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Trade Costs and Real Exchange Rate Volatility: The Role of Ricardian Comparative Advantage

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Trade Costs and Real Exchange Rate Volatility: The Role of Ricardian Comparative Advantage

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Abstract

This paper examines the impact of trade costs on real exchange rate volatility. We incorporate a multi-country Ricardian model of trade, based on the work of Eaton and Kortum (2002), into a macroeconomic model to show how bilateral real exchange rate volatility depends on relative technological differences and trade costs. These differences highlight a new channel, in which the similarity of a pair of countries' set of suppliers of traded goods affects bilateral exchange rate volatility. We then test the importance of this channel using a large panel of cross-country data over 1970–97, and find strong evidence supporting the channel.

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I. Introduction

What impact does globalization have on the international macroeconomy? More specifically, what are the macroeconomic consequences of increased integration in international trade? These are large, but important, questions to consider given the continuing integration of countries across the world. This paper seeks to better understand the effect of trade integration on one important macroeconomic variable, the real exchange rate. In particular, we study the determinants of *long-run* real exchange rate volatility, and focus on the effects of trade costs on volatility. We emphasize a new channel relating these two variables theoretically in a multi-country setting, and provide empirical evidence supporting the channel.

The importance of trade costs has traditionally been examined in the international trade literature, but more recently researchers have begun focusing on the impact of these costs on the international macroeconomy.[2] As Obstfeld and Rogoff (2001) so elegantly show, small trade costs can have large effects on many macroeconomic phenomena—arguably solving six international macroeconomic puzzles. Another strand of the literature, exemplified by the work of Backus, Kehoe, and Kydland (1992, 1995), is the international real business cycle (RBC) literature. The models in this literature try to quantitatively replicate patterns found in the data and emphasize goods trade in a two-country setting, but have not been completely successful and have left several puzzles open. One such puzzle is the "price anomaly," which arises when models cannot generate terms of trade (and thus real exchange rate) volatility as high as that found in the data.[3]

This paper highlights a new channel through which trade costs affect real exchange rate volatility in the context of a simple model and provide empirical evidence supporting the existence of the channel. Specifically, we emphasize the interaction of two countries with all other countries in the rest of the world, rather than just their bilateral interaction.[4] We show that the heterogeneity in suppliers of traded goods impacts how technological shocks diffuse across countries, and thereby affect the relative price indices of two countries. For example, the model predicts that two countries which are close to each other and have similar technological endowments will have a similar set of supplier countries for traded goods. Therefore, ceteris paribus, shocks to countries around the world will diffuse to the two countries in a similar manner (via trade), which in turn will lead to similar movements in their

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[2] See Anderson and van Wincoop (2004) for a comprehensive survey.

[3] Recent work, such as Ravn and Mazzenga (2004), have tried to solve this anomaly by modeling the impact of bilateral trade costs in more depth, but results have been mixed. Heathcote and Perri (2002) have had more success by concentrating on frictions in the financial market.

[4] The emphasis on more than just bilateral relationships complements the work of Anderson and van Wincoop (2003) in the trade literature, and Kose and Yi (2004) in the international RBC literature. Also see Fitzgerald (2004) for work that highlights other country effects.

prices indices, and thus lower bilateral real exchange rate volatility.

We incorporate Ricardian comparative advantage into a static macroeconomic framework by constructing a multi-country model that builds on the innovative work of Eaton and Kortum (2002). Their work lends itself to a very tractable and coherent modeling of some of the fundamental characteristics underlying trade across countries. In this world, the distribution of trade is governed by relative technologies and trade costs. The key impact of trade costs is not on tradable/nontradable sectors' relative sizes as is often considered in the international macroeconomic literature, but instead on the dissimilarity of the *set* of providers of traded goods that each country has.[5] In particular, there is no longer complete specialization in the production of any given good, so different countries may import the same good from different source countries. This difference arises endogenously due to transport costs and technological differences across countries.

We then take the model to the data. Though most tests in the empirical literature that studies real exchange rates rely on the time series properties of the data, our specifications also rely on the cross-sectional dimension for identification.[6] In particular, we use panel data covering the period of 1970–97 over five year periods, where the unit of observation is the country-pair.[7] We exploit detailed trade data in order to construct a common supplier index of traded goods, which we use as a proxy to measure the channel through which trade costs affect exchange rate volatility in our model. This variable has the advantage of varying over time, therefore it is not lost when controlling for country-pair fixed effects like other geographical proxies for trade costs (e.g., distance). We further control for other standard economic variables, and estimate the model across different sub-samples of the data (defined by level of development). For the whole sample, the impact of a standard deviation decrease in the supplier index implies a 5 percentage point decrease in bilateral real exchange rate volatility over five years. This effect is significant, economically large, and robust to different specifications. Furthermore, the index is also significant in the various sub-samples. We

[5]See Bravo-Ortega and di Giovanni (2005) for a model that endogenizes the impact of tradable/nontradables sectors relative size on long real exchange rate volatility.

[6]There are several papers in the empirical literature that highlight the importance of trade costs (whether they be physical, institutional, or informational) playing a predominant role in causing deviations from the law of one price (LOOP) and purchasing price parity (PPP). For example, Engel and Rogers (1996) explicitly control for distance and the border to capture the effects of a myriad of trade costs on price dispersion across the United States and Canada. Furthermore, the existence of trade costs motivates “commodity points” and the use of threshold autogressive models in testing for PPP and LOOP relationships (Obstfeld and Taylor, 1997).

[7]Broda and Romalis (2004) is another recent paper that also exploits panel estimation in examining exchange rate volatility.

interpret these results as support for our model, and as a measure of why trade costs matter.

Our work differs from some recent literature that incorporates more realistic features of trade into the macroeconomic environment. We choose a static modeling strategy to highlight the common supplier channel in as intuitive a way as possible. Moreover, this strategy naturally leads to a way of thinking of a reduced form estimation in order to test for the relevance of the channel. Our goal is therefore not to build a fully specified dynamic model to simulate and match moments of the data. However, by highlighting a new channel through which trade costs affect the macroeconomy, our contribution is meant to complement a growing literature that analyzes the impact of trade integration on the macroeconomy in a more dynamic setting. Of particular relevance is Hau (2002), who examines the impact of nontradability on real exchange rate volatility in a New Open Economy Macroeconomic framework, where the relative size of the tradable/nontradable sectors is exogenous and he highlights the role of openness on real exchange rate volatility. Naknoi (2004) extends this analysis into a dynamic general equilibrium model that endogenizes tradability. Other recent papers that incorporate richer trade structures and other realistic features into dynamic macroeconomic models include Bergin and Glick (2003a, 2003b), Ghironi and Melitz (2004), and Kose and Yi (2001, 2004).

They key distinction that must be made between most of this recent work and our contribution is our explicit consideration of multi-country interactions. Furthermore, we provide a simple methodology to implement this idea empirically and test for its effect on bilateral real exchange rate volatility in a panel setting. Given continuing globalization and the changing nature of trade, we believe that the channel we highlight and provide evidence for is an important one to consider.[8]

The remainder of the paper is structured as follows. Section II presents the model. Section III present a numerical example analyzing the model. Section IV presents evidence supporting the channel emphasized by the model. Section V concludes and discusses some suggestions for potential future work.

II. Multi-Country Model

This section develops a simple general equilibrium model, based on the multi-country Ricardian model of Eaton and Kortum (2002). The model is static and is only meant for illustrative purposes to motivate the empirical work below.[9] We extend the model to include a nontradable sector by building on a standard model (Fujita, Krugman, and Venables, 1999),

[8]Indeed, the macroeconomic consequences of trade agreements such as NAFTA have potential multi-country impacts. See Kose and Cardarelli (2004) and Kose, Meredith, and Towe (2004) for some recent work studying the impact of this agreement.

[9]See Alvarez and Lucas (2004) for a particular general equilibrium version of the Eaton-Kortum model, along with calibrations.

but do not model nontradability endogenously.

The mechanism through which we highlight the impact of trade costs on real exchange rate volatility is the following. Given technological differences and trade barriers, any two countries may have different trading partners for a given good. Therefore, though each country's import basket is composed of the same goods, any good may be provided by a different supplier. As a result, the diffusion of each country's idiosyncratic shocks to other countries' price indices will be heterogeneous.

We present the general equilibrium structure of the model before deriving the solution for the real exchange rate volatility. Section A presents consumers' preferences. Section B presents the production technology of the economy. Section C presents the global equilibrium. Finally, Sections D and E present the volatility result.[10] The intuition behind our result is quite straightforward, but the simple derivative of volatility with respect to trade costs cannot be signed unambiguously. Therefore, Section III presents a simple numerical example to confirm that bilateral real exchange rate volatility increases with trade costs given a reasonable set of parameters.

A. Preferences

An agent's preferences over both nontradable (NT) and tradable (T) goods are:

$$\begin{aligned} U &= Q_{NT}^{\mu} Q_T^{1-\mu}, \text{ with} \\ Q_{NT} &= \left(\int_0^m q_{NT}(j)^{\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}} \\ Q_T &= \left(\int_0^1 q_T(j)^{\frac{\rho-1}{\rho}} dj \right)^{\frac{\rho}{\rho-1}} \end{aligned} \tag{1}$$

These are standard Dixit and Stiglitz (1977) preferences, where each lower case q represents a different variety, each produced by a distinct firm. The key difference in the structures of the nontradable and tradable sectors is that the number of varieties in the nontradable sector, m, is endogenous. This generalization is made in order to ensure that labor supplies are not fixed in both sectors.

We present simple a model of a nontradable sector of the domestic economy, which is applicable to each country. We choose not to introduce uncertainty directly in this sector (unlike in the tradable sector below) in order to simplify our results, and to not detract from the main mechanism, we highlight in the tradable sector. Rather, this stylized model helps pin down the wage and distribution of labor across sectors in equilibrium.[11]

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[10]Appendix I discusses some useful statistical theories for deriving this measure.

[11]Introducing uncertainty would not alter the main results, however.

The consumer solves his maximization problem in two stages. First, he chooses consumption in the nontradable sector and then in tradable sector. The standard maximization problem yields demand for a given nontradable good:

$$q_{NT}(j) = \left(\frac{p_{NT}(j)}{P_{NT}}\right)^{\frac{1}{\eta-1}} Q_{NT}, \tag{2}$$

where P_{NT} is the price index of all nontradable goods and is equal to:

$$P_{NT} = \left(\int_0^m p_{NT}(j)^{1-\eta} dj\right)^{\frac{1}{1-\eta}} = p_{NT} m^{\frac{1}{1-\eta}}, \tag{3}$$

where we use the fact that in equilibrium quantities and prices are the same for each variety.[12]

The demand side in the tradable sector is modeled similarly to the nontradable sector, with the aggregate consumption of tradable goods defined by Q_T in (1). However, unlike in the nontradable sector, a good $q_T(j)$ need not be produced domestically. Given the similar structure to the nontradable side, we omit the derivation of the demand and price index.

B. Technology

We first examine the production side of the nontradable sector. Production requires labor, which has a marginal input requirement of c_{NT} per unit of output and a fixed cost F.[13] That is:

$$l_{NT} = F + c_{NT} q_{NT}.$$

Monopolistic firms then maximize profits:

$$\Pi = p_{NT} q_{NT} - w(F + c_{NT} q_{NT}),$$

where w is the wage rate. The first-order condition yields the standard mark-up pricing rule of a monopolistic producer:

$$p_{NT} = \frac{\eta}{\eta - 1} c_{NT} w. \tag{4}$$

Given this price, the the zero profit condition implies that the equilibrium output of any firm is given by:

$$q^*_{NT} = \frac{F(\eta - 1)}{c_{NT}} \tag{5}$$

and the labor requirement is:

$$l^*_{NT} = F + c_{NT} q^*_{NT} = F\eta. \tag{6}$$

[12]The price index P_{NT} is solved for by minimizing total expenditures $\int_0^m p_{NT}(j) q_{NT}(j) dj$ subject to consuming a unit of nontradables; i.e., setting $Q_{NT} = 1$.

[13]Note that we assume that these costs are equal across all firms in the nontradable sector, and therefore suppress the index j in what follows.

Thus, if L_{NT} is the number of workers in the nontradable sector, we have that the equilibrium number of nontradable firms is given by:

$$m^* = \frac{L_{NT}}{l^*_{NT}} = \frac{L_{NT}}{F\eta}. \tag{7}$$

In equilibrium, the wage will be the factor return that links the nontradable and tradable sectors. We therefore express the equilibrium wage as follows. First, using the demand function (2) to express the level of production of the firms as:

$$q^*_{NT} = (\mu Y)(p_{NT} P^{\eta-1}_{NT}),$$

where Y is total income of the economy, and given Cobb-Douglas preferences (1), the consumer spends a share μ on nontradables. The zero profit condition that determines q^* can then be rewritten as:

$$(p_{NT})^\eta = \frac{\mu}{q^*_{NT}} Y P^{\eta-1}_{NT}.$$

Combining this equation with the price index for nontradable goods (3), one can then express the equilibrium wage as:

$$\begin{aligned} w &= \left(\frac{\eta-1}{\eta c_{NT}}\right)\left[\frac{\mu}{q^*_{NT}} Y P^{\eta-1}_{NT}\right]^{\frac{1}{\eta}} \\ &= \left(\frac{\eta-1}{\eta c_{NT}}\right)\left[\frac{\mu}{q^*_{NT}} Y p^{\eta-1}_{NT} m^*\right]^{\frac{1}{\eta}}. \end{aligned} \tag{8}$$

Equations (2)-(8) express the system for the nontradable sector, where, for country k, the set of endogenous variables $p_{NT,k}$, m^*_k, q^*_{NT} as a function of w_k, $L_{NT,k}$ and Y_k. To solve the system, we must complete solving for the tradable sector.

The production structure for the tradable sector is built around the model of Eaton and Kortum (2002), which in turn is based on Dornbusch, Fischer, and Samuelson (1977) as a starting point. The particularity of this new model is that it allows for extension of Dornbusch et al.'s model to a multi-country setting through the introduction of uncertainty in a country's efficiency in producing any given good.

As in Eaton and Kortum we assume that country i's efficiency in producing good $j \in [0, 1]$, that we denote $z_i(j)$, follows a Fréchet distribution, conditional on idiosyncratic shocks. A key assumption that facilitates the determinations of each country's price index is that this distribution applies to all goods.

The cost of inputs, $c_{T,i}$, is assumed to be equal across goods in a given country. Therefore, with constant returns to scale, the cost of producing a unit of good j in country i is given by $c_{T,i}/z_i(j)$. Trade costs are modeled as an iceberg transport cost between countries i and n, $\tau_{ni} > 1$. We choose to use iceberg costs for several reasons. First, the introduction of these ad valorem costs allow us to emphasize the nature of trade costs that we are most interest in examining (i.e., transport costs and other costs of doing trade) and highlight the main channel emphasized in the paper. Another approach would be to examine fixed costs of entering into trade, as in Broda and Romalis (2004) or Ghironi and Melitz (2004), but such an approach would greatly complicate the analysis and would not help in highlighting the channel through which trade costs affect volatility that we focus on. Similarly, choosing more complicated functional forms of the iceberg costs (e.g., a quadratic formulation) would only create additional complexity with no value added conceptually.

The price of an unit of good j produced in country i and offered in country n is therefore:

$$p_{T,ni}(j) = \frac{c_{T,i}}{z_i(j)} \cdot \tau_{ni}.$$

Given that the same good can come from N countries, shoppers in country n, under conditions of perfect competition, will pay the cheapest price offered in the market. This price is:

$$P_{T,n}(j) = \min\{p_{T,ni}(j) : i = 1, ..., N\}.$$

Given the assumptions made concerning production and consumption of tradable goods across countries, a country's exact price index as the solution:[14]

$$P_{T,n} = \gamma \Phi_n^{-1/\theta} = \gamma \left(\sum_{i=1}^{N} A_{T,i} (c_{T,i}\tau_{ni})^{-\theta} \right)^{-1/\theta}, \tag{9}$$

where $\gamma = \left[\Gamma\left(\frac{\theta+1-\rho}{\theta}\right)\right]^{1/(1-\rho)}$, Γ is the gamma function, $A_{T,i}$ is a country i's state of technology, which governs its *absolute advantage*, $c_{T,i}$ is country i's input cost, τ_{ni} is an iceberg transport cost between countries i and n ($\tau_{ni} > 1$ if $n \neq i$ and $= 1$ if $n = i$), and θ regulates its *comparative advantage* across countries. Note that Φ_n summarizes how prices are affected by variables around the world: (i) states of technology, (ii) input costs, and (iii) geographic barriers.

C. Global Equilibrium

Given the setup of the model, it is possible to show that a country n's share of expenditures on goods from country i relative to n's total expenditures is:

$$\Lambda_{ni} \equiv \frac{X_{ni}}{X_n} = \frac{A_{T,i}(\tau_{nk} c_{T,i})^{-\theta}}{\Phi_n}.$$

One may therefore represent the equilibrium in the external sector as:

$$w_k L_{T,k} = \sum_{n=1}^{N} \Lambda_{nk}(1-\mu)Y_n = \sum_{n=1}^{N} A_{T,n} \left(\frac{\gamma \tau_{nk} w_n}{P_{T,n}}\right)^{-\theta} (1-\mu)Y_n, \tag{10}$$

[14] See Eaton and Kortum (2002) for the full derivation.

where this equation simply states that total wage labor in the tradable sector of country k must equal the value of its total exports.[15] Note that we have used the fact, from preferences (1), that any country n will spend a share $1-\mu$ of its income, Y_n, on traded goods. We have further made the simplifying assumption that input costs equal the wage; i.e., $c_{T,n} = w_n$.[16]

Equation (10) therefore connects the set of endogenous variables (for any country k) in the tradable sector: $P_{T,k}$, $L_{T,k}$ as a function of w_k, and Y_n. Now we use the information from the nontradable sector to solve for the set of endogenous variables there as well as the set in in the tradable sector, and finally total output Y_n for all countries. In particular, there is an equilibrium in the tradable sector across all N countries, and equilibrium across sectors in each economy.

We can express the relation between sectoral labor and total income for country k as:

$$\bar{L}_k = (L_{NT,k} + L_{T,k}) \tag{11}$$

$$Y_k = \bar{L}_k w_k = (L_{NT,k} + L_{T,k}) w_k, \tag{12}$$

where $\bar{L}_k$ is total labor in country k. As one can see equations (8), (10), (11) and (12) provide a system of $4N$ equations and $4N$ unknowns $L_{T,k}$, $L_{NT,k}$, Y_k and w_k. This set of equations solves the world or global equilibrium. Unfortunately, this system is non-linear and must be solved numerically.[17]

D. Relative Tradable Price Volatility

We are interested in determining the volatility of two countries' bilateral real exchange rate given idiosyncratic technological shocks. Eaton and Kortum treat technology, $z_i(j)$, as random, whose distribution depends on the parameters $A_{T,i}$ and θ. An outcome of this probabilistic representation can be thought of as representing a cross-section of countries. Examining exchange rate volatility requires looking at intertemporal variation in the data. We therefore choose to model shocks to $A_{T,i}$ as an additional form of uncertainty. Our framework is static, and therefore ignores potential economic rigidities. Furthermore, we do not model how shocks to $A_{T,i}$ affects the original cross-sectional distribution of prices and trade; i.e. how comparative advantage changes.[18] We assume that the technological shocks are

[15] Note that we are assuming that this is a barter economy, which implies that there is balanced trade. Heathcote and Perri (2002) show how introducing financial autarky into a dynamic general equilibrium model helps generate exchange rate volatility seen in the data.

[16] Note that Eaton and Kortum (2002) assume that these inputs costs are a function of the wage and the price of tradables.

[17] Give the scope and interest of this paper, we do not present any exercises that solve the full global equilibrium.

[18] Our empirical work does attempt to control for this effect by using panel data.

lognormal. In particular,

$$\begin{aligned} A_{T,i} &= \tilde{A}_{T,i}\exp(\varepsilon_i), \text{ with} \\ \varepsilon_i &\sim \mathrm{N}\left(0, \sigma_\varepsilon^2\right), \end{aligned} \tag{13}$$

where $\tilde{A}_{T,i} > 1$, and may also $= A_T > 1 \; \forall \; i$. This assumption essentially posits that the steady-state/long-run technological level of countries may or may not differ. Furthermore, it is assumed that $\text{Cov}\{\varepsilon_i, \varepsilon_j\} = 0 \; \forall \; i \neq j$.[19]

It is not possible solve for an exact closed-form of solution real exchange rate volatility in the multi-country model, but we are able to find a closed-form solution by using a first-order Taylor approximation around the steady-state. The derivation is not too complicated, but long, so it is relegated to Appendix I, which shows that:

$$\begin{aligned} \text{Var}\left\{\log\left[\frac{P_{T,1}}{P_{T,2}}\right]\right\} \approx \Upsilon & \left(\underbrace{\frac{\sum_{i=1}^N \tilde{A}_{T,i}^2 (c_{T,i}\tau_{1i})^{-2\theta}}{\left[\sum_{i=1}^N \tilde{A}_{T,i}(c_{T,i}\tau_{1i})^{-\theta}\right]^2}}_{[1]} + \underbrace{\frac{\sum_{i=1}^N \tilde{A}_{T,i}^2 (c_{T,i}\tau_{2i})^{-2\theta}}{\left[\sum_{i=1}^N \tilde{A}_{T,i}(c_{T,i}\tau_{2i})^{-\theta}\right]^2}}_{[2]} \right) \\ & - 2\Upsilon \left(\underbrace{\frac{\sum_{i=1}^N \tilde{A}_{T,i}^2 (c_{T,i}^2\tau_{1i}\tau_{2i})^{-\theta}}{\sum_{i=1}^N \tilde{A}_{T,i}(c_{T,i}\tau_{1i})^{-\theta} \sum_{i=1}^N \tilde{A}_{T,i}(c_{T,i}\tau_{2i})^{-\theta}}}_{[3]} \right), \end{aligned} \tag{14}$$

where $\Upsilon = \left(\frac{e^{\sigma_\varepsilon^2}\left[e^{\sigma_\varepsilon^2} - 1\right]}{\theta}\right) > 0$.

One can easily take the derivative of the real exchange rate variance in (14) with respect to bilateral trade costs $\tau_{12} = \tau_{21}$. However, signing this derivative is not straightforward given that it generally has an inflection point. Therefore, Section III presents a numerical example that shows that this derivative is in fact usually negative. However, it is worthwhile to first give a description of the three components of the variance term in equation (14).

The three terms are a cumulative weighting that reflects the composition of country 1's (country 2's) consumption of goods from the rest of the world. In particular, by inspection it is easy to see that as τ_{1i} (τ_{2i}) approaches 1, that [1] ([2]) will only depend on relative technological and cost differentials (i.e., as world of frictionless trade), which in turn will imply that the shocks to other countries will pass directly to country 1's (country 2's) price index one-for-one. Therefore, term [1] ([2]) will increase as trade costs increase. This in turn

[19] This assumption may be considered extreme, but simplifies the analysis. However, Appendix I presents the solution when we relax the assumption of zero correlation of shocks.

implies an increase in bilateral real exchange rate volatility. The third term [3] essentially reflects a covariance term, which captures how shocks have an impact on the two countries' baskets. In sum, the three terms show how similarities in trade costs and technology viz. the rest of the world for a country pair have an effect on bilateral real exchange rate volatility. For example, one may think of two countries that are very close to each other and have similar technologies. In this case, terms [1]-[3] will be quite small, and shocks will diffuse similarly across both economies, thereby resulting in lower real exchange rate volatility than if the two countries were farther apart or had very different technological endowments.

Two further examples can help better understand (14). Suppose that there is a group of countries on a straight line, where each country is equally spaced from each other and have the same technology and factor cost. The real exchange rate volatility between the countries located at the two opposite extremes will be zero because technological shocks will diffuse equally to their respective price indices. Indeed, the sum of terms [1] and [2] will be equal to term [3]. However, if there are differences in the technologies or costs in the countries located along the straight line then the real exchange rate volatility will not be zero because of the loss of symmetry. Now consider a country moving along the line. In this case its distances to each extreme country will be moving in an opposite direction (i.e., shrinking between one country and growing with the other). Taking this asymmetry in distance into account and applying this property to each country over the straight line we can note that real exchange rate volatility will increase through term [3]. In this last case terms [1] and [2] will be different as well.

E. Aggregate Real Exchange Rate Volatility

Given the consumer's preferences over nontradable and tradable goods in equation (1), it is possible to show (as in the case of the nontradable and tradable sectors) that the following is the aggregate price index:

$$P = \frac{P_T^{\mu} P_{NT}^{1-\mu}}{\mu^{\mu}(1-\mu)^{1-\mu}}, \tag{15}$$

where P_T corresponds to $P_{T,n}$ in (9). Taking the logarithm of the ratio of P_1 and P_2, where we assume that the preference parameter $\mu = \mu_1 = \mu_2$, one has the log bilateral real exchange rate:

$$q = p_1 - p_2 = (1-\mu)(p_{T,2} - p_{T,1}) + \mu(p_{NT,1} - p_{NT,2}), \tag{16}$$

where q is the log real exchange rate, and lower case p represents the log price level. This model essentially reflects the decomposition in Engel (1999). The model presented in Section D describes how greater trade costs can lead to higher volatility of the first term in (16); i.e., of the traded goods basket. In the following sections we focus on the traded goods component of the price index given that we are interested on the impact of trade costs on the diffusion of technological shocks.[20]

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[20]As Engel's work points out, it is the traded component of the price index that tends to drive the volatility of the real exchange rate, therefore focusing on this component matches nicely with previous literature.

III. EXAMPLE

This section presents a numerical example that will allow us to explore the impact of changes in different parameters on real exchange rate volatility.[21] In particular, we will concentrate on changes in bilateral trade costs. We simulate the bilateral exchange rate between a country that is very close to a group of countries (in fact infinitely close, such that $\tau = 1$) and another country that is far from this group.

In the simulations the number of countries (N) varies between 30 and 150, a wide range that allows us to capture any variation in the real exchange rate volatility due to the size of the group of countries. This increasing size can be also interpreted as an increase in the degree of globalization. The parameter θ is taken from Eaton and Kortum. We normalize the mean of the technology (A) of the group two to one, so that it is easy to discern a 10% increase in this technological gap. We also examine differences in productivity shocks (σ_ε) and input costs (c) by increasing them at 10% increments. We vary trade costs, τ, between 1 and 4, with 1 corresponding to zero trade costs. Indeed, we can express $\tau = 1/(1-\tau_2)$, with τ_2 equal to the share of the traded good that "melts" (either due to transport costs or tariffs) by moving from origin to destination. In the case of the developing world, τ can easily be over 2 for many goods. Specifically, for countries 1 and 2, the parameters considered are as follows:

- Country 1 is not in the group of countries. Countries $2, \ldots, N$ are part of the group of countries and are identical, $N \geq 30$.
- $\theta = 8.26$, $\sigma_\varepsilon \geq 0.1$.
- Technologies:
  - $A_{T,1} = 2$.
  - $A_{T,2} = (1 + \Delta A_T)A_{T,1}$, $\Delta A_T > 0.1$, $A_{T,i} = A_{T,2}$ for $i = 2, \ldots, N$.
- Costs:
  - $c_{T,1} = 0.5$.
  - $c_{T,2} = (1 + \Delta c_T)c_{T,1}$, $\Delta c_T > 0.1$, $c_{T,i} = c_{T,2}$ for $i = 2, \ldots, N$.
- Trade costs:
  - $\tau_{1i} = \tau_{i1} = \tau \geq 1$ for $i = 2, \ldots, N$.

[21]Note that this example only considers the volatility of the relative traded good prices, but we will refer to this relative price as the real exchange rate throughout the remainder of the paper. Furthermore, the simulations ignore the general equilibrium effect and only concentrates on the tradable sector given exogenous wages. However, relaxing this assumption would not alter the main qualitative results.

– $\tau_{2i} = \tau_{i2} = 1$ for $i = 2, \ldots, N$.

Given this selection of parameters, Figure 1 examines the impact of trade costs on real exchange rate volatility. Fig. 1(a) examines the impact of changing trade costs, τ, for differing values in the variance of the productivity shocks. In all cases, we assume that $N = 150$, $A_{T,1} = 2$, $\Delta A_T = 0$, $c_{T,1} = 1$, and $\Delta c_T = 0$. The technological and cost gaps are referred to the group of countries with respect to country 1. The real exchange rate volatility is increasing in bilateral trade costs for all σ_ε. The other fact to notice is that a rise in the volatility of productivity shocks (σ_ε) has an increasing effect on real exchange rate volatility as σ_ε grows.

Fig. 1(b) examines the impact of changes in τ for different ranges of technological gaps between countries 1 and and the group of countries. In all cases, we assume that $\sigma_\varepsilon = 0.5$, $N = 150$, $A_{T,1} = 2$, $c_{T,1} = 1$, and $\Delta c_T = 0$. The real exchange rate volatility is increasing in bilateral trade costs for all ΔA_T. Moreover, the difference in the impact of changes in the technological gap is not great for all ranges of trade costs. However, and increase in the technological gap reduces volatility.

Fig. 1(c) examines the impact changes in τ for different ranges of cost gaps between countries 1 and the group of countries. In all cases, we assume that $\sigma_\varepsilon = 0.5$, $N = 150$, $A_{T,1} = 2$, $\Delta A_T = 0$, and $c_{T,1} = 1$. The real exchange rate volatility is increasing in bilateral trade costs for all Δc_T. However, as one can see in the figure, this rate of increase is not monotonic. It is also interesting to note that, unlike changes in the technological gap, changes in the cost gap has increasing and quite large impacts on real exchange rate volatility, and its response to changes in trade costs.

Fig. 1(d) examines the impact changes in τ for different sizes of the group of countries $(N - 1)$. In all cases, we assume that $\sigma_\varepsilon = 0.5$, $A_{T,1} = 2$, $\Delta A_T = 0$, $c_{T,1} = 1$, and $\Delta c_T = 0$. The real exchange rate volatility is increasing in bilateral trade costs for all N. The most interesting feature of this experiment is that real exchange rate volatility *decreases* as the size of the group of countries *increases*. This finding reflects the impact of diversification: as the group of countries size grows, countries 1 and 2 have more common suppliers of goods (as long as there is trade), which implies that countries 1 and 2's price indices will be subject to more common shocks.

Finally, Figure 2 breaks down the three components of volatility from equation (14). We assume that $\sigma_\varepsilon = 0.5$, $N = 150$, $A_{T,1} = 2$, $\Delta A_T = 0$, $c_{T,1} = 1$, and $\Delta c_T = 0$. Fig. 2(a) plots the total variance; Fig. 2(b) plots the first variance term [1]; Fig. 2(c) plots the second variance term [2], and Fig. 2(d) plots the covariance term [3]. Most of the action is coming from term [1]. This is not surprising given that trade costs between country 2 and all other countries, except country 1, are fixed at 1, since country 2 already belongs to the group of countries. Meanwhile, the covariance term decreases with increasing trade costs (note that Fig. 3(d) plots the negative of the covariance). This result is due to the fact that the volatility of the price index of country 2 stabilizes once trade costs with country 1 are significantly greater than 2 and the price index of country 1 keeps increasing with the trade costs.

This example confirms the multi-country's model prediction that trade costs increase bilateral real exchange rate volatility. However, it is also important to examine whether a model's prediction stands up to the data. The following section do exactly this by testing for the importance of the channel highlighted in Section II.

IV. Empirical Evidence

The central prediction from the multi-country model in Section II is that, *ceteris paribus*, countries that have more common suppliers of traded goods should also experience lower bilateral real exchange rate volatility. This result arises because the more common the suppliers of goods, the more two countries' price indices will move together given shocks to countries around the world. This section attempts to operationalize this concept in a reduced form, as well as test for its validity using a large sample of data.

We construct a common supplier index using bilateral trade data. One would ideally like to use a weighted measure of prices for traded goods, but these data are not available. Therefore, we construct an index based on the relative value of goods that any two countries import from a common country. Given the model, it would be ideal to do this at the most disaggregated level (i.e., the good level) as possible. Unfortunately, as will be discussed in Section A we must rely on more aggregated data.

The index is constructed as follows. Consider a world with N countries, M sectors/goods, and X_{rsm} is exports of good m from country r to country s. Then, the index of common suppliers for countries i and j can be written as:

$$CS_{ij} = \frac{\sum_{k \neq (i \text{ or } j)}^{N} \sum_{m=1}^{M} 1\left(X_{kim} > 0, X_{kjm} > 0\right)\left[X_{kim} + X_{kjm}\right]}{\sum_{k \neq (i \text{ or } j)}^{N} \sum_{m=1}^{M} \left(X_{kim} + X_{kjm}\right)}, \tag{17}$$

where 1 is the indicator function. The numerator captures the value of imports from common suppliers for countries i and j, while the denominator uses countries i and j's total trade with the world (except with each other) as a normalization. This normalization helps to deal with the effect of country size—i.e., the probability of two large countries importing a larger amount of a good from a given country is higher than that for two smaller countries, *ceteris paribus*, simply because of sheer size of the countries (and not, for example, trade costs). Moreover, the normalization bounds the index between 0 and 1.

One can relate the index (17) to the volatility of the relative prices of traded goods (14) as follows. Volatility is a function of productivity shocks of countries around the world, where relative trade costs and technology affect how common the diffusion of these shocks are to the two countries' prices (i.e., the left-hand side of (14)). The common supplier index is meant to capture the weights ([1], [2], and [3]), where the higher this index the smaller is the cumulative effect of the weights, and thus the higher the volatility of the relative prices of traded goods. In essence, the similarity of two countries' trading partners is determined by the two countries' relative trade costs and technologies (viz. each other and countries around the world), and the index captures this similarity. We will give more intuition on the appropriateness of this index as a proxy for trade costs in Section A.

We may then relate this index to real exchange rate volatility as follows. Given the proceeding discussion, the index is negatively related to the volatility of the relative prices of traded goods. Next, one notes that given the equation for the real exchange rate (16), the higher the volatility of the relative prices of traded goods, the higher real exchange rate volatility. Thus, one should expect that the smaller the index, the larger real exchange rate volatility will be. To be more specific, if σ^{RER} is real exchange rate volatility, and is a function of the common supplier index (CS) and other variables (X): $\sigma^{RER} = f(CS, X)$, then

$$\frac{\partial \sigma^{RER}}{\partial CS} = \frac{\partial f(CS, X)}{\partial CS} < 0.$$

We test for this relationship using the following linear regression model of bilateral real exchange rate volatility:

$$\sigma_{ij,t}^{RER} = \beta_0 + \beta_1 CS_{ij,t-1} + \gamma \mathbf{X} + \mu_{ij} + \delta_t + \zeta_{ij,t}, \tag{18}$$

where the central prediction of the model is that $\beta_1 < 0$. $\sigma_{ij,t}^{RER}$ is the real exchange rate volatility measure between $t-1$ and t; $CS_{ij,t-1}$ is the common supplier index at the beginning of the period; $\mathbf{X}$ is a matrix of controls, which includes (i) the natural logarithm of the product of real GDP of i and j, (ii) the natural logarithm of the product of real GDP per capita of i and j, (iii) a variable indicating whether i and j have a regional trade agreement in place, (iv) the natural logarithm of countries i and j's Herfindahl index of export concentration, (v) a measure of correlation of countries i and j's output shocks, and (vi) exchange rate regime variables; μ_{ij} is a vector of country nuisance parameters—either developed and less developed country dummies or country-pair fixed effects; and δ_t is a vector of time dummies. This equation is estimated in five year panels.[22] We both pool the data and estimate the model using country-pair fixed effects.

The inclusion of the income variables captures potential determinants of bilateral trade, and are motivated by the "gravity" specification from the empirical trade literature.[23] The income variables along with the correlation of output shocks are also motivated by the optimum currency literature.[24] The export concentration measure is included to capture how diversified

[22] We also experiment with ten year panels, and results are generally robust.

[23] Note that since we estimate the model using fixed effects, we do not include other gravity-type variables, such as distance, common border, common language, or area.

[24] For example, see Bayoumi and Eichengreen (1998), Devereux and Lane (2003) or Engel and Rose (2002).

a country's export sector is, and is measured using a Herfindahl index.[25] One should expect that a more diversified economy will be less sensitive to shocks (both domestic and foreign) if its export sector is more diversified, thus leading to lower swing in the exchange rate. The regional trade agreement variable captures a time varying measure of potential trade costs. We also include exchange regime variables, which capture whether any two countries are pegged, whether the peg is between each other, if they have a common base country (whether pegged or floating), and a currency union dummy. These exchange rate indicators are meant to capture the obvious fact that nominal exchange rate volatility may be dampened by different regimes. Finally, equation (18) is also estimated for sub-samples, which are dependent on the country-pair level of development: (i) developed-developed, (ii) developed-less developed, and (iii) less developed-less developed.[26]

A. Data

The greatest challenge in collecting data is to obtain the necessary series to construct (17). As discussed above, the more disaggregated these data, the better. Hummels and Klenow (2004) exploit some very disaggregated trade data produced by UNCTAD. Unfortunately, these data are not available for a very long time series, and this lack of time series component is not trivial.

We therefore exploit the World Trade Database for 1970–97. This database provides worldwide annual bilateral trade flows, which are disaggregated at the 4-digit Standard International Trade Classification (SITC) level.[27] This is still quite a high level of aggregation, but yields both intertemporal variation, as witnessed in Figure 3, as well as cross-sectional variation.[28] We therefore construct the common supplier index for countries that actually have some bilateral trade in the database. The means and standard deviations of the index for the

[25]We define country i's Herfindahl index, H_i, as:

$$H_i = \sum_j \left(\frac{X_{ij}}{X_i} \right)^2 ,$$

where X_{ij} is country i's exports of good j, and X_i is country i's total exports. Goods j are disaggregate at the 4-digit SITC level.

[26]The developed and less developed country samples are based on income groups taken from the World Development Indicators.

[27]We also experimented with cruder cuts at the data; i.e., at 2- and 3-digit SITC levels. However, given the model's prediction, we did not expect these indices to perform as well in the regressions, which was indeed the case.

[28]Note that the world average plotted in Figure 3 is for all the data in the database, and not only the sample we use in the estimation.

observations that we use in the estimations are 0.04 and 0.045, respectively.[29]

Furthermore, an additional reason to believe that there might be some interesting time series variation is how the nature of trade has changed over time. For example, Yi (2003) highlights how small changes in tariffs over time have increased trade substantially due to “vertical specialization”; i.e., stages of production being globalized, with intermediate goods being shipped through several countries during production. The secular increase of the index starting in the 1980s in Figure 3 corresponds nicely to this fact.[30]

It is also important to consider whether the common supplier index is a reasonable proxy for trade costs. Work in the international trade and macroeconomics literatures often uses physical distance between countries as a proxy for potential trade costs. However, distance is a non-time-varying “catch all” variable, which may be interpreted in many different ways.

In the context of our model, two countries that are close to each other (geographically) will naturally also face similar physical trade costs with other countries in the world to some degree.[31] Therefore, given the prediction of our model, one might expect that the index and distance are negatively related, since two countries that are far apart may also have differing trade partners. Figure 4 plots the index against distance for a sample of country-pairs, which we use in our formal analysis below. The common supplier index is the average value between country-pairs over 1970–1997. There is a negative relationship for not only the whole sample of countries, but by income groups. Furthermore, the relationship appears to be quite strong.[32]

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[29]Note that the average of this index is in general quite small. This partly reflects the fact that we do not consider direct trade between countries, and given asymmetries, this in turn may lead to some very small numbers even for countries that are quite close to each other. For example, almost 80% of Canadian trade is with the United States, but the same is not the case for the United States, which in turn will lead to a small index since the denominator of the index includes U.S. trade with the rest of the world. See Table A1 for summary statistics of this index across different income groups and over time.

[30]The fall and then slow rise again of the index in the latter part of the 1970s and early 1980s may be due to several factors. This period of time marked high rises in oil prices that depressed global trade in general. Furthermore, this period also witnessed the era of “new protectionism”, where protectionist trade policy relied heavily on quantity restrictions (Baldwin 1987). Investigating the causes of this U-shape pattern is beyond the scope of this paper, but is a potential avenue of interesting future research.

[31]Of course, distance between two countries is only one dimension of potentially many other physical trade costs (e.g., geography within a country or proximity to seaports.)

[32]The estimates coefficients on Log(Distance) (and R^2s) for each figure are the following (each is significant at the 99% confidence level). Fig. 4(a): -0.025 (0.26); Fig. 4(b): -0.017 (0.21); Fig. 4(c): -0.020 (0.14) ; Fig. 4(d): -0.026 (0.35).

The bilateral real exchange variable is constructed using nominal exchange rate and CPI data from Global Financial Database in order to maximize country-pairs.[33] The volatility measure is calculated by first taking the annual real exchange rate change (in log differences) each month; e.g., we take the change between Feb94–Feb95, and then Mar94–Mar95, and so on (i.e., a "rolling window" of annual real exchange rate changes).[34] We then compute the standard deviation of these annual changes over different time periods (i.e., between $t-1$ and t, which is either the whole sample period or by decade) as our measure of long-run volatility.[35]

The Herfindahl index is calculated using data from the World Trade Database. Income and income per capita data are primarily taken from the Penn World Tables (Heston, Summers, and Aten 2002), with holes filled in from the World Development Indicators and the International Financial Statistics. Finally, the exchange rate regime variables are taken from Shambaugh (2004). We also experimented with data from Reinhart and Rogoff (2004). The results were very similar to when using Shambaugh's data, but we lose observations.[36]

B. Empirical Results

This section presents results for estimates of equation (18). As discussed above, we estimate this equation for both pooled data as well as using country-pair fixed effects, as well as for different sub-samples of the data based on income groups. This analysis allow use to check for robustness across different types of countries around the world, as well as examining whether the estimated relationship is being identified primarily via the cross-sectional or time

[33]We also experimented with data from *International Financial Statistics*, but lost observations. However, our results were robust to using this data source.

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

[35]We also experimented in detrending the real exchange rate data using common filtering techniques: Hodrick and Prescott (1997) and Baxter and King (1999), but our results did not vary qualitatively. See Tables A1 and A2 for summary statistics of the different exchange rate measure as well as robustness checks. The HP filter is applied to the natural logarithm of monthly real exchange rate data with a smoothing parameter $\lambda = 14400$. The BK filter is applied to the natural logarithm of monthly real exchange rate data with band-width parameters (18,96) months, and a lead-lag length of the filter set to twelve months. Note that the HP and BK filters yield less volatile exchange rates on average that the rolling window approach.

[36]We would like to thank Jay Shambaugh for sharing all these data with us, as well as discussions concerning the comparability of the two classifications systems. Indeed, the classifications are highly correlated post-1973.

series properties of the data. In general, we find that the coefficient on the common supplier index (a semi-elasticity) both negative and significant, thus confirming the prediction of our model. However, the relative size and significance of the estimation relationship varies across sub-samples and specifications.

Before turning to results for the full specification of the regression model, we present some simple preliminary regressions to assess the relationship between the common supplier index and real exchange rate volatility for the whole sample in Table 1. The first two specifications are for the pooled data, and the last two specifications control for annual and country-pair effects. We regress volatility on the index, and then on index controlling for other potential trade determinants. We do not want to emphasize these results given that further analysis includes other important controls, but the coefficient on the index is negative in all specifications and is both economically and statistically significant.

Whole Sample Results

Table 2 presents results using the whole sample of data. Columns (1) and (2) present estimates using pooled data, with specification (2) using the exchange rate regime variables as additional controls for a robustness check.[37] Columns (3) and (4) include country-pair effects and thus capture the within-effect (temporal) relationship of the estimation, with (4) including the exchange rate regime variables.

According to the average estimate of the common supplier index across the four specifications, a one standard deviation increase in the index (i.e., 4.5%) will decrease bilateral long-run real exchange rate volatility by 5.1% (over a five-year period). This number is both economically and statistically significant. Furthermore, the estimates do not vary greatly when examining pooled and fixed-effects regressions. Therefore, as two countries increase their trade integration (similarly) with the rest of the world, this will result in more similar consumption baskets of imported goods, which in turn leads to less relative price volatility.

Turning to the coefficients of the other controls, only the coefficient on the measure of export concentration (the Hefindahl Index) is significant across all specifications. Furthermore, the coefficient is of the expected sign (i.e., more diversified economies will have less volatile prices). Looking at the gravity variables, it is curious that the GDP variable coefficients are positively signed in the pooled results, since we would expect that larger and richer countries would trade more and in general have lower volatility.[38] However, these results are either weakened or completely reversed when including the country-pair fixed effects in the (3) and

[37]Note that all pooled results also include annual effects, unlike in the simple estimates of Table 1.

[38]Note that the coefficients for developed/less developed country dummies are always negative and significant.

(4) columns.[39] The coefficient for trade agreements is generally not significant, though it is positive and significant in (2). This result is counter-intuitive, but it is not robust to including country-pair dummies nor to most of the subsample specifications. Though the coefficients on the output correlations are not significant, they have the expected sign. That is, bilateral real exchange rates will be less volatile the more correlated two countries' economic fluctuations are. The distance and border coefficients are positively signed and significant in the pooled regressions. The result for the distance coefficient is intuitive and matches previous literature. However, the positive sign on the border is counterintuitive, and is investigated in the subsample analysis below.

Finally, the coefficients on the exchange rate regime (γ_{ij}^{err}) are jointly significant both for the pooled and fixed effects regressions. The individual coefficients are all negative in the pooled regressions, as expected, and the indicators of whether each country has a fixed regime or not and whether they share the same base country are significant (the currency union and bilateral peg indicators are not significant). The coefficients remain negative (except for the currency union dummy) in the fixed effects regression, but are for the most part not significant. It is also interesting to note that including these regime variables increase the point estimate (in absolute value) on the common supplier index (though only slightly). This result is expected if countries that are more similarly integrated with the rest of the world also share similar exchange rate regimes (i.e., omitting the regime variables would bias the common supplier index coefficient towards zero).

Developed-Developed Country Sample Results

Table 3 presents results using the developed-developed country sample of data. The common supplier index is significant across three of the four specifications, and does not vary greatly across the pooled and fixed effects regressions, except for specification (1). The other controls do not vary greatly under the various specifications, though the GDP variables switch significance across the specifications. The P-value for the F-test of the joint significance of the fixed effects is close to one in both specifications, indicating that these effects are in fact not significant. We interpret these results as revealing that the relationship is stronger in the cross-section, when compared with the fixed effects or within country variation in which the significance of the coefficient associated to the common supplier index decreases; potentially due to small variation through time.[40] The coefficients for the regional trade agreement and output shocks are not significant for the most part. Interestingly, the coefficient for the Herfindahl Index for the pooled results is positive and significant, though the significance of this result disappears in the fixed effects regressions. Similarly, the joint significance of the

[39]Note that the country-pair dummies, μ_{ij} are (jointly) statistically different from zero.

[40]Indeed, as Table A1 shows, the mean of the index and the real exchange volatility measures to do not vary greatly over time for the developed-developed subsample.

exchange rate regime variables is wiped out by the fixed effects.[41] The border and distance coefficients have the expected signs, but are not significant in the pooled regressions.

It is worth commenting on the increase in common supplier index coefficient when moving from the pooled regressions to the fixed effects regressions. In particular, the developed-developed country subsample includes many countries that are close to each other (e.g., Europe) and share similar technological endowments. Thus, one might expect most of the identification to take place via the time series property of the data, which is somewhat the case here.[42] However, the estimates are also more imprecise indicating some heterogeneity in the levels of integration of the developed economies and as we mentioned small variation in the index through the time, so that it is not possible to identify more clearly its effect. It is also not surprising that the exchange rate regime variables are wiped out by including country-pair fixed effects.

Developed-Less Developed Country Sample Results

Table 4 presents results using the developed-less developed country sample of data. Unlike the developed-developed subsample, this subsample represents the most diverse cross-section of the whole sample. The effect of this fact is seen immediately when comparing the coefficients on the common supplier index across the pooled regressions in columns (1) and (2) with the fixed effects regressions in columns (3) and (4). Whereas the coefficients are negative, large and very significant in the pooled regressions, the coefficients are actually positive, though not significant, in the fixed effects regressions.[43] Similarly, most of the other controls also change sign and/or significance across estimation methods. However, coefficients for the output shocks correlations are negative and significant in three specifications. The distance coefficient is positive and strongly significant in the pooled results, which agrees with conventional wisdom, while the border coefficient is not significant.

The main message from this analysis is that the common supplier index does a good job at picking up differences in the cross-section for very heterogeneous country-pairs. However, it performs weakly when looking at the data over time. It is also worth noting that the standard errors of the estimated coefficients are about eight times the estimated coefficients, therefore a ninety five percent confidence interval includes a significant negative range for these coefficients. One plausible explanation for this results is that world trade has expanded at a very non-linear pace over the last two decades (Yi 2003), and trade between the developed and less developed countries still makes up a very small component of world trade. Therefore,

[41] These coefficients are again negative, and the peg variables are individually significant in the pooled, but not fixed effects regressions.

[42] Of course, this result may not hold if we were able to use finer levels of disaggregation of trade data.

[43] The country-pair fixed effects, μ_{ij} are jointly significant in this subsample.

it is not surprising that the index does not perform well over the time series. However, we might also expect that as countries converge, the channel we highlight may play a greater role in the future for this subsample.

Less Developed-Less Developed Country Sample Results

Table 5 presents results using the less developed-less developed sample of data. We did not have strong priors when first looking at this subsample. On the one hand, these countries do not make up a great of world trade and there is quite a bit of heterogeneity between the countries on many other levels. On the other hand, as trade has grown over time, the developing world has become more important in world trade, and we would thus expect our model to become more relevant. Examining specifications (1)-(4), we find this posited relationship to hold. In particular, the common supplier index is larger and more significant for the fixed effect regressions than for the pooled results. Notice how this result is the reverse of the developed-less developed subsample in Table 4. Therefore the main message from this analysis is that the common supplier index does a better job at explaining the within country pairs variation over time.

The coefficients on the GDP and regional trade agreements are also reversed when including the fixed effects (though the trade agreement coefficient is never significant). The level of export concentration seems to matter for this subsample, though we cannot identify this relationship in the fixed effects regressions. The distance coefficient is positive, but not significant, while the border coefficient is positive and very significant in the pooled results. Evidently, the counter-intuitive border effect in the whole sample results of Table 2 is driven by this subsample of the data. This effect may simply be picking up the fact that there are regions of developing countries (which border each other) that have a tendency to exhibit high volatility during the whole sample period. The fixed effects regressions generalize this potential effect, and may thus be more appropriate to consider. Finally, unsurprisingly, the exchange rate regime variables are jointly significant across specifications, and the significance of the individual peg indicators does not change going from pooled to fixed effects specifications.

Overall, this section has presented reduced form results that confirm the main prediction of the multi-country model of Section II. That is, countries' bilateral real exchange rate volatility is smaller if they share a more similar import basket. This result is robust across specifications when using the whole sample of data, and picks up characteristics that we expected when looking across sub-samples. A natural extension to this work would be to estimate a more structural model, where we control directly for two countries' relative trade costs with trading partners as well as relative technological differences.

V. CONCLUSION

This paper examines the impact of trade costs on real exchange rate volatility. In particular, we highlight a distinct channel through which these costs affect volatility: the impact of trade costs on the heterogeneity of the set of suppliers of traded goods between countries. We endogenize this channel using a Ricardian model of trade in a multi-country setting. Finally, we take the model to the data and directly test our theoretical prediction, which is indeed supported.

We view this paper as a good starting point to analyze more formally the impact of trade and its determinants on macroeconomic volatility and other international macroeconomic issues. Indeed, one line of potential research would be to try to incorporate the channel that we emphasize into a dynamic general equilibrium macroeconomic model. Incorporating such a multi-country setting into a sophisticated intertemporal environment will not be easy, but doing so offers another channel that will help in resolving various puzzles/anomolies in the literature.

MULTI-COUNTRY REAL EXCHANGE RATE VOLATILITY

A. Statistical Theorems

The key statistical theorem that we apply is Taylor's Theorem in order to approximate the variance using a first-order approximation.[44] In particular, let $T_1, \ldots, T_k$ be random variables with means $\theta_1, \ldots, \theta_k$, and define $\mathbf{T} = (T_1, \ldots, T_k)$ and $\theta = (\theta_1, \ldots, \theta_k)$. Suppose there is a differentiable function $g(\mathbf{T})$ (an estimator of some parameter – i.e., the relative price of tradable goods) for which we want an approximate estimate of variance. Then it can be shown that:

$$\mathrm{E}_\theta g(\mathbf{T}) \approx g(\theta). \tag{A.1}$$

We can now approximate the variance of $g(\mathbf{T})$ by

$$\mathrm{Var}_\theta g(\mathbf{T}) \approx \sum_{i=1}^{k} [g_i'(\theta)]^2 \mathrm{Var}_\theta T_i + 2 \sum_{i>j} g_i'(\theta) g_j'(\theta) \mathrm{Cov}_\theta \{T_i, T_j\}, \tag{A.2}$$

where the last equality comes from expanding the square and using the definition of variance and covariance. Approximation (A.2) is very useful because it gives us a variance formula for a general function, using only simple variance and covariances.

Useful Properties of the Lognormal Distribution

If X is a random variable whose logarithm is normally distributed (that is $\log X \sim \mathrm{N}(\mu, \sigma^2)$ then one can solve for its moments and variance exactly. Specifically, given that the variable $Y \equiv \log X$ has the moment generating function $M_Y(t) = \exp(\mu t + \sigma^2 t^2/2)$, one has that:

$$\mathrm{E}\{X\} = \mathrm{E}\{\exp[\log X] = \exp(\mu + \sigma^2/2) \tag{A.3}$$

$$\mathrm{Var}\{X\} = \exp[2(\mu + \sigma^2)] - \exp(2\mu + \sigma^2) \tag{A.4}$$

[44] See Casella and Berger (2002) for details.

B. Volatility Solution: Zero Correlation of Shocks

First, define the variance of the natural logarithm of the bilateral real exchange rate between countries 1 and 2 as[45]:

$$\begin{aligned}\text{Var}\left\{\log\left[\frac{P_{T,1}}{P_{T,2}}\right]\right\} &= \text{Var}\left\{\log\left[\frac{\Phi_1}{\Phi_2}\right]^{-1/\theta}\right\} \\ &= \text{Var}\left\{\log\left[\frac{\sum_{i=1}^{N} A_{T,i}(c_{T,i}\tau_{1i})^{-\theta}}{\sum_{i=1}^{N} A_{T,i}(c_{T,i}\tau_{2i})^{-\theta}}\right]^{-1/\theta}\right\}\end{aligned} \tag{A.5}$$

Step 1: Mean and Variance of $A_{T,i}$

To solve for these values, we may use equations (A.3)-(A.4) and (13). Specifically, this yields the following:

$$\text{E}\left\{A_{T,i}\right\} = \text{E}\{\exp[\log A_{T,i}]\} = \exp\left[\log \tilde{A}_{T,i} + \sigma_\varepsilon^2/2\right] = \tilde{A}_{T,i}e^{\sigma_\varepsilon^2/2} \tag{A.6}$$

$$\text{E}\left\{A_{T,i}^2\right\} = \text{E}\{\exp[2\log A_{T,i}]\} = \exp\left[2\log \tilde{A}_{T,i} + 2\sigma_\varepsilon^2/2\right] = \tilde{A}_{T,i}^2 e^{2\sigma_\varepsilon^2} \tag{A.7}$$

$$\text{Var}\left\{A_{T,i}\right\} = \text{E}\left\{A_{T,i}^2\right\} - \text{E}^2\left\{A_{T,i}\right\} = \tilde{A}_{T,i}^2 e^{\sigma_\varepsilon^2}\left(e^{\sigma_\varepsilon^2} - 1\right), \tag{A.8}$$

where we have used the fact that E $\{\log A_{T,i}\} = \log \tilde{A}_{T,i}$.

Step 2: Expectation of Φ_i's definition

It is helpful to define the following two terms to simplify notation later:

$$\mu_1 \equiv \text{E}\{\Phi_1\} = e^{\sigma_\varepsilon^2/2}\sum_{i=1}^{N}\tilde{A}_{T,i}(c_{T,i}\tau_{1i})^{-\theta}$$

$$\mu_2 \equiv \text{E}\{\Phi_2\} = e^{\sigma_\varepsilon^2/2}\sum_{i=1}^{N}\tilde{A}_{T,i}(c_{T,i}\tau_{2i})^{-\theta}$$

In particular, we will apply Taylor's Theorem to solve for (A.5) around (μ_1, μ_2).

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[45]It is important to note that we are actually calculating a conditional/hierarchical variance. In particular, we are interested in the variances of the price indices, which are dependent on a parameter, $A_{T,i}$, which in turn we treat as a random variable. Therefore, in thinking about the conditional variance, one may use the identity: Var$X = \text{E}\{\text{Var}\{X|Y\}\} + \text{Var}\{\text{E}\{X|Y\}\}$ (Theorem 4.4.7, Casella and Berger (2002), p. 167). In our example, p_n is X and is $A_{T,i}$ is Y. Now, given the definition of the price index p_n, its variance conditional on $A_{T,i}$ will be zero, therefore the first term of the conditional variance identity is zero. Meanwhile, the expected price index is as defined in (9), as shown by Eaton and Kortum (2002).

Step 3: Solving the variance of the log of the real exchange rate around (μ_1, μ_2)

We may solve (approximately) for (A.5) by applying equation (A.2) in using Taylor's Theorem, where in this case $g(\mu_1, \mu_2) \equiv \log(p_1/p_2)$. In particular, begin by noting that

$$\frac{\partial}{\partial \mu_1} g(\mu_1, \mu_2) = \frac{1}{\mu_1} \qquad \frac{\partial}{\partial \mu_2} g(\mu_1, \mu_2) = \frac{1}{\mu_2}$$

One may then simply use these partial derivatives and apply (A.2) to find that:

$$\begin{aligned}
\text{Var}\left\{\log\left[\frac{P_{T,1}}{P_{T,2}}\right]\right\} &\approx \left(\frac{1}{\theta^2}\right)\left[\left(\frac{1}{\mu_1}\right)^2 \text{Var}\{\Phi_1\} + \left(\frac{1}{\mu_2}\right)^2 \text{Var}\{\Phi_2\} - \frac{2}{\mu_1\mu_2}\text{Cov}\{\Phi_1, \Phi_2\}\right] \\
&= \left(\frac{1}{\theta^2}\right)\left[\left(\frac{1}{\mu_1}\right)^2 \sum_{i=1}^{N} \text{Var}\{A_{T,i}\}(c_{T,i}\tau_{1i})^{-2\theta}\right. \\
&\qquad \left. + \left(\frac{1}{\mu_2}\right)^2 \sum_{i=1}^{N} \text{Var}\{A_{T,i}\}(c_{T,i}\tau_{2i})^{-2\theta}\right] \\
&\quad - \left(\frac{1}{\theta^2}\right)\left[\frac{2}{\mu_1\mu_2}\text{Cov}\left\{\sum_{i=1}^{N} A_{T,i}(c_{T,i}\tau_{1i})^{-\theta}, \sum_{i=1}^{N} A_{T,i}(c_{T,i}\tau_{2i})^{-\theta}\right\}\right] \\
&= \Upsilon\left[\left(\frac{1}{\mu_1}\right)^2 \sum_{i=1}^{N} \tilde{A}^2_{T,i}(c_{T,i}\tau_{1i})^{-2\theta} + \left(\frac{1}{\mu_2}\right)^2 \sum_{i=1}^{N} \tilde{A}^2_{T,i}(c_{T,i}\tau_{2i})^{-2\theta}\right] \\
&\quad - 2\Upsilon\left[\left(\frac{1}{\mu_1\mu_2}\right) \sum_{i=1}^{N} \tilde{A}^2_{T,i}(c^2_{T,i}\tau_{1i}\tau_{2i})^{-\theta}\right] \\
&= \Upsilon\left(\underbrace{\frac{\sum_{i=1}^{N} \tilde{A}^2_{T,i}(c_{T,i}\tau_{1i})^{-2\theta}}{\left[\sum_{i=1}^{N} \tilde{A}_{T,i}(c_{T,i}\tau_{1i})^{-\theta}\right]^2}}_{[1]} + \underbrace{\frac{\sum_{i=1}^{N} \tilde{A}^2_{T,i}(c_{T,i}\tau_{2i})^{-2\theta}}{\left[\sum_{i=1}^{N} \tilde{A}_{T,i}(c_{T,i}\tau_{2i})^{-\theta}\right]^2}}_{[2]}\right) \\
&\quad - 2\Upsilon\left(\underbrace{\frac{\sum_{i=1}^{N} \tilde{A}^2_{T,i}(c^2_{T,i}\tau_{1i}\tau_{2i})^{-\theta}}{\sum_{i=1}^{N} \tilde{A}_{T,i}(c_{T,i}\tau_{1i})^{-\theta}\sum_{i=1}^{N} \tilde{A}_{T,i}(c_{T,i}\tau_{2i})^{-\theta}}}_{[3]}\right),
\end{aligned} \tag{A.9}$$

where $\Upsilon = \left(\frac{e^{\sigma^2_\varepsilon}\left[e^{\sigma^2_\varepsilon}-1\right]}{\theta}\right) > 0$. The Cov$\{\cdot\}$ term is found by noting that $\text{E}\{A_{T,i}T_j\} = \tilde{A}_{T,i}\tilde{A}_{T,j}e^{\sigma^2_\varepsilon}$ if $i \neq j$, and that $\text{E}\left(A^2_{T,i}\right)$ is (A.7).

C. Volatility Solution: Non-Zero Correlation of Shocks

This section relaxes the assumption that Cov$(\varepsilon_i, \varepsilon_j) = 0$. In particular, we now assume that there is a vector of production shocks $\varepsilon = \{\varepsilon_1, \ldots \varepsilon_N\}$, which is distributed $n(\mathbf{0}, \mathbf{\Sigma})$, where we assume that,

$$\mathbf{\Sigma} = \sigma_\varepsilon^2 \begin{bmatrix} 1 & \rho_{12} & \cdots & \rho_{1N} \\ \rho_{12} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & \rho_{N-1,N} \\ \rho_{1N} & \cdots & \rho_{N-1,N} & 1 \end{bmatrix},$$

where $\rho_{i,j} \in [-1, 1]$ is the correlation between any technological shock i and j. Given that the shocks are distributed multivariate normally, it is also true that any subset of these shocks are also distributed normally (Anderson 1958). Of particular interest, the moment generating function for the multivariate normal density can be written as:

$$M_{\mathbf{Y}}(\mathbf{t}) = \exp(\mathbf{t}'\mu + \mathbf{t}'\mathbf{\Sigma}\mathbf{t}/2), \tag{A.10}$$

which is analogous to the moment generating function for a univariate normally distributed variable discussed in subsection A above. In particular, $\mathbf{t}$ is an $N \times 1$ vector, and will be set such that the last $N - 2$ terms are equal to zero in what follows. Of further use are the two following equalities:

$$\text{Var}\left(\sum_{i=1}^{N} a_i X_i\right) = \sum_{i=1}^{N} a_i^2 \text{Var}(X_i) + 2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} a_i a_j \text{Cov}(X_i, X_j) \tag{A.11}$$

$$\text{Cov}\left(\sum_{i=1}^{N} a_i X_i, \sum_{i=1}^{N} b_i X_i\right) = \sum_{i=1}^{N} a_i b_i \text{Var}(X_i) + \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} (a_i b_j + a_j b_i) \text{Cov}(X_i, X_j). \tag{A.12}$$

One may apply equations (A.11) and (A.12) to (A.5) to find a general form of (14). Before doing so, though, the crucial term that must now be solved for is Cov(T_i, T_j), which is now different given that the productivity shocks are now assumed to be correlated. In particular,

$$\begin{aligned} \text{Cov}(T_i, T_j) &= \text{E}(T_i T_j) - \text{E}(T_i)\text{E}(T_j) \\ &= \text{E}(\tilde{T}_i \exp\varepsilon_i \cdot \tilde{T}_j \exp\varepsilon_j) - \tilde{T}_i\tilde{T}_j e^{\sigma_\varepsilon^2} && \text{(from (A.6))} \\ &= \tilde{T}_i\tilde{T}_j M_{\hat{\varepsilon}}(\mathbf{1}) - \tilde{T}_i\tilde{T}_j e^{\sigma_\varepsilon^2} && (\text{where } \hat{\varepsilon} \subset \varepsilon) \\ &= \tilde{T}_i\tilde{T}_j \exp(\sigma_\varepsilon^2 \cdot 1^2/2 + \sigma_\varepsilon^2 \cdot 1^2/2 + 1 \cdot \rho_{ij}\sigma_\varepsilon^2 \cdot 1) - \tilde{T}_i\tilde{T}_j e^{\sigma_\varepsilon^2} \\ &= \tilde{T}_i\tilde{T}_j e^{\sigma_\varepsilon^2}\left(e^{\rho_{ij}} - 1\right), \end{aligned} \tag{A.13}$$

where the third line follows from using (A.10) with $\mu = \mathbf{0}$.

One may now apply (A.10)-(A.12) and the work done in Section B to show that the following is true:

$$\begin{aligned}\mathrm{Var}(\Phi_1) &= \sum_{i=1}^{N}(c_{T,i}\tau_{1i})^{-2\theta}\tilde{T}_i^2 e^{\sigma_\varepsilon^2}(e^{\sigma_\varepsilon^2}-1) \\ &+ 2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(c_{T,i}c_j\tau_{1i}\tau_{1j})^{-\theta}\tilde{T}_i\tilde{T}_j e^{\sigma_\varepsilon^2}(e^{\rho_{ij}}-1)\end{aligned} \tag{A.14}$$

$$\begin{aligned}\mathrm{Var}(\Phi_2) &= \sum_{i=1}^{N}(c_{T,i}\tau_{2i})^{-2\theta}\tilde{T}_i^2 e^{\sigma_\varepsilon^2}(e^{\sigma_\varepsilon^2}-1) \\ &+ 2\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(c_{T,i}c_j\tau_{2i}\tau_{2j})^{-\theta}\tilde{T}_i\tilde{T}_j e^{\sigma_\varepsilon^2}(e^{\rho_{ij}}-1)\end{aligned} \tag{A.15}$$

$$\begin{aligned}\mathrm{Cov}(\Phi_1,\Phi_2) &= \sum_{i=1}^{N}(c_{T,i}^2\tau_{1i}\tau_{2i})^{-\theta}\tilde{T}_i^2 e^{\sigma_\varepsilon^2}(e^{\sigma_\varepsilon^2}-1) \\ &+ \sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(c_{T,i}c_j)^{-\theta}\left[(\tau_{1i}\tau_{2j})^{-\theta}+(\tau_{1j}\tau_{2i})^{-\theta}\right]\tilde{T}_i\tilde{T}_j e^{\sigma_\varepsilon^2}(e^{\rho_{ij}}-1)\end{aligned} \tag{A.16}$$

These three terms are similar to [1], [2], and [3] in the solution (14). However, each term now as an additional piece that captures the correlation (ρ_{ij}) between shocks. It is again impossible to sign the derivative of the real exchange rate volatility with respect to trade costs. But, from inspection of (A.14) and (A.15), a negative correlation of shocks will decrease bilateral real exchange volatility, while (A.16) implies the opposite from holding.

Table 1. Determinants of Bilateral Real Exchange Rate Volatility:
Simple Specification for Whole Sample (1970–97)

	Pooled		*Fixed Effects*	
	(1)	(2)	(3)	(4)
Common supplier index	-1.294^{**}	-2.155^{**}	-1.863^{**}	-1.077^{+}
	(0.437)	(0.470)	(0.564)	(0.561)
Log(Product Real GDP)		0.045^{**}		0.189^{+}
		(0.010)		(0.101)
Log(Product Real GDP/Capita)		-0.023		-0.988^{**}
		(0.014)		(0.104)
Log(Distance)		0.134^{**}		
		(0.025)		
Border		0.975^{**}		
		(0.205)		
Observations	11880	11880	11880	11880
Country pairs	-	-	2136	2136
H_0: all $u_i = 0$ (*P*-value)	-	-	0.00	0.00
R^2	0.00	0.02	0.07	0.10

Notes: Exchange rate volatilities are calculated using rolling twelve month natural logarithm real exchange rate changes over five-year periods. Index and GDP variables are beginning of period. Robust clustered standard errors in parentheses; $^{+}$ significant at 10%; * significant at 5%; ** significant at 1%. Fixed effects regressions include country-pair and annual fixed effects.

Table 2. Determinants of Bilateral Real Exchange Rate Volatility:Whole Sample (1970–97)

	Pooled		*Fixed Effects*	
	(1)	(2)	(3)	(4)
Common supplier index	-1.299^{**}	-1.524^{**}	-1.087^{+}	-1.148^{*}
	(0.420)	(0.435)	(0.561)	(0.561)
Log(Product Real GDP)	0.062^{**}	0.042^{**}	0.181^{+}	0.014
	(0.010)	(0.010)	(0.103)	(0.107)
Log(Product Real GDP/Capita)	0.144^{**}	0.150^{**}	-0.981^{**}	-0.800^{**}
	(0.018)	(0.017)	(0.106)	(0.112)
Regional Trade Agreement	0.041	0.181^{*}	−0.023	−0.015
	(0.073)	(0.073)	(0.129)	(0.129)
Log(Product Herfindahl Index)	-0.130^{**}	-0.130^{**}	-0.029^{+}	-0.028^{+}
	(0.014)	(0.014)	(0.016)	(0.016)
Correlation(Output Shocks)	−0.008	−0.014	−0.024	−0.026
	(0.019)	(0.018)	(0.020)	(0.020)
Log(Distance)	0.110^{**}	0.085^{**}	-	-
	(0.023)	(0.023)		
Border	0.756^{**}	0.711^{**}	-	-
	(0.173)	(0.167)		
Exchange Rate Regime Variables	No	Yes	No	Yes
H_0: all $\gamma_i^{err} = 0$ (*P*-value)	-	0.00	-	0.00
Observations	11880	11880	11880	11880
Country pairs	-	-	2136	2136
H_0: all $u_i = 0$ (*P*-value)	-	-	0.00	0.00
R^2	0.12	0.13	0.10	0.10

Notes: Exchange rate volatilities are calculated using rolling twelve month natural logarithm real exchange rate changes over five-year periods. Annual and developed/less developed country dummies omitted. Index and GDP variables are beginning of period, while other are average or standard-deviation over five year period. Output shocks calculated by applying the Baxter-King filter to annual real GDP data with band-width parameters (1.5,8) years, and a lead-lag of the filter set to three years. Exchange rate regime measure are: (i) currency union (Rose and van Wincoop 2001), (ii) country 1 pegged or not, (iii) country 2 pegged or not, (iv) country 1 is pegged to country 2 (or vice versa), (v) country 1 and country 2 share the same base country (for pegging or floating). Variables (ii)-(v) are from Shambaugh (2004). Robust clustered standard errors in parentheses; $^{+}$ significant at 10%; * significant at 5%; ** significant at 1%.

Table 3. Determinants of Bilateral Real Exchange Rate Volatility:
Developed-Developed Country Sample (1970–97)

	Pooled		*Fixed Effects*	
	(1)	(2)	(3)	(4)
Common supplier index	-0.143	-0.313^{*}	-0.477^{+}	-0.499^{+}
	(0.143)	(0.140)	(0.278)	(0.282)
Log(Product Real GDP)	-0.028^{**}	-0.029^{**}	-0.063	-0.097
	(0.004)	(0.003)	(0.144)	(0.153)
Log(Product Real GDP/Capita)	0.048^{*}	0.064^{**}	0.385^{*}	0.418^{**}
	(0.022)	(0.022)	(0.153)	(0.160)
Regional Trade Agreement	0.021^{+}	0.029^{*}	0.034	0.033
	(0.012)	(0.012)	(0.029)	(0.029)
Log(Product Herfindahl Index)	0.032^{**}	0.025^{**}	0.002	0.002
	(0.008)	(0.007)	(0.014)	(0.014)
Correlation(Output Shocks)	0.010	0.010	0.005	0.004
	(0.009)	(0.009)	(0.013)	(0.013)
Log(Distance)	0.010	0.004	-	-
	(0.007)	(0.006)		
Border	-0.024	-0.025	-	-
	(0.018)	(0.019)		
Exchange Rate Regime Variables	No	Yes	No	Yes
H_0: all $\gamma_i^{err} = 0$ (*P*-value)	-	0.00	-	0.95
Observations	1254	1254	1254	1254
Country pairs	-	-	209	209
H_0: all $u_i = 0$ (*P*-value)	-	-	0.94	0.99
R^2	0.16	0.17	0.12	0.12

Notes: Regression specifications correspond those in to Table 2. See notes in that table. Robust clustered standard errors in parentheses; $^{+}$ significant at 10%; * significant at 5%; ** significant at 1%.

Table 4. Determinants of Bilateral Real Exchange Rate Volatility:
Developed-Less Developed Country Sample (1970–97)

	Pooled		*Fixed Effects*	
	(1)	(2)	(3)	(4)
Common supplier index	-0.932^{+}	-0.876^{+}	0.084	0.052
	(0.492)	(0.501)	(0.633)	(0.633)
Log(Product Real GDP)	0.053^{**}	0.040^{**}	-0.721^{**}	-0.757^{**}
	(0.013)	(0.012)	(0.185)	(0.187)
Log(Product Real GDP/Capita)	0.121^{**}	0.117^{**}	-0.029	0.033
	(0.018)	(0.017)	(0.177)	(0.180)
Regional Trade Agreement	-0.071	-0.123	0.002	-0.013
	(0.089)	(0.081)	(0.568)	(0.568)
Log(Product Herfindahl Index)	-0.104^{**}	-0.097^{**}	0.012	0.013
	(0.016)	(0.016)	(0.020)	(0.021)
Correlation(Output Shocks)	-0.039^{+}	-0.049^{*}	-0.062^{**}	-0.062^{**}
	(0.021)	(0.021)	(0.024)	(0.024)
Log(Distance)	0.211^{**}	0.219^{**}	-	-
	(0.030)	(0.030)		
Border	0.167	0.108	-	-
	(0.151)	(0.165)		
Exchange Rate Regime Variables	No	Yes	No	Yes
H_0: all $\gamma_i^{err} = 0$ (*P*-value)	-	0.00	-	0.11
Observations	6206	6206	6206	6206
Country pairs	-	-	1102	1102
H_0: all $u_i = 0$ (*P*-value)	-	-	0.00	0.00
R^2	0.07	0.10	0.08	0.08

Notes: Regression specifications correspond those in to Table 2. See notes in that table. Robust clustered standard errors in parentheses; $^{+}$ significant at 10%; * significant at 5%; ** significant at 1%.

Table 5. Determinants of Bilateral Real Exchange Rate Volatility:
Less Developed-Less Developed Country Sample (1970–97)

	Pooled		*Fixed Effects*	
	(1)	(2)	(3)	(4)
Common supplier index	-2.165^{+}	-2.224^{*}	-2.926^{*}	-2.928^{*}
	(1.103)	(1.083)	(1.333)	(1.333)
Log(Product Real GDP)	0.118^{**}	0.076^{**}	-0.463^{+}	-0.456^{+}
	(0.022)	(0.021)	(0.270)	(0.272)
Log(Product Real GDP/Capita)	0.181^{**}	0.175^{**}	-0.467^{+}	-0.448^{+}
	(0.029)	(0.028)	(0.268)	(0.272)
Regional Trade Agreement	0.181	0.266	-0.526	-0.49
	(0.253)	(0.245)	(0.428)	(0.443)
Log(Product Herfindahl Index)	-0.153^{**}	-0.166^{**}	-0.029	-0.034
	(0.023)	(0.023)	(0.030)	(0.030)
Correlation(Output Shocks)	0.046	0.035	0.034	0.033
	(0.039)	(0.038)	(0.042)	(0.042)
Log(Distance)	0.041	0.038	-	-
	(0.048)	(0.046)		
Border	1.063^{**}	0.990^{**}	-	-
	(0.257)	(0.249)		
EExchange Rate Regime Variables	No	Yes	No	Yes
H_0: all $\gamma_i^{err} = 0$ (*P*-value)	-	0.00	-	0.02
Observations	4420	4420	4420	4420
Country pairs	-	-	825	825
H_0: all $u_i = 0$ (*P*-value)	-	-	0.00	0.00
R^2	0.13	0.16	0.15	0.15

Notes: Regression specifications correspond those in to Table 2. See notes in that table. Robust clustered standard errors in parentheses; $^{+}$ significant at 10%; * significant at 5%; ** significant at 1%.

Table A1. Summary Statistics: Sample Means

		Common supplier index		**Real exchange rate volatility**		
	Country pairs	Mean	St. Dev.	$\sigma(\Delta q)$	$\sigma(\mathrm{HP}_q)$	$\sigma(\mathrm{BK}_q)$
Whole sample period						
Whole sample	11880	0.04	0.045	0.58	0.24	0.18
Developed-Developed	1254	0.08	0.048	0.12	0.05	0.03
Developed-Less Developed	6206	0.04	0.039	0.44	0.19	0.14
Less Developed-Less Developed	4420	0.02	0.043	0.90	0.38	0.28
1970s						
Whole sample	3637	0.04	0.047	0.31	0.15	0.10
Developed-Developed	418	0.08	0.054	0.09	0.04	0.03
Developed-Less Developed	1920	0.04	0.043	0.26	0.12	0.08
Less Developed-Less Developed	1299	0.02	0.042	0.47	0.23	0.16
1980s						
Whole sample	3981	0.03	0.043	0.75	0.33	0.25
Developed-Developed	418	0.08	0.051	0.18	0.07	0.05
Developed-Less Developed	2083	0.03	0.037	0.58	0.25	0.19
Less Developed-Less Developed	1480	0.02	0.041	1.14	0.52	0.39
1990s						
Whole sample	4262	0.04	0.043	0.65	0.24	0.17
Developed-Developed	418	0.08	0.037	0.09	0.03	0.02
Developed-Less Developed	2203	0.04	0.038	0.48	0.18	0.13
Less Developed-Less Developed	1641	0.03	0.044	1.01	0.36	0.27

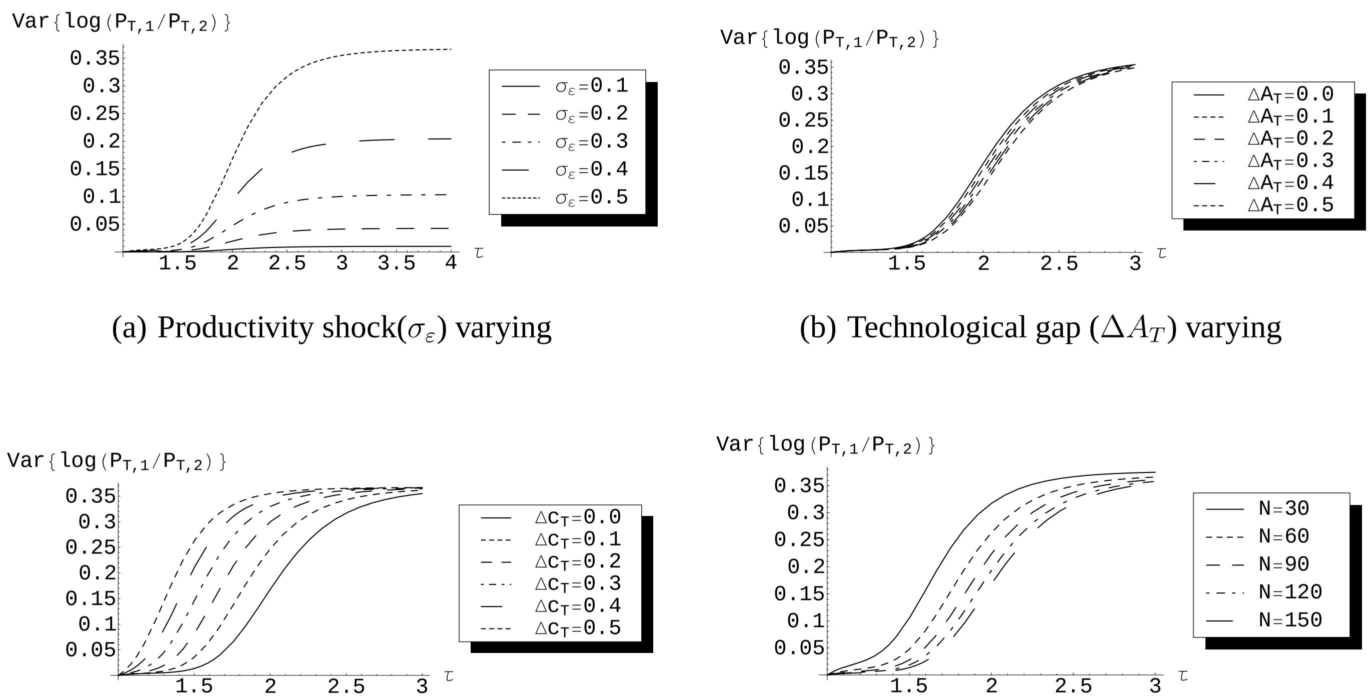
Notes: Summary statistics only presented for data used in regressions in Tables 2-5. q stands for real exchange rate, $\Delta q = \log q - \log q_{-12}$, HP_q stands for Hodrick-Prescott filtered $\log q$, and BK_q stands for Baxter-King filtered $\log q$. The Hodrick-Prescott filter is applied to the natural logarithm of monthly real exchange rate data with a smoothing parameter $\lambda = 14400$. The Baxter-King filter is applied to the natural logarithm of monthly real exchange rate data with band-width parameters (18,96) months, and a lead-lag length of the filter set to twelve months.

Table A2. Robustness Checks Using Volatility Measure with Filtered Real Exchange Rate Data: Common Supplier Index Coefficient

	Pooled		*Fixed Effects*	
Country sample	(1)	(2)	(3)	(4)
	Hodrick-Prescott Filter			
Whole	-0.608	-0.702	-0.668	-0.697
	(0.178)	(0.183)	(0.209)	(0.208)
Developed-Developed	-0.087	-0.157	-0.208	-0.216
	(0.054)	(0.054)	(0.109)	(0.110)
Developed-Less Developed	-0.420	-0.402	0.027	0.015
	(0.205)	(0.208)	(0.239)	(0.239)
Less Developed-Less Developed	-1.063	-1.084	-1.779	-1.775
	(0.482)	(0.474)	(0.491)	(0.490)
	Baxter-King Filter			
Whole	-0.439	-0.505	-0.407	-0.422
	(0.133)	(0.137)	(0.154)	(0.154)
Developed-Developed	-0.055	-0.103	-0.148	-0.154
	(0.043)	(0.042)	(0.084)	(0.085)
Developed-Less Developed	-0.308	-0.290	0.027	0.022
	(0.156)	(0.158)	(0.175)	(0.175)
Less Developed-Less Developed	-0.687	-0.702	-1.044	-1.040
	(0.353)	(0.347)	(0.366)	(0.365)

Notes: Whole refers to Table 2; Developed-Developed refers to Table 3; Developed-Less Developed refers to Table 4; Less Developed-Less Developed refers to Table 5. The Hodrick-Prescott filter is applied to the natural logarithm of monthly real exchange rate data with a smoothing parameter $\lambda = 14400$. The Baxter-King filter is applied to the natural logarithm of monthly real exchange rate data with band-width parameters (18,96) months, and a lead-lag length of the filter set to twelve months. Volatility measures are then calculated using the filtered series over five-year periods as in Tables 2-5.

Figure 1. Impact of Changing Trade Costs on Volatility



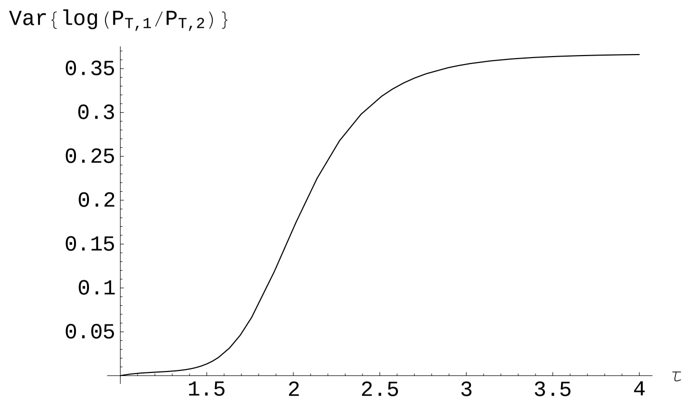
(a) Productivity shock(σ_ε) varying

(b) Technological gap (ΔA_T) varying

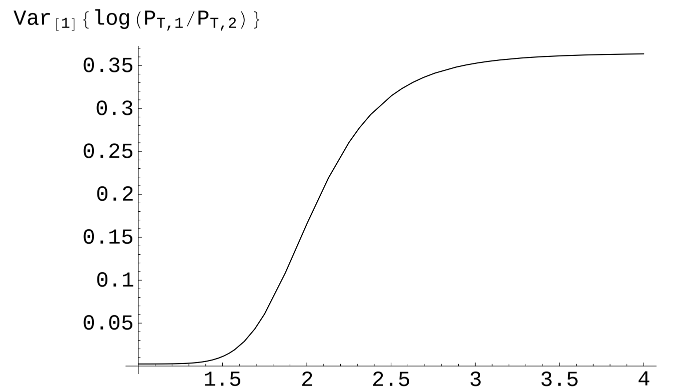
(c) Cost gap (Δc_T) varying

(d) Size of group of countries (N) varying

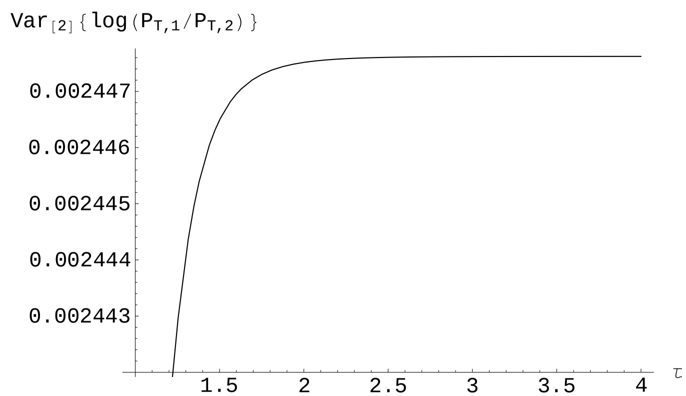
Figure 2. Breakdown of Volatility Into Components



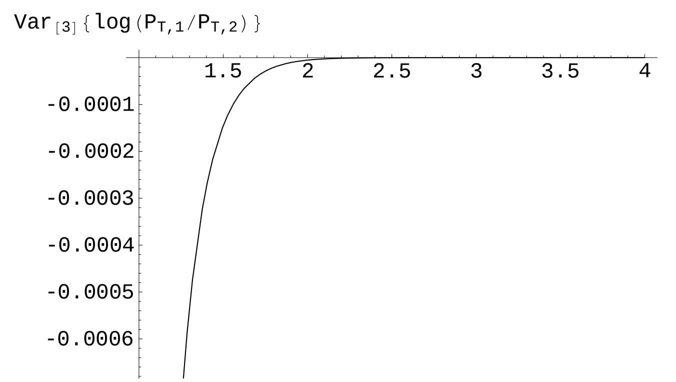
(a) Total volatility = $\Upsilon \times \{(1) + (2)\} - 2\Upsilon \times (3)$



(b) $\Upsilon \times (1)$



(c) $\Upsilon \times (2)$



(d) $-2\Upsilon \times (3)$

Figure 3. Annual World Average of Common Supplier Index

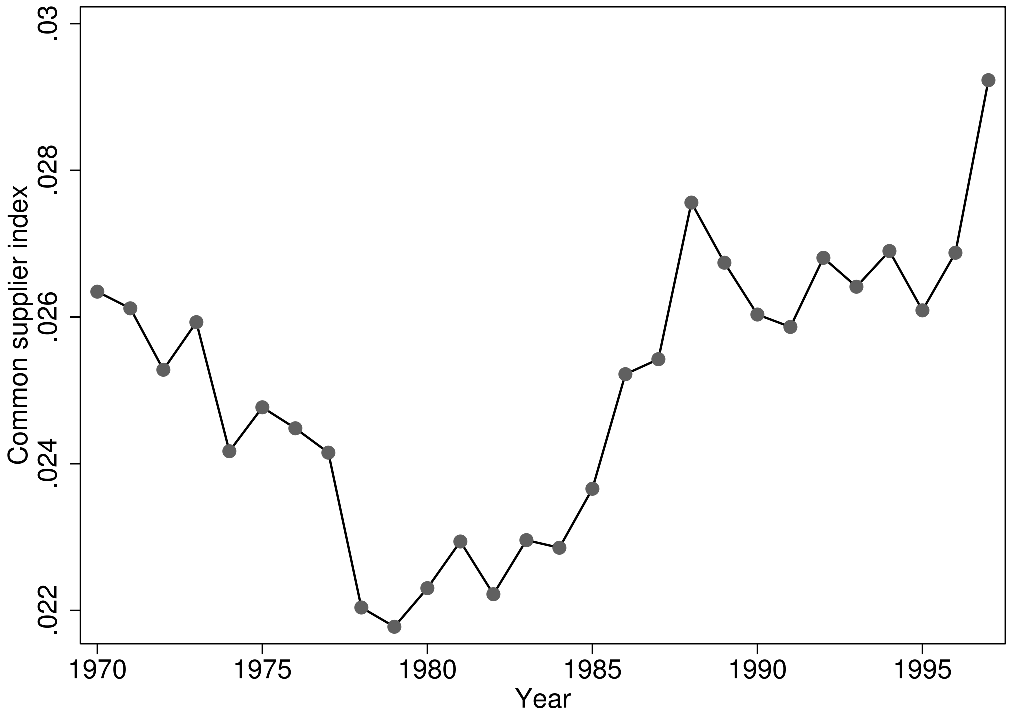
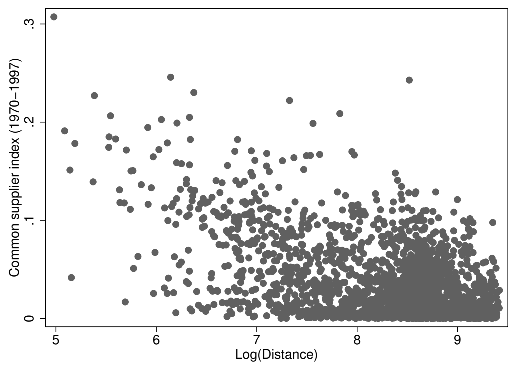
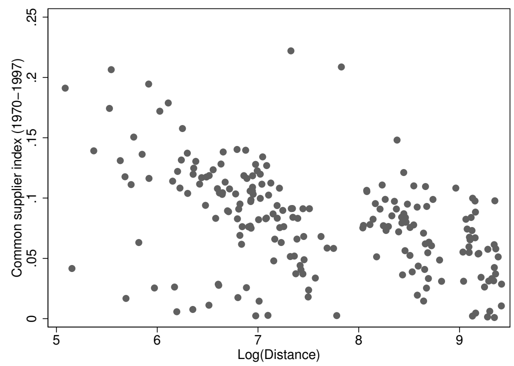


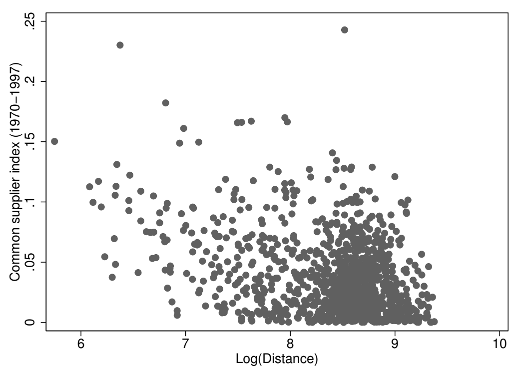
Figure 4. Common Supplier Index vs. Distance



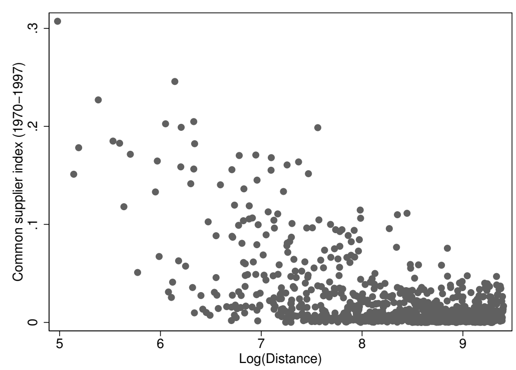
(a) Whole sample



(b) Developed-developed countries



(c) Developed-less developed countries



(d) Less developed-less developed countries

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