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Remoteness and Real Exchange Rate Volatility

CLAUDIO BRAVO-ORTEGA and JULIAN DI GIOVANNI*

This paper examines the impact of trade costs on real exchange rate volatility. The relationship is examined by constructing a two-country Ricardian model of trade, based on the work of Dornbusch, Fischer, and Samuelson (1977), which shows that higher trade costs result in a larger nontradables sector, in turn leading to higher real exchange rate volatility. We then construct a remoteness index to proxy for trade costs, and provide empirical evidence supporting the channel. [JEL F30, F40]

International trade has grown at a startling pace over the past two decades. This growth can be explained by many factors, such as the lowering of trade costs, improved technology, and reduced trade barriers. This globalization also affects the macroeconomy. As Obstfeld and Rogoff (2001) show, small trade costs can have large effects on many macroeconomic phenomena. There has also recently been an open debate on the contribution of geography and institutions to economic growth (see Gallup, Sachs, and Mellinger, 1998; and Acemoglu, Johnson, and Robinson, 2001) because geographical barriers naturally lead to higher transport costs. Furthermore, another branch of the economic growth literature has shown that macroeconomic volatility tends to have a negative impact on growth.[1]

These different literatures point to potentially strong linkages between trade costs and the macroeconomy. Yet there is still little rigorous work that examines

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*Claudio Bravo-Ortega is an Assistant Professor of Economics at the Universidad de Chile; Julian di Giovanni is an Economist in the Research Department of the IMF. The authors would like to thank Müge Adalet, Barry Eichengreen, Miguel Fuentes, Pierre-Olivier Gourinchas, Gian Maria Milesi-Ferretti, Maurice Obstfeld, Andrew Rose, an anonymous referee, and the Editor, Bob Flood, for comments. We thank Susanne Winkler for research assistance.

[1]See Ramey and Ramey (1995) for an early contribution and Rodrik (1999) for a more recent one.

the channels through which trade imperfections affect macroeconomic variables. In this paper, we provide a simple, intuitive model and empirical evidence, both of which allow us to analyze the impact of trade costs on the *long-run* volatility of a key macroeconomic variable: the real exchange rate. In particular, we incorporate Ricardian comparative advantage into a macroeconomic model to demonstrate that trade imperfections impact real exchange rate volatility.

The model shows how higher trade costs will lead to a greater range of nontradable goods, thereby resulting in a country's having higher real exchange rate volatility.[2] Our model builds on the classic work of Dornbusch, Fischer, and Samuelson (1977). In particular, we incorporate uncertainty in the form of productivity shocks. We then present empirical results that support the model. Our result is based on the following intuition: in a Ricardian world without trade costs, productivity shocks will lead to changes in comparative advantage in producing goods across countries. However, the law of one price will continue to hold. Transport costs create a wedge between prices for some of the goods in which the domestic and foreign economies specialize. This wedge will result in the production in both economies of nontradable goods, whose prices are independent of the other country's productivity shock. Therefore, given country shocks, relative prices of these goods will not equate across countries; and because a country's overall price index is made up of both tradable and nontradable goods, the real exchange rate will move. Therefore, the higher the trade costs are (measured as iceberg costs; i.e., a constant fraction of the good melts away in transit), the higher the real exchange rate volatility will be.

We believe that this is a simple point that has not been fully explored in the literature. Indeed, our paper complements Hau's (2002) result that more open economies experience less real exchange rate volatility, although we highlight a different mechanism than he does. Hau shows that in an economy with nominal rigidities, imported goods provide a channel for a rapid adjustment of the domestic aggregate price level.[3] We, in turn, show that trade costs determine the size of the nontradables sector. In our model, a larger nontradables sector implies a greater level of heterogeneity in the diffusion of productivity shocks among different economies. Thus, our paper is related to trade costs (either tariffs or transport costs), whereas these trade imperfections play no explicit role in Hau's work.[4] Our work also differs from Hau's in that he assumes nominal rigidities and we do not, because we have a *rigid* productive structure that gives a fundamental role to productivity shocks and nontradables price adjustment in the long run. The crucial role of productivity shocks on the long-run real exchange rate has been recently supported by the work of Alexius (2005), who finds that when considering the relationship between funda-

[2]In Bravo-Ortega and di Giovanni (2005), we highlight a different mechanism through which trade costs affect real exchange rate volatility. In this paper, the impact of heterogeneous suppliers of traded goods on real exchange rate volatility is examined using a multicountry model of trade.

[3]In Hau's paper, the size of the nontraded goods sector is fixed, and there is only one traded good.

[4]Naknoi (2004) has also examined a similar channel in a dynamic general equilibrium framework. However, her work concentrates on short-run dynamics, whereas we argue that endogenous nontradability should be modeled in a long-run context. Furthermore, we provide direct evidence to test the hypothesis drawn from our model.

mental variables and real exchange rates over the long run, productivity shocks play an important role in explaining real exchange rate movements. Finally, we note that our approach is complementary to the new open macroeconomics literature in that we focus on the study of long-run static relationships for a cross-section of countries rather than stochastic *dynamic* general equilibrium relationships.

Measuring the potential impact of our channel for a large cross-section of countries is not easy given data constraints. Therefore, our main measure is based on how close a country is to the center of world trade. *We refer to this proxy of trade costs as "Remoteness."* As can be seen in Figure 1, our proposed relationship appears to exist in the data, that is, countries that are more remote all exhibit greater real exchange rate volatility.

I. Two-Country Model

The model that we build provides a simple illustration of how increases in trade costs can increase real exchange rate volatility by creating a wedge between the tradables and nontradables sectors so that shocks do not transmit perfectly across countries. The model is set up in a two-country framework, but the foreign country represents the rest of the world. This distinction must be made because an individual country's range of nontradable goods depends on its trade costs with all of its potential trading partners. We also make this distinction in the empirical work by using a country's real effective exchange rate and proxying overall trade costs by a country's closeness to the world trade center. Furthermore, this model is meant to explain *long-run* real exchange rate volatility. The two-country model borrows heavily from Obstfeld and Rogoff (1996) and makes one central prediction: real exchange rate volatility increases with trade costs and, therefore, increases with the distance between one country and its trade partners around the world. We outline the model below and solve for real exchange rate volatility.

Consumers

The demand side is modeled using a representative agent that maximizes consumption of a continuum of goods z, which is defined on the line [0,1]. The agent receives only labor income and maximizes the following utility function:

$$U(c) = \exp\left[\int_0^1 \log(c(z))\,dz\right], \tag{1}$$

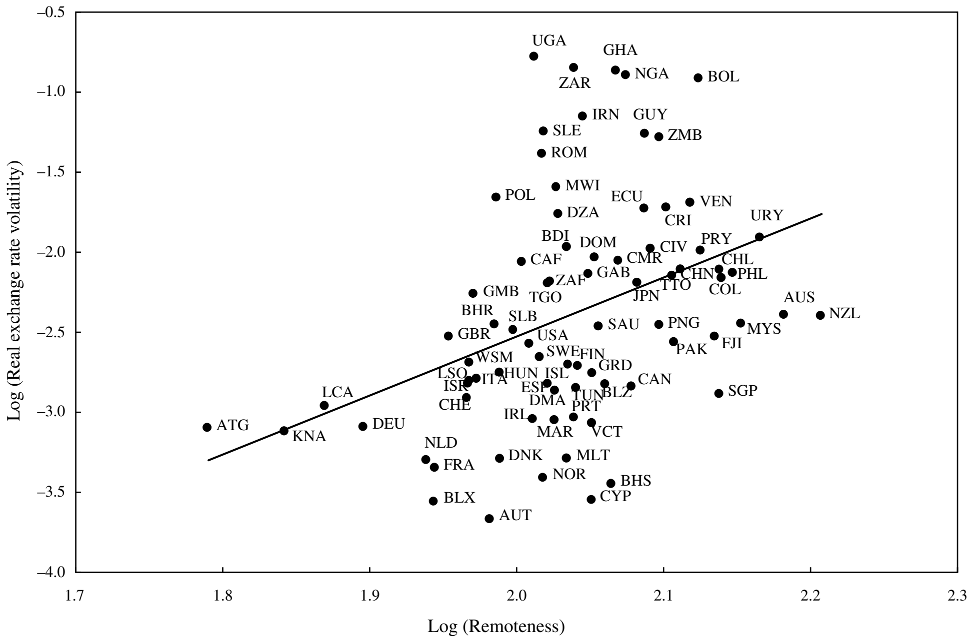
where the elasticity of substitution is set to 1.[5] If we take the good $z = 1$ to be the numeraire so that the wage rates and commodity prices are expressed in units of good 1, the price index is

$$P = \exp\left[\int_0^1 \log(p(z))\,dz\right]. \tag{2}$$

[5]The results can be obtained using the more general constant elasticity of substitution (CES) function, but the CES function greatly complicates the algebra. Therefore, the more specific function (that is, logarithmic) is used for clarity.

Figure 1. Real Exchange Rate Volatility and Remoteness Relationship

(a) Whole Sample



(b) High-Income Countries

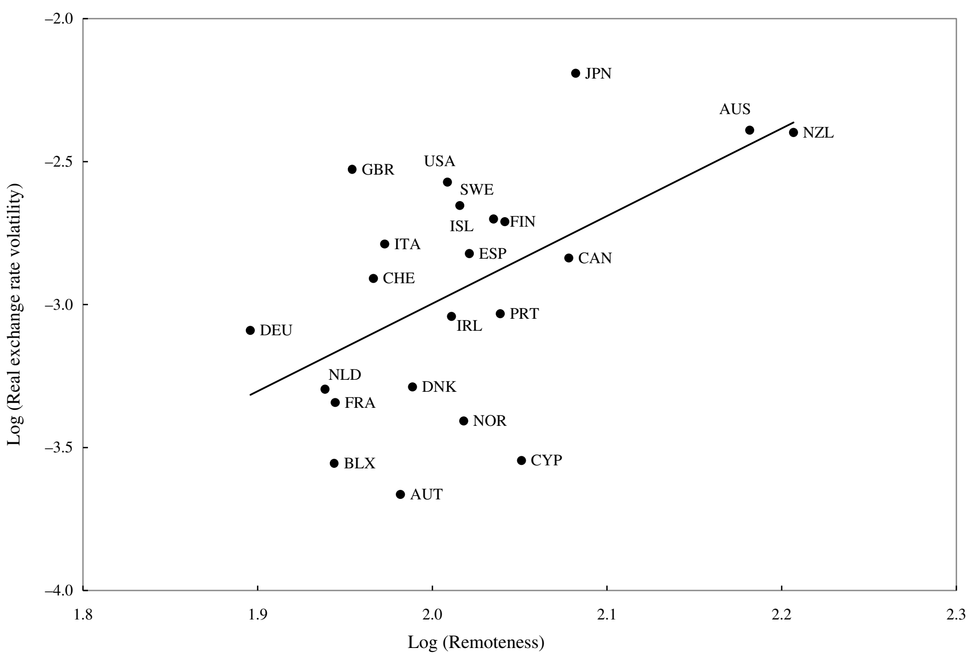
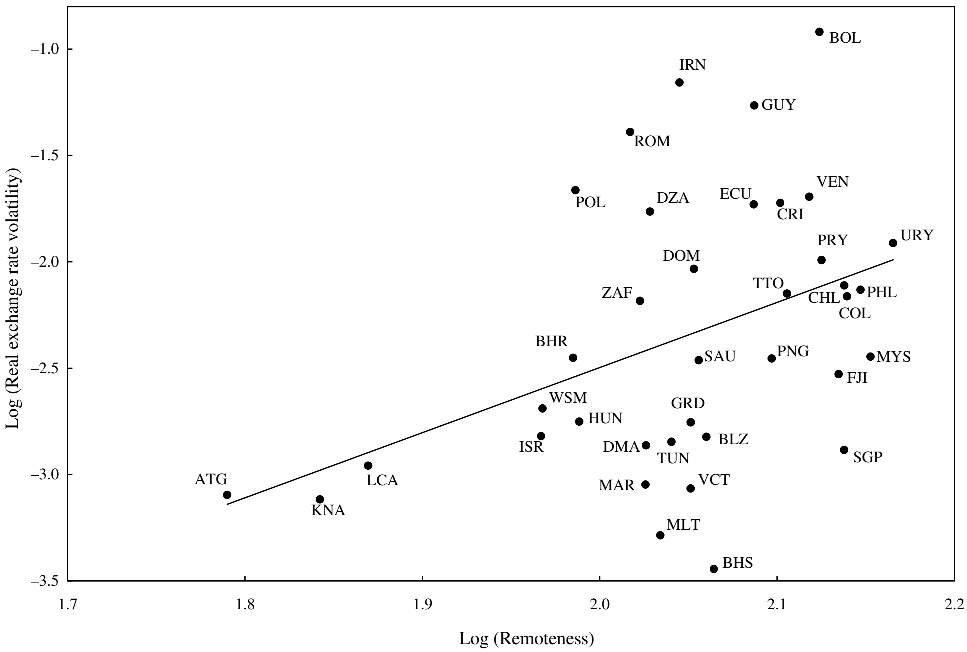
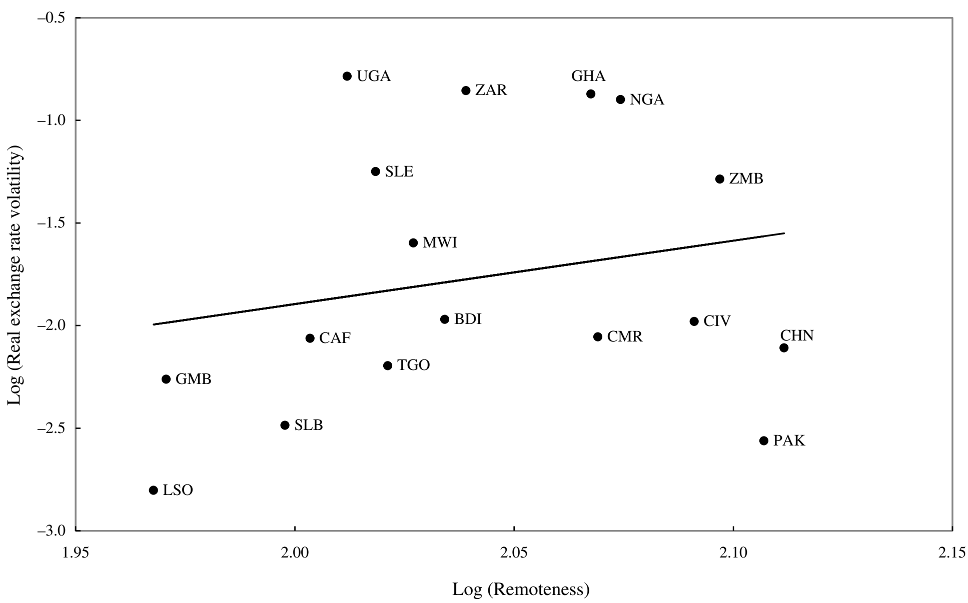


Figure 1 *(continued)*

(c) Middle-Income Countries



(d) Low-Income Countries



Notes: The figures are based on regressions of the log real exchange rate volatility on the Remoteness log. Exchange rate volatilities are calculated using 12-month log exchange rate changes over 1980–2000. Remoteness is the beginning of period value.

Similarly, the price index for the foreign country is

$$P^* = \exp\left[\int_0^1 \log(p^*(z))\,dz\right]. \tag{3}$$

Producers

Production takes place in a two-country world, in which the technology of the producers is stochastic and only requires labor input. Specifically, the home and foreign firms have the following labor requirement to produce one unit of good *z:*

$$\text{Home: } a(z) = \alpha(z)\cdot\exp(\varepsilon)$$
$$\text{Foreign: } a^*(z) = \alpha^*(z)\cdot\exp\left(\varepsilon^*\right),$$

where ε and ε^* are technological shocks that are independent of each other and identically distributed, $N(0, \sigma^2)$.[6]

Firms in each sector at home (and abroad) maximize their profits ex ante, conditional on the distribution of these shocks. Given a fixed labor supply in each country, firms in each sector choose labor such that the real wage is equal to the marginal product of labor; therefore, given labor mobility across sectors, this is equivalent to $\frac{w}{P} = \frac{1}{a(z)}$.

Given this condition in each country, a relative labor schedule that regulates comparative advantage may then be defined as:

$$A(z) = \frac{a^*(z)}{a(z)}. \tag{4}$$

This schedule is used to solve for the equilibrium wages, prices, and distribution of production across countries. This schedule holds both before and after the shocks hit the economies. Furthermore, we assume that goods are ordered such that the schedule is decreasing with respect to *z,* that is, $A'(z) < 0$.

Equilibrium

In equilibrium, the range of goods that a country produces or imports depends on productivity differentials and trade costs, $\tau > 0$. We assume that the steady-state productive structure is such that there is a zero trade balance in equilibrium, given the expected value of the relative productivity schedule, $A(z)$, defined by equation (4).

[6]The assumption of independent productivity shocks, that is, $\text{Cov}(\varepsilon, \varepsilon^*) = 0$, may seem strong. However, the assumption does not alter our main result. If there were covariance in the shocks, one extra term would be added.

We believe that this is a realistic assumption for the steady-state equilibrium. In particular, the home country will produce goods ex ante such that[7]

$$E\{w \cdot a(z)\} < E\left\{\frac{w^* \cdot a^*(z)}{1-\tau}\right\},$$

and the foreign country will produce goods such that

$$E\left\{\frac{w \cdot a(z)}{1-\tau}\right\} > E\{w^* \cdot a^*(z)\}.$$

Given the trade costs, a range of goods $z \in (z^F, z^H)$ are nontraded, where z^F is foreign goods and z^H is home goods. It is for these goods that prices in the domestic and foreign sectors are given by $p(z) = w \cdot a(z)$ and $p^*(z) = w^* \cdot a^*(z)$. The price of traded goods will not be equal, given the trade cost τ that must be paid across countries (that is, the law of one price no longer holds). In short, the Ricardian nature of the model implies specialization of each country in a range of tradable goods whose prices differ between countries by a constant factor related to trade costs.

For the sake of tractability and simplicity of exposition, we suppose that there are two periods. In the first period, the firms choose the marginal good of production, taking the expected value of the comparative advantage and trade as balanced. This has been the traditional approach in the initial model setups of Dornbusch, Fischer, and Samuelson (1977) and Krugman (1987). In a more general context, this assumption may be rational. The production structure, z^F and z^H, will be determined in the first period, which represents the steady state of the economy. The variable z^F is determined by the intersection of the $(1 - \tau)A(z)$ schedule and the trade balance schedule. The variable z^H is determined by the schedule $\frac{A(z)}{1-\tau}$ evaluated at the relative wages, w/w^*, which are determined by the previous intersection (see equation (5), where the trade balance, TB, equals zero in the first period).[8]

Thus, in the second period when a shock is realized, the schedule $A(z)$ shifts only because of the shocks; given the previously determined variables, z^F and z^H, which we assume remain fixed, relative wages and prices will adjust to the extent of the relative shocks, thereby creating a trade imbalance ex post.[9] We believe that this is a reasonable assumption given that the production structures of countries change very slowly over time compared with wage and price movements. This in turn implies that the trade balance will no longer necessarily equal zero out of steady state. We will not go through the whole derivation of equilibrium; however, if we represent home and foreign labor supplies as L and L^*, respectively, and define the trade balance as total income less total consumption ($TB = wL - PC$ for

[7]Note that similar conditions will hold ex post.

[8]For more details, see Obstfeld and Rogoff (1996).

[9]These assumptions allow us to introduce uncertainty in a tractable manner.

the home country and $TB = wL^* - PC$ for the foreign country), the relative wages can be expressed as

$$\frac{w_2}{w_2^*} = \left\{ \frac{-\left(z^H - z^F\right)TB}{\left[L^*/a^*(1)\right]} + z^F \right\} \frac{L^*/L}{\left(1 - z^H\right)}. \tag{5}$$

This equation illustrates that once the relative wages fully adjust to the extent of the relative shocks, the trade balance must adjust to a new level that might be out of the steady-state equilibrium. We now move on to explore the properties of the real exchange rate in more detail.

Real Exchange Rate Volatility

Given equations (2) and (3) and the discussion above on how one can solve for individual goods prices, the real exchange rate can be written as

$$\frac{P}{P^*} = \exp\left\{ \int_{z^F}^{z^H} \log\left(\frac{w_1 \cdot \alpha(z)}{w_1^* \cdot \alpha^*(z)} \cdot \frac{\exp(\varepsilon)}{\exp(\varepsilon^*)} \right) dz + \left[z^F - \left(1 - z^H\right)\right] \log(1 - \tau) \right\}, \tag{6}$$

where the relative prices not only depend on the prices of nontradables but also on the international specialization pattern. To solve for the volatility of the real exchange rate, we take the variance of the logarithm of this equation. In doing so, it is only the shocks, ε and ε^*, that drive the volatility of the exchange rate. In particular, the volatility of the real exchange rate can thus be expressed as

$$\mathrm{Var}\left\{ \log\left(\frac{P}{P^*} \right) \right\} - 2\left(z^H - z^F\right)^2 \sigma^2. \tag{7}$$

See the appendix for the full derivation. Given this expression, the main result of this section can then be stated (and proved) by the following proposition:

Proposition 1: *Real exchange rate volatility increases with trade costs and, therefore, increases as barriers to trade—both natural (for example, distance) and artificial (for example, tariffs)—increase.*

Proof: $\mathrm{Var}\left\{ \log\left(\frac{P}{P^*} \right) \right\} = 2\left(z^H - z^F\right)^2 \sigma^2$ and $z^F = A^{-1}\left(\frac{w_1}{w_1^*} \cdot \frac{1}{1 - \tau} \right)$, with A^{-1} decreasing given the setup of the problem. Similarly, $z^H = A^{-1}\left(\frac{w_1}{w_1^*} \cdot [1 - \tau] \right)$. Thus, $\frac{\partial z^F}{\partial \tau} < 0$ and $\frac{\partial z^H}{\partial \tau} > 0$. Therefore, one can conclude that

$$\frac{\partial}{\partial \tau}\left(\mathrm{Var}\left\{ \int_{z^F}^{z^H} (\varepsilon(z) - \varepsilon^*(z)) \partial z \right\} \right) = \frac{\partial}{\partial \tau}\left[2\left(z^H - z^F\right)^2 \sigma^2 \right] = \frac{\partial z^H}{\partial \tau} - \frac{\partial z^F}{\partial \tau} > 0,$$

and therefore that the volatility of the real exchange rate increases with trade costs. Further, if trade costs are assumed to increase with distance, as is standard in the trade literature, volatility increases with the degree of a country's geographical and commercial isolation (Q.E.D.).

This completes the theoretical part of this paper for the two-country model.[10] Empirical results in the next section confirm that Proposition 1 holds.

II. Empirical Evidence

According to the model in Section I, we expect that a country's real exchange rate volatility increases with transport costs. Because we do not have a good direct measure of transport costs, we use a distance proxy (to be discussed below). We therefore estimate the following empirical model:

$$\log\left(\sigma_i^{RER}\right) = \beta_0 + \beta_1 \log(\text{Remoteness}_i) + \gamma \mathbf{X}_i + v_i, \tag{8}$$

where σ_i^{RER} is the measure of country i's real exchange rate volatility, which is calculated over the estimated period. The methodology used to calculate this measure is discussed below. Remoteness is country i's transport-cost proxy at the beginning of the period; $\mathbf{X}_i$ includes country i's (log) real GDP per capita at the beginning of the period, measures of import tariffs and export duties, and openness and productivity shocks for robustness checks. Income per capita is included to capture other potential country characteristics that are correlated with exchange rate and general macroeconomic volatility. Indeed, there is empirical and theoretical literature that relates a country's income level to its macroeconomic volatility (for example, Acemoglu and Zilibotti, 1997).[11] Following Hau, we also include a measure of a country's openness to trade (Exports & Imports/GDP) as a robustness check. Finally, the standard errors v_i are clustered at the country level.

The model predicts the testable hypothesis that $\beta_1 > 0$. That is, the higher our measure of trade costs, the greater the bilateral real exchange rate volatility. In examining Figure 1, this relationship does appear to hold unconditionally when looking at the full sample of countries over a 20-year period. Furthermore, this result also appears to show up in the different subsamples of countries, though the strength of this relationship varies across groups.[12]

Our model relies on the propagation of productivity shocks across countries to generate real exchange rate volatility. Therefore, a more refined test of our model would examine the impact of Remoteness on the real exchange rate volatility owing to productivity shocks. Because of data limitations, a decomposition of the

[10]Note that, as argued in the previous footnote, the assumption of independent domestic and foreign shocks does not alter our results. Given the setup of the model, the solution for real exchange rate volatility, equation (7), would have the additional term Cov(ε, ε^*)($z^H - z^F$). Therefore, volatility will always increase as trade costs increase.

[11]We also experimented with fixed versus floating exchange rate dummies, but our results were robust to the inclusion of these variables.

[12]We include some countries that experience hyperinflation, such as Bolivia (BOL), Uganda (UGA), and the Democratic Republic of the Congo (ZAR), where exchange rate volatility is very high owing to a short period of time. However, if anything, including these countries will bias our estimation away from finding a strong relationship between volatility and remoteness.

real exchange rate between productivity and other shocks is beyond the scope of this paper. However, we are able to examine the impact of productivity shocks and Remoteness on the real exchange rate volatility by using shocks to total factor productivity (TFP) growth. In particular, we expand our estimating equation (8) to the following specification:

$$\log\left(\sigma_i^{RER}\right) = \beta_0 + \beta_1 \log(\text{Remoteness}_i) + \beta_2 \log(\text{Remoteness}_i) \times \log\left(\sigma_i^{TFP}\right) + \gamma \mathbf{X} + \eta_i, \tag{8'}$$

where σ_i^{TFP} is calculated as the volatility of TFP annual growth rates using data from Klenow and Rodríguez-Clare (2004). A more stringent test of the model is now that $\beta_1 > 0$ and $\beta_2 > 0$.

Equations (8) and (8') are both estimated cross-sectionally over the period 1980–2000 and over a "mini-panel" for the periods 1980–89 and 1990–2000. We choose start-of-period exogenous values to deal with potential endogeneity problems. Our model is meant to explain a long-run relationship, so we do not expect results to vary greatly over different specifications. Furthermore, we estimate this model for the whole sample, and also for the countries split into three income groups: high, middle, and low.

Data

Because the empirical specification is for a country with respect to the rest of the world, we must measure a country's real exchange rate relative to the rest of the world. We therefore use the monthly real effective exchange rate found in the International Financial Statistics (IFS) database. The volatility measure is calculated by first taking the annual real exchange rate change (in log differences) each month; for example, we take the change between February 1994 and February 1995, then the change between March 1994 and March 1995, and so on, thereby creating a rolling window of annual real exchange rate changes.[13] We then compute the standard deviation of these annual changes over different periods (that is, over either the whole sample period or over each decade) as our measure of long-run volatility.[14]

The crucial variable that we construct is Remoteness. This variable is defined as the distance from country *i* to the center of world trade. This measure captures a country's trade remoteness vis-à-vis the rest of the world. We use this measure rather than the size of the nontradables sector for several reasons. First, Remoteness captures the strength of a country's commercial ties with the rest of the world, which plays an important role in defining the size of the nontradables sector. This

[13]Taking the volatility of the log change has two advantages over taking the volatility of the log level: (1) the resulting measure is invariant to the country, and (2) the measure allows us to interpret the coefficients in the regressions essentially as elasticities.

[14]We also experimented in detrending the real exchange rate data by using common filtering techniques (Hodrick and Prescott, 1997; and Baxter and King, 1999), but our results did not vary qualitatively. Results do not vary greatly using these data instead of the annual changes.

point follows from the fact that it is not a country's distance to its closest economic pole that defines the nontradables sector, because each country has different comparative advantages. Second, Remoteness is easy to measure homogeneously across countries. Third, trying to explicitly measure a country's tradables and nontradables sectors is inherently difficult given that the nexus of the two is not obvious. For example, the price of tradable goods incorporates nontradable components owing to the distribution channel within a country; similarly, nontradable goods often incorporate traded inputs. Fourth, given the previous two points, among other issues, the Remoteness measure is probably subject to less measurement error than other potential controls. Following Frankel and Romer (1999) and Wei (2000), we define Remoteness from country *i* to the world trade center as follows:

$$\text{Remoteness}_i = \sum_{j \neq i} \pi_j \cdot \log\left(\text{distance}_{i,j}\right),$$

where *j* is an index for all countries in the world, and with

$$\pi_j = \frac{\text{Trade}_j}{\sum_k \text{Trade}_k},$$

where each country *j* is one of *i*'s trading partners, *k* represents all countries in the world, and Trade is defined as the sum of Exports and Imports. The term π_j is a weighting that captures how much total trade country *j* does compared with total world trade. The larger this term, the larger is the contribution of the bilateral distance between countries *i* and *j* to the total index of country *i.* For example, if country *j* conducts a large amount of trade and country *j* is very close to country *i,* the Remoteness_i index will be smaller, and country *i* is thus closer to the world trade center (that is, less remote). The assumption behind this index is that the closer a country is to countries that conduct a large amount of trade, the more likely the country is to be more open and to have lower trade costs. The advantage of using this index rather than an openness measure is that it does not include country *i*'s actual trade; therefore, it reduces any simultaneity concerns. The trade data are from the IMF's Direction of Trade database, and the distances between country capitals are taken from the U.S. Central Intelligence Agency.

We also collect data on import taxes and export duties from the World Bank's World Development Indicators (WDI). We take the ratios of these measures vis-à-vis total imports and exports, respectively. These ratios are used as additional potential measures of trade imperfections. However, the data are quite sparse for many countries and subject to potential measurement error (especially for the low-income countries). Therefore, we consider the regressions with these measures as simple robustness checks for the significance of the Remoteness measure. Income per capita data are primarily taken from the Penn World Tables (Heston, Summers, and Aten, 2002), with gaps filled in from the WDI and the IFS. Country income groups and the openness measure are taken from the WDI.[15]

[15]The income grouping is based on the World Bank's Atlas method. Further information and the country groups can be found at http://www.worldbank.org/data/countryclass/classgroups.htm

Empirical Results

This section presents results for estimates of equation (8). As discussed above, we estimate this equation for the cross-section as well as a panel of two decades. We also examine different subsamples of the data based on income groups. This analysis allows us to check for robustness across different types of countries around the world. In general, we find that the coefficient on the Remoteness index is both positive and significant, thus confirming the prediction of our model. However, the relative size and significance of the estimation relationship varies across subsamples and specifications.

Whole sample results

The results in Table 1 support the model's main prediction. First, with regard to the cross-sectional results (1980–2000), the measure of transport costs, Remoteness, is positive and significant as expected in all specifications. Furthermore, the coefficient is quite stable in looking across specifications (1), (3), and (4). A higher export duties–to-exports ratio corresponds to higher real exchange rate volatility, whereas the imports ratio results are mostly not significant. This latter result is puzzling and varies across specifications; thus we do not attribute much significance to it. However, the fact that taxes on exports show a positive and significant sign is consistent with the fact that these taxes are detrimental to the development of the tradables sector and hence increase real exchange rate volatility. The negative coefficient on the income variable supports the hypothesis that richer countries also exhibit less economic volatility. If we consider the panel results (1980–89/1990–2000), the estimates are similar to the cross-sectional regressions. Specification (5) includes Openness. Its coefficient is both negative and significant, which is consistent with previous evidence. The Remoteness coefficient remains positive and significant and is thus robust to including Openness. Finally, specification (6) estimates equation (8') by including the interaction of TFP volatility and Remoteness. The coefficient on Remoteness remains positive and significant. Moreover, the interaction term is positive, as hypothesized. The interaction coefficient is only significant for the panel results, but the joint tests of Remoteness and its interaction are very significant in both the cross-section and panel estimations. We interpret these results as consistent with our model's predictions.[16]

High-income country sample results

Table 2 presents results using only the high-income country sample. The Remoteness coefficient is both positive and significant in both the cross-sectional and panel regressions. This is reassuring, particularly given the strong relationship that appears in Figure 1(b). The export and import ratios are rarely significant and vary highly over the different specifications. The income per capita variable is actually positive

[16]Note that in reporting subsample analysis, we only include measures of import and export taxes for robustness checks. However, Remoteness is robust to the inclusion of all the other controls.

Table 1. Determinants of Real Exchange Rate Volatility: Whole Sample

	1980–2000					
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Remoteness)	3.651**		3.645**	3.304**	2.302**	2.615**
	(0.679)		(0.711)	(0.597)	(0.609)	(0.779)
× Log(TFP vol)						0.125
						(0.090)
Export duties/exports		8.745**	8.645**	3.112		
		(1.774)	(1.833)	(2.334)		
Import taxes/imports		0.903	1.196	–2.765+		
		(1.331)	(1.267)	(1.574)		
Log(Openness)					–0.350*	
					(0.133)	
Log(GDP per capita)				–0.430**	–0.384**	–0.366**
				(0.101)	(0.056)	(0.091)
Constant	–9.839**	–2.502**	–10.014**	–5.261**	–2.334	–3.660*
	(1.377)	(0.127)	(1.429)	(1.433)	(1.738)	(1.766)
No. of observations	78	76	70	70	72	58
R^2	0.15	0.16	0.32	0.49	0.55	0.54
Joint test of Remoteness and Remoteness × TFP vol: *F*-statistic = 6.60, *p*-value = 0.0026						
	1980–89/1990–2000					
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Remoteness)	3.454**		3.447**	3.040**	1.576**	1.992*
	(0.610)		(0.618)	(0.568)	(0.540)	(0.821)
× Log(TFP vol)						0.121*
						(0.054)
Export duties/exports		8.403**	8.406**	4.790*		
		(1.611)	(1.553)	(1.940)		
Import taxes/imports		1.652	1.228	–2.090		
		(1.136)	(1.080)	(1.310)		
Log(Openness)					–0.448**	
					(0.111)	
Log(GDP per capita)				–0.325**	–0.361**	–0.321**
				(0.087)	(0.054)	(0.073)
Constant	–9.580**	–2.696**	–9.768**	–5.820**	–0.716	–2.896
	(1.250)	(0.102)	(1.244)	(1.544)	(1.584)	(2.122)
No. of observations	156	133	127	127	145	114
R^2	0.11	0.16	0.29	0.36	0.45	0.38
Joint test of Remoteness and Remoteness × TFP vol: *F*-statistic = 6.04, *p*-value = 0.0042						

Notes: Exchange rate volatilities are calculated using rolling 12-month log exchange rate changes over specified time period. All other variables are beginning of period. Total factor productivity volatility (TFP vol) is calculated using annual growth rates of TFP. Openness is defined as total trade over GDP. Robust standard errors are in parentheses; + significant at 10 percent; *significant at 5 percent; **significant at 1 percent.

Table 2. Determinants of Real Exchange Rate Volatility: High-Income Country Sample

	1980–2000			
	(1)	(2)	(3)	(4)
Log(Remoteness)	3.061**		4.023**	4.662**
	(0.707)		(1.269)	(1.289)
Export duties/exports		122.896	–173.178	–328.896+
		(152.347)	(151.773)	(160.016)
Import taxes/imports		2.894	–3.59	–2.268
		(5.367)	(5.985)	(3.340)
Log(GDP per capita)				0.634**
				(0.215)
Constant	–9.119**	–3.000**	–10.933**	–18.323**
	(1.444)	(0.118)	(2.510)	(4.154)
No. of observations	22	21	21	21
R^2	0.30	0.05	0.31	0.45
	1980–89/1990–2000			
	(1)	(2)	(3)	(4)
Log(Remoteness)	2.855**		2.558*	2.651**
	(0.741)		(0.921)	(0.883)
Export duties/exports		107.060	22.300	–2.109
		(98.433)	(80.605)	(70.183)
Import taxes/imports		3.283	–0.342	1.185
		(4.813)	(5.329)	(3.552)
Log(GDP per capita)				0.475+
				(0.236)
Constant	–8.744**	–3.051**	–8.125**	–12.963**
	(1.502)	(0.098)	(1.828)	(3.483)
No. of observations	44	42	42	42
R^2	0.22	0.07	0.19	0.26

Notes: Exchange rate volatilities are calculated using rolling 12-month log exchange rate changes over specified time period. All other variables are beginning of period. Robust standard errors are in parentheses; + significant at 10 percent; *significant at 5 percent; **significant at 1 percent.

and significant in this subsample. This may be explained by the fact that countries such as the United States and Japan had volatile nominal rates during the period.

Middle-income country sample results

Table 3 presents results using only the middle-income country sample. The Remoteness coefficient is again positive and significant across almost all the specifications, though the coefficient is not significant in column 4 of the panel regressions. The export and import ratios are again changing sizes and signs, though the import ratio is consistently negative and more or less significant. The income per capita coefficient is negative as expected but is not significant in the panel estimation.

Table 3. Determinants of Real Exchange Rate Volatility: Middle-Income Country Sample

	1980–2000			
	(1)	(2)	(3)	(4)
Log(Remoteness)	3.024**		3.321**	3.179**
	(0.638)		(0.779)	(0.750)
Export duties/exports		5.051	–8.478	–11.225
		(9.163)	(11.503)	(13.139)
Import taxes/imports		–5.576*	–5.006+	–5.757*
		(2.599)	(2.748)	(2.497)
Log(GDP per capita)				–0.381*
				(0.184)
Constant	–8.565**	–1.797**	–8.613**	–5.002*
	(1.285)	(0.256)	(1.678)	(2.221)
No. of observations	38	37	32	32
R^2	0.16	0.16	0.28	0.35
	1980–89/1990–2000			
	(1)	(2)	(3)	(4)
Log(Remoteness)	1.949**		2.433**	2.063*
	(0.671)		(0.739)	(0.890)
Export duties/exports		11.890+	7.430	5.886
		(6.783)	(7.620)	(8.311)
Import taxes/imports		–3.553	–2.392	–3.267
		(2.187)	(2.184)	(2.226)
Log(GDP per capita)				–0.285
				(0.214)
Constant	–6.507**	–2.131**	–7.273**	–3.985
	(1.398)	(0.199)	(1.571)	(3.255)
No. of observations	76	61	56	56
R^2	0.05	0.08	0.11	0.14

Notes: Exchange rate volatilities are calculated using rolling 12-month log exchange rate changes over specified time period. All other variables are beginning of period. Robust standard errors are in parentheses; + significant at 10 percent; *significant at 5 percent; **significant at 1 percent.

Low-income country sample results

Table 4 presents results using only the low-income country sample. The Remoteness coefficient is positive in all the specifications but has very large standard errors and is thus never significant. Given the small sample size (as well as the weak unconditional relationship depicted in Figure 1(d)), this result is not very surprising. The export ratio coefficient is always positive, whereas the import ratio is negative. On the whole, they appear to cancel each other out, however. Meanwhile, the income per capita coefficient is negative but not significant.

Overall, this section has presented reduced form results that confirm the main prediction of the two-country model of Section I. That is, a country's long-run real exchange rate volatility increases with the trade costs that it faces (as measured by

Table 4. Determinants of Real Exchange Rate Volatility: Low-Income Country Sample

	1980–2000			
	(1)	(2)	(3)	(4)
Log(Remoteness)	3.091		2.498	3.216
	(3.730)		(2.579)	(3.223)
Export duties/exports		4.949+	4.828+	4.054
		(2.342)	(2.679)	(2.873)
Import taxes/imports		–4.150*	–4.523	–3.201
		(1.813)	(3.015)	(4.060)
Log(GDP per capita)				–0.355
				(0.292)
Constant	–8.077	–1.512**	–6.54	–5.627
	(7.606)	(0.310)	(5.277)	(5.546)
No. of observations	17	17	16	16
R^2	0.05	0.32	0.37	0.41
	1980–89/1990–2000			
	(1)	(2)	(3)	(4)
Log(Remoteness)	4.190		5.024	6.259+
	(3.825)		(3.213)	(3.311)
Export duties/exports		5.068*	5.482*	4.409+
		(1.991)	(2.183)	(2.350)
Import taxes/imports		–4.120+	–4.32	–2.771
		(1.944)	(3.003)	(2.987)
Log(GDP per capita)				–0.644**
				(0.207)
Constant	–10.539	–1.659**	–11.976+	–10.082
	(7.924)	(0.339)	(6.493)	(6.731)
No. of observations	34	28	27	27
R^2	0.05	0.25	0.31	0.41

Notes: Exchange rate volatilities are calculated using rolling 12-month log exchange rate changes over specified time period. All other variables are beginning of period. Robust standard errors are in parentheses; + significant at 10 percent; *significant at 5 percent; **significant at 1 percent.

Remoteness). This result is robust across specifications when using the whole sample of data and is significant across most subsamples.

III. Conclusions

This paper examines the impact of trade costs on real exchange rate volatility. The channel studied implies that the size of the nontradables sector is determined by trade costs. This channel then affects the degree to which idiosyncratic productivity shocks diffuse between countries; the extent to which these shocks diffuse is reflected in the dissimilarities of their price indices. We endogenize this channel using a simple Ricardian model of trade. Finally, we take the model to the data and directly test our theoretical prediction, which is indeed supported.

Appendix

Two-Country Real Exchange Rate Volatility

The variance of the real exchange rate can be expressed as follows:

$$\begin{aligned}
\mathrm{Var}\left\{\log\left(\frac{P}{P^*}\right)\right\} &= \mathrm{Var}\left\{\int_{z^F}^{z^H}\log\left(\frac{w_1\cdot a(z)}{w_1^*\cdot a^*(z)}\cdot\frac{\exp(\varepsilon)}{\exp(\varepsilon^*)}\right)_{TB=0} dz\right\} \\
&= \mathrm{Var}\left\{\int_{z^F}^{z^H}\log\left(\frac{w_1\cdot a(z)}{w_1^*\cdot a^*(z)}\right)_{TB=0} dz\right\} \\
&+ \mathrm{Var}\left\{\int_{z^F}^{z^H}\log\left(\frac{\exp(\varepsilon)}{\exp(\varepsilon^*)}\right) dz\right\} \\
&= \mathrm{Var}\left\{\int_{z^F}^{z^H}(\varepsilon-\varepsilon^*)\,dz\right\} \\
&= 2\left(z^H-z^F\right)^2\sigma^2,
\end{aligned} \tag{A.1}$$

where we have used the fact that only ε and ε^* are stochastic and that z^F and z^H remain fixed after shocks are realized.

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