For example, when the regression is re-run with the group of standard fundamental variables omitted, the resulted change in the adjusted R^2 value will then measure the incremental explanatory power of these variables. By doing this alternately for the other groups of variables, we can measure the incremental contribution of trade-related variables and that of finance-related variables as well. Using the contribution estimate for standard fundamentals as a yardstick, we compute the following measures of relative contribution (RC) for the trade- and finance-related factors:

$$RC_{Trade} = \frac{\text{Change in adjusted } R^2 \text{ when omitting the trade related factors}}{\text{Change in adjusted } R^2 \text{ when omitting the traditional fundamentals}} \quad (8a)$$

$$RC_{Finance} = \frac{\text{Change in adjusted } R^2 \text{ when omitting the financial factors}}{\text{Change in adjusted } R^2 \text{ when omitting the traditional fundamentals}} \quad (8b)$$

If the RC measure equals *m*, for instance, the respective factors would contribute *m* times as much explanatory power as the traditional fundamentals variables. A value larger (less) than one would mean these factors contribute more (less) explanatory power than the traditional fundamentals do.

Table 3 reports the relative contribution estimates for both trade- and finance-related factors over different horizons. At all the horizons under study, trade-related factors seem to contribute considerably more in explanatory power compared to any of the other groups of variables. The difference is particularly noticeable at shorter horizons. Relative to the standard fundamentals, trade-related factors contribute about 11 times as much explanatory power, and financial factors contribute about twice as much explanatory power at horizons of one to two quarters. Interestingly, the traditional fundamentals variables gain relative importance as the time horizon lengthens. Indeed, these fundamentals variables become

[12] Stiglitz (2000) notes that greater financial openness tends to induce greater macroeconomic stability because capital flows are strongly procyclical.

more significant in contribution than financial factors at the three-year and longer horizons. At the five-year horizon, the explanatory power of financial factors is no more than one-third of that of standard fundamentals variables. Hence, while trade-related factors remain relatively important in explaining RER volatility at longer horizons, the importance of financial factors is limited to shorter horizons only.

4. Explaining Bilateral Nominal Exchange Rate Volatility

Running parallel to the literature on RER volatility is another important strand of literature that investigates the sources of nominal exchange rate (NER) volatility. Bayoumi and Eichengreen (1998) evaluate the ability of optimum currency area (OCA) theory to explain the observed differences in bilateral NER volatility across industrial countries. Their study examines the volatility of one-year changes in bilateral NERs. Standard OCA factors – including trade interdependence, relative output volatility (which captures asymmetric output disturbances), and the size of economies (which governs the potential benefits from a stable currency) – are shown to account for a good portion of the cross-country variation in NER volatility during two sample periods, 1973-1982 and 1982-1992. In particular, NER volatility is found to decrease with bilateral trade but increase with the size of economies.

In addition to the standard OCA factors, Devereux and Lane (2003) analyze the importance of financial factors in determining bilateral NER volatility. Their analysis looks at two specific measures: one indicates the degree of financial interdependence between countries, and another indicates the depth of financial development within countries. Data for both developing and industrial countries are studied, and monthly NER volatility over the period 1995-2000 is examined. The study obtains a mixture of results. For developing countries, greater financial interdependence (measured in terms of external debt) tends to raise NER volatility. For industrial countries, however, no definite relation can be established between financial interdependence and NER volatility. On the other hand, greater financial depth tends to lower NER volatility for developing countries but raise it for industrial countries. According to Devereux and Lane (2003), these results are consistent with the proposition that financial constraints and frictions are much more important in developing than in industrial countries.

While short-term RER fluctuations are expected to come mostly from NER changes, long-term RER fluctuations may in large part reflect relative price changes as well. To the extent that relative price adjustment tends to offset NER changes more over longer horizons, as predicted by the purchasing power parity hypothesis, RER changes are expected to be increasingly less volatile compared to NER changes as the adjustment horizon extends. To verify this, we compute the average RER volatility and the average NER volatility at each time horizon. As reported in Table 4, the volatility of RERs increases with longer horizons, but at a slower rate than the volatility of NERs. Consequently, the NER to RER volatility ratio also increases steadily with the time horizon, as captured by the following estimated equation:

$$\text{VNER/VRER} = \underset{(0.010)}{0.972} + \underset{(0.005)}{0.053} \times \ln(\text{Horizon}) \qquad R^2 = 0.935 \qquad (9)$$

with the numbers in parentheses being standard errors. The cross-horizon estimates confirm that although RER volatility and NER volatility are, as expected, close in size at short horizons, they can differ substantially over long horizons.

A pertinent question is how much can the variables used earlier to explain RER volatility also explain NER volatility? Apart from our focus on bilateral rates between industrial countries only, the following analysis differs from Devereux and Lane (2003) in that we use a different volatility estimator and entertain a different set of potential determinants. Furthermore, this study examines exchange rate volatility over not just one specific time horizon but over a wide range of different horizons. Our analysis thus permits the empirical relation between NER volatility and its determining factors to vary across time horizons. Following equation (7), the empirical model to be estimated is given by

$$\begin{aligned} \text{VNER}_{jk} = {} & \beta_0 + \beta_1\text{VMS}_{jk} + \beta_2\text{VGOVT}_{jk} + \beta_3\text{VPROD}_{jk} + \beta_4\text{VOUT}_{jk} + \beta_5\text{LDIST}_{jk} \\ & + \beta_6\text{ATOPEN}_{jk} + \beta_7\text{VTOPEN}_{jk} + \beta_8\text{AFDEPTH}_{jk} + \beta_9\text{ANFA}_{jk} + \beta_{10}\text{AKOPEN}_{jk} \\ & + \beta_{11}\text{CONTIG}_{jk} + \beta_{12}\text{LSIZE}_{jk} + \varepsilon_{jk} \end{aligned} \qquad (10)$$

where VNER_{jk} is the volatility of bilateral NER changes between country j and country k, and all the other explanatory variables are defined earlier in equation (7).

Table 5 summarizes the estimation results for NER volatility. In general, the empirical model seems able to fit the data reasonably well. In comparison to those results for RER volatility, we get some similar and some different results depending on the explanatory variable being examined. Among the traditional fundamental variables, we still find that the money growth is the only significant contributor to NER volatility over a wide range of horizons.

Among the trade-related factors, transport costs have a significant positive relation with NER volatility – as with RER volatility – over both short and long horizons. Our earlier results show that RER volatility tends to decrease with the level of trade openness but increase with the variability of trade openness changes. Similar relations can be found between trade openness and NER volatility. However, both relations involving trade openness become insignificant at horizons longer than four years. Comparing the results between RER and NER volatility suggests that trade openness seems to have a longer impact on RER volatility than on NER volatility. A possible interpretation of the difference in impact is that trade openness may affect RER volatility through relative price adjustment over long horizons.

The potential impact of financial deepening on NER volatility is a contested issue, as discussed by Devereux and Lane (2003). All else being equal, more financially developed countries are able to tolerate greater NER volatility. On the other hand, greater domestic financial development can help stabilize NERs by facilitating intertemporal smoothing by households and firms and by adding liquidity to financial markets. The former argument supports a positive relation between financial depth and NER volatility, whereas the latter suggests a negative relation between them.

In their empirical analysis, Devereux and Lane (2003) find a significant positive relation between financial depth and short-horizon NER volatility for industrial countries. Our analysis produces interestingly different results depending on the horizon over which NER volatility is measured. Greater financial depth tends to be associated with significantly lower NER volatility at horizons shorter than two years but with higher NER volatility at horizons longer than four years. The difference between our results and those of Devereux and Lane (2003) may be attributed partly to the difference in model specifications. Our estimated model includes two trade-related variables (trade openness and transport cost proxy) not considered by Devereux and Lane (2003). We observe that if these two trade-related variables were dropped from the model, we would detect a significant positive relation between financial depth and NER volatility at both short and long horizons. After controlling for the effects of the trade-related variables, however, we find a significant negative, rather than positive, relation between financial depth and NER volatility at short horizons.

The two financial openness variables, on the other hand, have consistently a positive coefficient. In contrast to the RER results, however, the relation between the *de jure* financial openness variable and NER volatility is not statistically significant over any horizons. Evidently, the *de facto* variable (ANFA) appears more relevant than the *de jure* variable (AKOPEN) in explaining NER volatility. A significant relation can be found between the *de facto* financial openness variable and NER volatility over horizons of less than two years. Accordingly, the impact of financial openness on NER volatility is limited to relatively short horizons.

5. Further Analysis of Bilateral RER Volatility

We next examine two additional issues: one relates to the effect of the choice of a nominal exchange rate regime and the other to the effect of the choice of a numeraire currency.

5.1 The Issues

Did the European Monetary System (EMS) matter? Studies by, e.g., Mussa (1986) and Baxter and Stockman (1989) have suggested that high exchange rate volatility is not strongly tied to high volatility of macroeconomic fundamentals and that the flexibility of the exchange rate regime matters in producing high RER volatility under floating rates. Our dataset includes a number of countries participating in the EMS. These EMS member countries pegged their currencies against one another but let their currencies float against other currencies. Indeed, the EMS country pairs account for about 20% of the sample observations. This brings us to the question whether the EMS reduced the bilateral RER volatility among member countries. To examine the potential impact of the exchange rate regime on RER volatility, we incorporate into our analysis a dummy variable for intra-EMS country pairs that takes a value of one when the two countries are both members of the EMS and a value of zero otherwise.

Is there a numeraire currency effect? Under our bilateral approach, all possible combinations of country pairs are considered. By not basing our analysis on any arbitrary choice of a base country, it bypasses the issue of whether the choice of a numeraire currency matters. In a related literature on the reverting behavior of RERs, Koedijk *et al*. (1998) and Papell and Theodoridis (2001) point out that it is exceptionally difficult to find evidence of mean reversion in RERs when using the US dollar – and even more so when using the Japanese yen – as the numeraire currency. Papell and Theodoridis (2001) further observe that, among other factors, the differing exchange rate volatility across currencies may play a role in explaining the numeraire effect. Because the power of stationarity tests decreases with the volatility of the data series, stronger test results are more likely to come from currencies that are less volatile. Should we expect to find a similar numeraire currency effect on RER volatility? This leads us to the question of whether dollar-based and yen-based RER series are generally more volatile than other RER series.

5.2 Empirical Results

Table 6 reports the average estimates of RER volatility for different subgroups of countries. These estimates generally show that intra-EMS real rates are, on average, less volatile than other real rates. They also indicate that US dollar-based real rates have, on average, higher volatility than non-dollar-based rates and that yen-based real rates have, on average, higher volatility than non-yen-based rates. All these patterns seem to hold up independent of the time horizon over which RER volatility is measured. The key issue then is whether the observed patterns of volatility differences reflect simply some systematic inter-country differences or something more intrinsic. Would the EMS regime effect still exist after controlling for the other determinants of RER volatility? Would the currency numeraire effect still exist after accounting for the other determinants of RER volatility?

To investigate the empirical relevance of either the EMS regime effect or the numeraire currency effect on RER volatility, we augment the empirical model in equation (7) with three additional dummy variables. They are defined as follows: $EMSDU_{jk}$ is a dummy variable that takes a value of one when country j and country k are both EMS countries and a value of zero otherwise; $USDU_{jk}$ is a dummy variable that takes a value of one when either country j or country k is the US and a value of zero otherwise; and $JPDU_{jk}$ is a dummy variable that has a value of one when either country j or country k is Japan and a value of zero otherwise. The expanded empirical model is given by

$$\begin{aligned} VRER_{jk} = \ & \beta_0 + \beta_1 VMS_{jk} + \beta_2 VGOVT_{jk} + \beta_3 VPROD_{jk} + \beta_4 VOUT_{jk} + \beta_5 LDIST_{jk} \\ & + \beta_6 ATOPEN_{jk} + \beta_7 VTOPEN_{jk} + \beta_8 AFDEPTH_{jk} + \beta_9 ANFA_{jk} + \beta_{10} AKOPEN_{jk} \\ & + \beta_{11} CONTIG_{jk} + \beta_{12} LSIZE_{jk} + \beta_{13} EMSDU_{jk} + \beta_{14} USDU_{jk} + \beta_{15} JPDU_{jk} + \varepsilon_{jk} \qquad (11) \end{aligned}$$

We note that the three newly added dummy variables can also be viewed as additional control variables. The augmented model may thus provide a further check on the robustness of our earlier findings.

Table 7 presents the results from estimating equation (11). The coefficient on the intra-EMS dummy variable is significantly negative at short horizons of one to two quarters but not at longer horizons. Hence, the regime effect is limited to RER volatility at short horizons only. There is still a significant EMS regime effect on short-horizon RER volatility even after controlling for the effects of all the other determinants. In addition, the dollar-rate dummy variable is mostly insignificant except at horizons longer than four years. At shorter horizons, the dollar-rate dummy variable may even have a negative coefficient. Similar results apply to the yen-rate dummy variable, which has no significantly positive coefficient at any horizons. Overall, the results provide little support for the existence of any systematic numeraire currency effect on RER volatility.

We next evaluate the robustness of our earlier results from Table 2 concerning other determinants. In most cases, qualitatively similar results are obtained in Table 7. Among the traditional macroeconomic fundamentals variables, the money growth volatility continues to be the only significant contributor to RER volatility. All the trade-related factors are also significant and have the appropriate signs at every horizon. On the impact of financial openness, the allowance for the EMS regime effect seems to weaker the statistical relation between financial openness and RER volatility at long horizons. Nonetheless, greater financial openness still induces significantly lower RER volatility at shorter horizons, as shown in Table 2. As for financial depth, some short-horizon evidence remains supportive of a negative effect of financial deepening on RER volatility.

Moreover, the coefficient on the geographic contiguity variable is consistently negative in sign and has a magnitude comparable to those reported earlier but, unlike in our previous results, it is no longer statistically significant. The change in results may be explained by the fact that many of the pairs of contiguous countries in our data involve EMS countries. Consequently, the inclusion of the intra-EMS variable may dilute the contiguity effect and make it difficult to detect its statistical significance. For the country size effect, short-horizon RER volatility continues to have a negative relation with country size even after controlling for the other determinants of RER volatility.

6. Concluding Remarks

The RER is a key relative price variable for macroeconomic adjustment in an open economy. Over recent decades, the world has witnessed rapid liberalization in trade and capital flows. With increasing openness to trade and cross-border investment, important questions have been raised about their implications for macroeconomic volatility. In this context, our analysis goes beyond the traditional macroeconomic fundamental variables and examines whether, and how much, trade- and finance-related factors contribute to RER volatility. Analyzing both trade- and finance-related factors together is particularly relevant, given that trade growth and financial development often go together.

This study provides a systematic analysis of the observed cross-country differences in bilateral RER volatility between industrial countries. The results of our analysis affirm the contributing role of both trade- and finance-related factors in RER volatility. In a departure from previous studies, our RER volatility analysis employs a multiple-horizon approach. It properly recognizes that the empirical relation between RER volatility and its determinants can vary depending on the time scale at which volatility is evaluated. The multiple-horizon analysis allows us to identify which determinants may influence RER volatility at both short and long horizons and which determinants may contribute to RER volatility at only short or only long horizons (and not both).

Our findings show that while higher transport costs tend to raise RER volatility, greater trade openness tends to reduce RER volatility. In either case, the empirical relation is found to be significant over both short and long horizons. The effects of finance-related factors on RER volatility are limited primarily to short horizons, however. According to the internal financial measure, economies with greater financial depth tend to have lower RER volatility over short horizons. According to the external financial measure, economies with greater financial openness tend to have higher RER volatility over short horizons. Further results also suggest a significant EMS regime effect on RER volatility at short horizons of one to two quarters – though not at longer horizons – after controlling for the effects of all the other determinants. In general, the relative importance of the different types of RER volatility determinants can vary across horizons. The financial factors are found to be more important than the traditional macroeconomic fundamentals in explaining RER volatility over short horizons. However, the traditional fundamentals variables steadily gain importance in explanatory power as the time horizon lengthens, and they become more important than the financial factors at longer horizons. Similar to that of the financial factors, the explanatory power of the trade-related factors also declines at longer horizons. Nonetheless, the trade-related factors remain to be more important than either the traditional fundamentals or the financial factors in explaining RER volatility at all the horizons examined. All in all, time horizon does matter when evaluating the determinants of RER volatility.

As a caveat, the scope of this multiple-horizon study of RER volatility is limited to industrial countries. Compared to industrial countries, developing countries display much greater heterogeneity in their stage of economic development. While equilibrium models of RERs typically examine the steady-state behavior, many developing countries are still in their long transition process to a full market economy, with their economies being far from a steady state. Aside from having significantly less efficient goods and capital markets, developing countries are also more susceptible to such idiosyncratic events as banking and currency crises, which can generate enormous RER volatility. Hence, weaker empirical results may more likely be obtained from developing countries than from industrial countries. To be sure, more research will be needed to determine to what extent our findings can be applied to developing countries.

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Table 1. Relations between RER Volatility and Trade-Related Factors over Different Horizons

	h = 1	*h* = 2	*h* = 4	*h* = 6	*h* = 8	h = 10	*h* = 12	*h* = 14	*h* = 16	*h* = 18	*h* = 20
VMS	0.081 *	0.105 *	0.106 *	0.110 *	0.113 **	0.114 **	0.102 *	0.106 **	0.116 **	0.110 **	0.098 **
	(0.038)	(0.042)	(0.041)	(0.044)	(0.042)	(0.043)	(0.040)*	(0.039)	(0.037)	(0.037)	(0.035)
VGOVT	0.019	0.060 *	0.083 *	0.079 *	0.045	0.035	0.021	0.019	0.007	0.005	0.014
	(0.019)	(0.027)	(0.037)	(0.040)	(0.047)	(0.048)	(0.050)	(0.045)	(0.044)	(0.042)	(0.038)
VPROD	-0.017	-0.018	-0.020	-0.006	-0.023	0.003	-0.022	0.005	-0.061	-0.057	-0.094
	(0.011)	(0.016)	(0.023)	(0.033)	(0.040)	(0.049)	(0.052)	(0.060)	(0.062)	(0.070)	(0.071)
VRGDP	-0.012	-0.009	0.000	0.006	0.057	0.023	0.084	0.030	0.101	0.023	0.026
	(0.022)	(0.038)	(0.090)	(0.067)	(0.105)	(0.083)	(0.104)	(0.086)	(0.100)	(0.090)	(0.097)
LDIST	0.812 **	1.171 **	1.689 **	2.162 **	2.238 **	2.520 **	2.671 **	2.847 **	2.900 **	2.719 **	2.560 **
	(0.067)	(0.102)	(0.148)	(0.199)	(0.254)	(0.299)	(0.335)	(0.352)	(0.392)	(0.407)	(0.432)
ATOPEN	-0.007	-0.012	-0.020 *	-0.024 *	-0.037 *	-0.044 *	-0.055 **	-0.058 **	-0.059 *	-0.052 *	-0.064 *
	(0.005)	(0.007)	(0.009)	(0.012)	(0.015)	(0.017)	(0.020)	(0.021)	(0.023)	(0.023)	(0.026)
VTOPEN	0.031	0.076	0.143 *	0.203 *	0.318 **	0.411 **	0.544 **	0.580 **	0.618 **	0.558 **	0.623 **
	(0.033)	(0.048)	(0.071)	(0.088)	(0.113)	(0.123)	(0.146)	(0.145)	(0.160)	(0.155)	(0.167)
CONTIG	-0.498	-0.887 *	-1.203 *	-1.694 *	-2.180 *	-2.413 *	-2.745 *	-2.863 *	-3.085 *	-3.440 *	-3.617 *
	(0.284)	(0.412)	(0.599)	(0.748)	(0.910)	(1.078)	(1.227)	(1.309)	(1.393)	(1.452)	(1.475)
LSIZE	0.051	0.216 **	0.362 **	0.547 **	0.615 **	0.757 **	0.905 **	1.018 **	1.134 **	1.162 **	1.044 **
	(0.044)	(0.064)	(0.100)	(0.139)	(0.182)	(0.215)	(0.238)	(0.250)	(0.279)	(0.292)	(0.326)
Adjusted R^2	0.715	0.718	0.727	0.696	0.650	0.630	0.627	0.633	0.615	0.581	0.543

Notes: The estimated model is given by equation (6) and has a degree of freedom of 161. *h* indicates the time horizon (in quarters) over which the volatility of RER changes is evaluated. The number in parentheses shown beneath each individual coefficient estimate gives the robust standard error. Statistical significance is indicated by a single asterisk (*) for the 5% level and double asterisks (**) for the 1% level.

Table 2. Empirical Results with both Trade-Related and Financial Factors Included

	h = 1	*h* = 2	*h* = 4	*h* = 6	*h* = 8	h = 10	*h* = 12	*h* = 14	*h* = 16	*h* = 18	*h* = 20
VMS	0.117**	0.156**	0.189**	0.158**	0.171**	0.155**	0.142**	0.127**	0.137**	0.130**	0.117**
	(0.037)	(0.042)	(0.044)	(0.045)	(0.047)	(0.045)	(0.045)	(0.042)	(0.041)	(0.040)	(0.039)
VGOVT	-0.007	0.002	-0.009	0.001	-0.007	-0.013	-0.009	-0.027	-0.011	-0.012	0.011
	(0.017)	(0.029)	(0.049)	(0.049)	(0.062)	(0.062)	(0.068)	(0.060)	(0.061)	(0.057)	(0.058)
VPROD	-0.011	-0.005	-0.004	0.021	0.006	0.040	0.005	0.036	-0.040	-0.029	-0.082
	(0.009)	(0.013)	(0.019)	(0.029)	(0.034)	(0.043)	(0.048)	(0.056)	(0.059)	(0.066)	(0.067)
VRGDP	-0.031	-0.009	0.080	-0.004	0.078	-0.003	0.094	0.006	0.095	0.000	0.032
	(0.024)	(0.036)	(0.087)	(0.066)	(0.105)	(0.084)	(0.106)	(0.090)	(0.103)	(0.093)	(0.102)
LDIST	0.894**	1.295**	1.886**	2.188**	2.169**	2.297**	2.525**	2.670**	2.700**	2.447**	2.177**
	(0.078)	(0.118)	(0.174)	(0.235)	(0.296)	(0.348)	(0.393)	(0.415)	(0.453)	(0.469)	(0.488)
ATOPEN	-0.034**	-0.055**	-0.089**	-0.096**	-0.119**	-0.125**	-0.132**	-0.118**	-0.114**	-0.115**	-0.117**
	(0.007)	(0.010)	(0.016)	(0.021)	(0.026)	(0.031)	(0.036)	(0.037)	(0.040)	(0.041)	(0.044)
VTOPEN	0.135**	0.226**	0.378**	0.428**	0.553**	0.626**	0.745**	0.755**	0.749**	0.692**	0.670**
	(0.036)	(0.049)	(0.074)	(0.098)	(0.121)	(0.138)	(0.160)	(0.161)	(0.174)	(0.175)	(0.192)
AFDEPTH	-0.009*	-0.017**	-0.028*	-0.026	-0.036	-0.034	-0.036	-0.017	-0.025	-0.030	-0.044
	(0.004)	(0.006)	(0.011)	(0.013)	(0.019)	(0.020)	(0.026)	(0.026)	(0.029)	(0.028)	(0.032)
ANFA	0.033**	0.053**	0.082**	0.075**	0.081**	0.072*	0.073	0.050	0.046	0.051	0.039
	(0.007)	(0.010)	(0.018)	(0.022)	(0.030)	(0.034)	(0.041)	(0.042)	(0.046)	(0.047)	(0.050)
AKOPEN	0.373*	0.773**	1.242**	1.843**	2.509**	2.854**	2.558**	2.090*	2.138*	2.505*	2.726*
	(0.173)	(0.247)	(0.364)	(0.504)	(0.608)	(0.758)	(0.850)	(0.938)	(0.982)	(1.035)	(1.075)
CONTIG	-0.328	-0.567	-0.641	-1.299	-1.758	-2.170	-2.410	-2.728	-2.947*	-3.341*	-3.617*
	(0.242)	(0.358)	(0.549	(0.730)	(0.929)	(1.127)	(1.309)	(1.395)	(1.502)	(1.565)	(1.618)
LSIZE	-0.422**	-0.568**	-0.789**	-0.712*	-0.775*	-0.648	-0.390	-0.026	0.202	0.088	0.164
	(0.101)	(0.145)	(0.226)	(0.321)	(0.392)	(0.489)	(0.549)	(0.607)	(0.646)	(0.680)	(0.716)
Adjusted R^2	0.766	0.768	0.770	0.729	0.683	0.658	0.642	0.641	0.619	0.588	0.550

Notes: The estimated model is given by equation (7) and has a degree of freedom of 158. See Table 1 for additional notes.

Table 3. The Relative Importance of Trade- and Finance-Related Factors in Explaining RER Volatility

	h = 1	*h* = 2	*h* = 4	*h* = 6	*h* = 8	h = 10	*h* = 12	*h* = 14	*h* = 16	*h* = 18	*h* = 20
Trade-related	11.319	11.101	7.593	9.512	5.916	6.127	5.362	5.274	5.589	3.719	3.202
Finance-related	1.911	1.982	1.384	1.549	1.273	1.176	0.937	0.486	0.198	0.257	0.304

Notes: The benchmark value for the ratio measure is one. A value of *m*, in general, means the respective factors have *m* times as much explanatory power as the standard macroeconomic fundamentals do.

Table 4. Average Estimates of RER Volatility and of NER Volatility at Different Time Horizons

	h = 1	*h* = 2	*h* = 4	*h* = 6	*h* = 8	h = 10	*h* = 12	*h* = 14	*h* = 16	*h* = 18	*h* = 20
AVRER	0.048	0.069	0.098	0.123	0.141	0.156	0.169	0.177	0.184	0.189	0.191
AVNER	0.048	0.070	0.102	0.130	0.150	0.169	0.185	0.196	0.207	0.214	0.220
AVNER/AVRER	0.989	1.012	1.036	1.052	1.067	1.083	1.097	1.110	1.123	1.137	1.156

Notes: AVRER denotes the average volatility of RER changes over a given time horizon, whereas AVNER denotes the average volatility of NER changes over a given time horizon.

Table 5. Explaining Bilateral NER Volatility

	h = 1	*h* = 2	*h* = 4	*h* = 6	*h* = 8	h = 10	*h* = 12	*h* = 14	*h* = 16	*h* = 18	*h* = 20
VMS	0.110**	0.129**	0.145**	0.128**	0.142**	0.124**	0.107**	0.089**	0.090*	0.084*	0.062
	(0.037)	(0.041)	(0.045)	(0.046)	(0.049)	(0.048)	(0.047)	(0.043)	(0.044)	(0.042)	(0.043)
VGOVT	-0.006	-0.001	-0.001	0.008	0.010	0.001	0.015	0.011	0.040	0.040	0.073
	(0.017)	(0.029)	(0.052)	(0.052)	(0.068)	(0.068)	(0.076)	(0.070)	(0.072)	(0.068)	(0.071)
VPROD	-0.015	-0.016	-0.019	0.002	-0.018	0.009	-0.033	0.000	-0.070	-0.036	-0.108
	(0.009)	(0.013)	(0.021)	(0.033)	(0.041)	(0.054)	(0.060)	(0.072)	(0.077)	(0.091)	(0.094)
VRGDP	-0.032	-0.012	0.056	-0.037	0.023	-0.076	-0.004	-0.113	-0.051	-0.183	-0.157
	(0.024)	(0.037)	(0.091)	(0.072)	(0.115)	(0.094)	(0.120)	(0.103)	(0.119)	(0.109)	(0.125)
LDIST	0.970**	1.409**	2.031**	2.415**	2.432**	2.606**	2.867**	3.024**	3.252**	3.183**	3.279**
	(0.081)	(0.118)	(0.174)	(0.243)	(0.314)	(0.380)	(0.431)	(0.475)	(0.527)	(0.571)	(0.613)
ATOPEN	-0.035**	-0.054**	-0.080**	-0.081**	-0.092**	-0.095**	-0.090*	-0.072	-0.047	-0.043	-0.011
	(0.007)	(0.010)	(0.017)	(0.023)	(0.030)	(0.036)	(0.042)	(0.045)	(0.049)	(0.051)	(0.056)
VTOPEN	0.136**	0.226**	0.369**	0.407**	0.503**	0.556**	0.639**	0.614**	0.571**	0.478	0.340
	(0.036)	(0.050)	(0.077)	(0.104)	(0.132)	(0.153)	(0.180)	(0.190)	(0.209)	(0.266)	(0.243)
AFDEPTH	-0.010*	-0.014*	-0.015	-0.002	0.003	0.014	0.028	0.055	0.073	0.078*	0.088*
	(0.004)	(0.006)	(0.012)	(0.016)	(0.024)	(0.026)	(0.033)	(0.033)	(0.039)	(0.038)	(0.045)
ANFA	0.037**	0.055**	0.076**	0.065*	0.058	0.048	0.035	0.008	-0.023	-0.025	-0.071
	(0.007)	(0.010)	(0.019)	(0.026)	(0.036)	(0.042)	(0.050)	(0.053)	(0.059)	(0.061)	(0.069)
AKOPEN	0.298	0.393	0.350	0.372	0.377	0.261	-0.661	-1.430	-2.160	-2.368	-2.071
	(0.166)	(0.239)	(0.368)	(0.533)	(0.671)	(0.859)	(0.968)	(1.077)	(1.130)	(1.216)	(1.292)
CONTIG	-0.263	-0.540	-0.879	-1.645*	-2.237*	-2.740*	-2.995*	-3.340*	-3.336*	-3.595*	-3.544*
	(0.245)	(0.363)	(0.558)	(0.755)	(0.982)	(1.230)	(1.393)	(1.482)	(1.542)	(1.603)	(1.667)
LSIZE	-0.459**	-0.605**	-0.758**	-0.640	-0.571	-0.505	-0.201	0.083	0.522	0.285	0.774
	(0.105)	(0.153)	(0.247)	(0.365)	(0.461)	(0.582)	(0.661)	(0.733)	(0.789)	(0.845)	(0.914)
Adjusted R^2	0.772	0.768	0.752	0.693	0.619	0.573	0.542	0.530	0.505	0.477	0.438

Notes: The estimated model is given by equation (8) and has a degree of freedom of 155. See Table 1 for other notes.

Table 6. Inter-Country Group Estimates of RER Volatility

	h = 1	*h* = 2	*h* = 4	*h* = 6	*h* = 8	h = 10	*h* = 12	*h* = 14	*h* = 16	*h* = 18	*h* = 20
Intra-EMS rates	3.434	4.697	6.845	8.727	10.151	11.316	12.369	13.090	13.517	14.114	14.282
All others	5.170	7.460	10.643	13.265	15.105	16.754	18.060	18.921	19.707	20.118	20.330
Ratio	0.664	0.630	0.643	0.658	0.672	0.675	0.685	0.692	0.686	0.702	0.702
Dollar-based rates	5.589	8.244	12.055	15.794	18.628	21.229	23.395	24.792	26.550	27.488	29.303
All others	4.712	6.718	9.583	11.900	13.525	14.948	16.093	16.858	17.445	17.839	17.851
Ratio	1.186	1.227	1.258	1.327	1.377	1.420	1.454	1.471	1.522	1.541	1.641
Yen-based rates	6.045	9.112	13.634	16.745	18.546	20.529	22.582	23.885	23.601	23.232	21.575
All others	4.659	6.616	9.397	11.788	13.535	15.031	16.189	16.965	17.792	18.339	18.761
Ratio	1.298	1.377	1.451	1.421	1.370	1.366	1.395	1.408	1.327	1.267	1.150

Notes: The volatility estimate is the average volatility of RERs computed for each group of relevant country pairs.

Table 7. Multiple-Horizon Results with Allowance for both EMS and Currency Numeraire Effects

	h = 1	*h* = 2	*h* = 4	*h* = 6	*h* = 8	h = 10	*h* = 12	*h* = 14	*h* = 16	*h* = 18	*h* = 20
VMS	0.092*	0.121**	0.180**	0.159**	0.179**	0.165**	0.151**	0.138**	0.143**	0.142**	0.133**
	(0.038)	(0.043)	(0.047)	(0.048)	(0.051)	(0.049)	(0.049)	(0.045)	(0.044)	(0.043)	(0.040)
VGOVT	-0.005	0.007	-0.009	-0.002	-0.013	-0.025	-0.022	-0.047	-0.039	-0.049	-0.049
	(0.017)	(0.029)	(0.048)	(0.049)	(0.062)	(0.061)	(0.068)	(0.059)	(0.060)	(0.054)	(0.051)
VPROD	-0.008	-0.003	-0.007	0.017	0.005	0.037	-0.002	0.028	-0.031	-0.013	-0.057
	(0.010)	(0.014)	(0.020)	(0.029)	(0.034)	(0.042)	(0.046)	(0.055)	(0.058)	(0.065)	(0.065)
VRGDP	-0.021	-0.007	0.073	-0.009	0.076	0.001	0.087	0.005	0.120	0.036	0.111
	(0.024)	(0.038)	(0.091)	(0.070)	(0.106)	(0.085)	(0.108)	(0.092)	(0.102)	(0.091)	(0.094)
LDIST	0.916**	1.264**	1.822**	2.152**	2.206**	2.327**	2.529**	2.647**	2.869**	2.718**	2.697**
	(0.089)	(0.138)	(0.192)	(0.271)	(0.335)	(0.394)	(0.440)	(0.473)	(0.511)	(0.528)	(0.529)
ATOPEN	-0.029**	-0.044**	-0.083**	-0.095**	-0.125**	-0.134**	-0.140**	-0.128**	-0.123**	-0.133**	-0.147**
	(0.008)	(0.010)	(0.017)	(0.022)	(0.029)	(0.034)	(0.040)	(0.042)	(0.046)	(0.047)	(0.050)
VTOPEN	0.134**	0.211**	0.350**	0.421**	0.575**	0.661**	0.774**	0.793**	0.871**	0.859**	0.996**
	(0.036)	(0.051)	(0.078)	(0.103)	(0.132)	(0.149)	(0.175)	(0.174)	(0.190)	(0.186)	(0.201)
AFDEPTH	-0.004	-0.009	-0.027*	-0.029*	-0.038	-0.035	-0.037	-0.017	-0.009	-0.013	-0.009
	(0.005)	(0.007)	(0.013)	(0.015)	(0.022)	(0.023)	(0.029)	(0.029)	(0.033)	(0.032)	(0.034)
ANFA	0.026**	0.040**	0.074**	0.075**	0.091*	0.085*	0.087	0.067	0.064	0.082	0.089
	(0.008)	(0.012)	(0.021)	(0.026)	(0.035)	(0.040)	(0.048)	(0.050)	(0.055)	(0.056)	(0.058)
AKOPEN	0.215	0.504	1.225**	1.838**	2.527**	2.794**	2.478**	1.944	1.434	1.773	1.190
	(0.190)	(0.263)	(0.403)	(0.544)	(0.683)	(0.799)	(0.926)	(1.018)	(1.108)	(1.146)	(1.185)
CONTIG	-0.318	-0.574	-0.669	-1.293	-1.722	-2.085	-2.326	-2.596	-2.725	-3.017	-3.090
	(0.246)	(0.368)	(0.553)	(0.746)	(0.948)	(1.153)	(1.339)	(1.424)	(1.542)	(1.591)	(1.640)
LSIZE	-0.265*	-0.362*	-0.679*	-0.765	-0.972	-0.962	-0.775	-0.512	-0.107	-0.442	-0.506
	(0.122)	(0.176)	(0.283)	(0.399)	(0.501)	(0.611)	(0.695)	(0.769)	(0.836)	(0.871)	(0.908)
EMSDU	-0.362	-0.614	-0.208	0.003	0.284	0.311	0.361	0.331	-0.203	0.139	-0.380
	(0.173)*	(0.251)*	(0.383)	(0.498)	(0.617)	(0.711)	(0.830)	(0.903)	(1.013)	(1.069)	(1.155)
USDU	-0.325	-0.559	-0.494	0.293	0.931	1.713	2.177	2.809	3.177	4.181*	6.098**
	(0.260)	(0.394)	(0.573)	(0.832)	(1.018)	(1.238)	(1.402)	(1.533)	(1.685)	(1.727)	(1.860)
JPDU	-0.461	-0.361	0.368	0.347	0.007	0.179	0.452	0.744	-1.469	-1.867	-4.334**
	(0.239)	(0.362)	(0.533)	(0.805)	(1.087)	(1.349)	(1.561)	(1.605)	(1.721)	(1.677)	(1.646)
Adjusted R^2	0.770	0.773	0.769	0.724	0.679	0.656	0.642	0.643	0.628	0.609	0.615

Notes: The estimated model is given by equation (11) and has a degree of freedom of 155. See Table 1 for other notes.