

This PDF is a selection from a published volume from the
National Bureau of Economic Research

Volume Title: Commodity Prices and Markets, East Asia Seminar
on Economics, Volume 20

Volume Author/Editor: Takatoshi Ito and Andrew K. Rose, editors

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-38689-9
ISBN13: 978-0-226-38689-8

Volume URL: http://www.nber.org/books/ito_09-1

Conference Date: June 26-27, 2009

Publication Date: February 2011

Chapter Title: Identifying the Relationship Between Trade and
Exchange Rate Volatility

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Chapter URL: <http://www.nber.org/chapters/c11862>

Chapter pages in book: (79 - 110)

Identifying the Relationship between Trade and Exchange Rate Volatility

Christian Broda and John Romalis

3.1 Introduction

A traditional criticism of flexible exchange rate regimes is that flexible rates increase the level of exchange rate uncertainty, and thus reduce incentives to trade.¹ This criticism has generated a large literature that focuses on the impact of exchange rate volatility on trade. However, Mundell's (1961) optimal currency area hypothesis suggests an opposite direction of causality, where trade flows stabilize real exchange rate fluctuations, thus reducing real exchange rate volatility.² These two seminal ideas of international trade imply the existence of a standard identification problem: is the correlation between trade and exchange rate volatility indicative of the effect of volatility on trade, or vice versa?

Few theoretical and empirical papers have attempted to answer this question. Most of the existing studies have focused on the effects of exchange rate regimes or volatility on trade by effectively assuming that the exchange rate process is driven by exogenous shocks, and is unaffected by other endogenous variables.³ Well-known examples of this approach for currency unions commence with Rose (2000) and include Frankel and Rose (2002). By definition,

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1. Taussig (1924) was an early advocate of this idea.

2. Central banks in many developing countries have targeted real effective exchange rates in the past. This implies that even if trade does not act as an automatic stabilizer, policy interventions will reduce bilateral volatility with major trading partners.

3. Even in the full general equilibrium models of Bacchetta and van Wincoop (2000) and Obstfeld and Rogoff (2001), exchange rate volatility is purely determined by exogenous shocks.

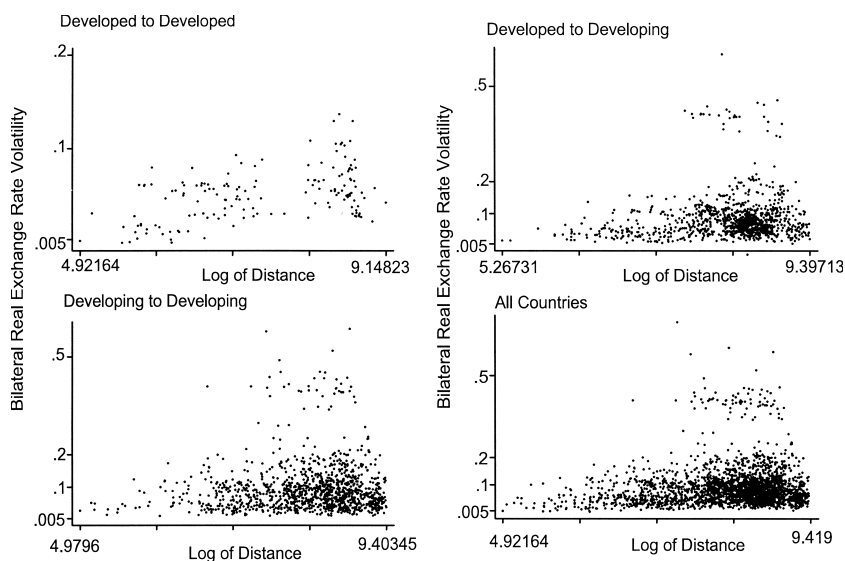


Fig. 3.1 Exchange rate volatility and distance between countries in 1997

this implies that the effect of trade on volatility is assumed inexistent rather than jointly estimated with the effect of volatility on trade.⁴ Figure 3.1 illustrates that this is not a benign assumption. This figure shows a strong positive relationship between real exchange rate volatility and distance between trading partners. Since distance cannot be affected by volatility, this strong relationship suggests that greater distance between countries significantly increases bilateral exchange rate volatility through the effect of distance on the intensity of commercial relationships such as trade.⁵ Ignoring the causal effect of trade on volatility results in overestimates of the true impact of exchange rate volatility on trade.

We use a model of bilateral trade to structurally estimate the effect on trade of exchange rate volatility and exchange rate regimes such as fixed exchange rates and currency boards. The model highlights the role of trade in determining bilateral real exchange rate volatilities (the source of reverse causality), and the differences in the impact of real exchange rate volatility on trade in different types of goods. These features of the model constitute the main building blocks of our identification strategy. First, real

4. The only exceptions are the empirical papers by Frankel and Wei (1993), Persson (2001), Teneyro and Barro (2007), and Teneyro (2007). We discuss the identification strategies of these papers in the main text.

5. This result is related to Engel and Rogers (1996) and Alesina, Barro, and Teneyro (2003), who examine the importance of distance in the comovement of price shocks across cities and countries, respectively. It also relates to recent work by Hau (2002), discussed on pages 7 and 8, who finds that differences in openness can explain the cross-country variation in the volatility of effective real exchange rates.

exchange rate volatility affects trade in differentiated products, but does not affect where a commodity gets sold. Second, trade in all products affects real exchange rate volatility. These two results will enable us to identify how exchange rate volatility affects trade in differentiated products. The reason for this is that commodity trade can be used to pinpoint how trade affects exchange rate volatility. This enables identification of how volatility affects trade in differentiated products. Since the model predicts that commodity trade is only affected by relative price levels and not by volatility, we identify the effect of volatility on total trade.

The intuition behind the main predictions of the model is fairly simple. First, in our model all trade acts as an automatic stabilizer of real exchange rates. To be consistent with our data, we take the real exchange rate between two countries to be the ratio of consumer price levels expressed in a common currency. In equilibrium, proximate countries have more similar consumption baskets than more distant countries. This implies that more proximate countries have lower real exchange rate volatility than more distant countries, consistent with the data presented in figure 3.1. This is because a shock that changes the price of a country's goods will affect the price of the consumption basket of a neighboring country more than that of a more distant country. In the limit, if baskets are identical, real exchange rates are constant.

Second, in our model exchange rate volatility only affects trade in differentiated products. In a model with more general preferences, the production mix between manufactures and commodities could be affected by exchange rate volatility, but conditional on production, where commodities get sold would remain unaffected. Commodity products are sold in organized exchanges. Subject to transport costs, buyers and sellers do not care who they buy from or sell to; what they end up paying or receiving is identical regardless of the counterparty. With differentiated products the same is not true. Rauch (1999) argues that the heterogeneity of most manufactured products in both characteristics and quality prevents traders from using organized exchanges for these products. Instead, connections between sellers and buyers are made through a costly search process. This cost can be associated with establishing networks, advertising, and marketing in general. Real exchange rate volatility that occurs after these costs are sunk will affect the profitability of these connections. Therefore, in contrast to commodity products, trade in differentiated products is affected by exchange rate volatility.⁶

We use disaggregated data to exploit our identification structure and test the predictions of the model. Rauch (1999) provides a categorization of Standard International Trade Classification (SITC) Revision 2 industries

6. The sign of the effect of volatility on trade in differentiated products depends on the degree of risk aversion of the firms that are exporting them. When firms are sufficiently risk averse (loving), relatively more differentiated products will be exported to countries that have low (high) exchange rate volatilities with the exporting country.

according to three possible product types: differentiated, reference priced, and commodity. The Rauch classification is widely used in empirical international trade literature. Bilateral trade data for each SITC industry is available for a large number of developed and developing countries during the period 1970 to 1997. This data is now a little dated, and it would be ideal if we extended it to recent years to identify the early effects of European Monetary Integration (EMU). We calculate several measures of bilateral real exchange rate volatility from monthly real exchange rate series for the same period. We source data on exchange rate regimes from Rose (2000) and Frankel and Rose (2002), the International Monetary Fund (IMF), Rogoff and Reinhart (2003), and Levy-Yeyati and Sturzenegger (2000) (hereafter LYS).

The empirical findings of this chapter provide support for the view that trade depresses real exchange rate volatility. A trading relationship that is 1 percent of the gross domestic product (GDP) greater than the median trade relationship implies that the volatility of the bilateral real exchange rate associated with the intense trading partner is 12 percent smaller than with the less intense partner. The empirical findings also support the view that real exchange rate volatility only moderately depresses exports. We find that doubling real exchange rate volatility decreases exports of differentiated products by 2 percent. The reduction from the ordinary least squares (OLS) estimates is because the model attributes most of the correlation between trade and volatility to the effect that trade has in depressing volatility.

The empirical methodology is suitable for testing the effect of exchange rate regimes on countries' trade performances. While several studies have found large positive effects of fixed regimes on trade (see, for example, Ghosh et al. [1997] and Frankel and Rose [2002]) they do not control for the reverse-causality problem. However, we observe many fixed regimes pegging their currency to that of countries that are their main trading partners, suggesting that reverse causality can be an important problem.⁷ Indeed, we find that the effect of fixed regimes on trade is much smaller when the reverse causation is modeled. In particular, the effect of currency unions is substantially reduced from 300 percent to between 10 and 25 percent when we apply our methodology to Frankel and Rose's data, with very little loss of precision.

This chapter departs from the existing literature in several dimensions. First, this chapter represents the first attempt to structurally estimate the relationship between trade and exchange rate volatility. We provide a model that incorporates both directions of causality and suggests an identification structure. Previous attempts to correct for the problem of reverse causality relied on assumptions about appropriate instruments. Frankel and Wei (1993) use the standard deviation of relative money supplies as an instrument for the volatility of exchange rates. Barro and Tenreyro (2007) and

7. The European Monetary System and the Central Franc Zone are just two examples of this behavior.

Tenreyro (2007) model the formation of exchange rate regimes to derive an instrument for volatility. They develop an instrument for membership in a currency union (or pegged regime) based on the probability that the countries independently adopt (or peg to) the same common currency. The probability that a single country adopts the currency of another country is a linear combination of the same gravity variables that affect trade directly. They get identification by assuming that “bilateral trade between countries i and j depends on gravity variables for countries i and j , but not on gravity variables involving third countries, notably the potential anchors” (Barro and Tenreyro 2007, 5). Their instrumental variable (IV) estimates of the effect of currency unions on trade are substantially larger than OLS estimates, opposite to our results. By contrast, in the case of fixed exchange rates, Tenreyro (2007) finds no effects of fixed exchange rates on trade, whereas we find modest but statistically significant effects. But their identification assumption is unusual. In most models of trade, the trade between countries i and j will greatly depend on the trading opportunities with third countries. That is an important feature of our relatively standard trade model. Persson (2001) also models selection into currency unions to construct control groups for countries “treated” with a currency union. He finds that a common currency boosts trade by between 13 and 65 percent, which is much closer to our estimates of 10 to 25 percent. His method also identifies exogenous differences in currency union status. Recent papers that examine the trade effects of the euro are also relevant. The introduction of the euro provides an exogenous shift (a “before” and an “after”) that can be used to identify the effect of currency unions on trade. Early results using gravity regressions suggest very modest trade increases (see, for example, Micco, Stein, and Ordoñez [2003]). But the experiment may not be as clean as it appears. The introduction of the euro was long anticipated. These papers will need to work hard to separate the trade effects of the common currency from the trade effects of other market integration measures adopted by the European Union in recent years.

Second, we know of no paper that models and estimates the effect of exchange rate volatility on the composition of trade. In previous empirical studies, Bini-Smaghi (1991) and Klein (1990) have attempted to use disaggregate data to test whether uncertainty has different effects for different products. They find that different products are affected differently by volatility, but the characteristics of those products that have larger effects are not identified.

Third, we model how trade costs affect real exchange rate volatility. Hau (2002) shows theoretically and empirically that openness can affect real exchange rate volatility through the share of tradable goods in consumption. In his model, however, this share is exogenously given while in our model differences in consumption baskets are endogenously determined by trading and searching costs. In our model the bilateral pattern of real exchange rate

volatility can differ across countries, even though the underlying shocks to each country are identical. This different approach has very real identification implications. Hau (2002) recognizes that openness is an endogenous variable and may be affected by exchange rate volatility. He follows Romer (1993) and uses land area as a suitable instrument for openness in his regressions. In our model we can see why land area is related to openness—it affects individual product prices through trade costs and aggregate price indexes through market size. Trade costs and aggregate price indexes belong in our equation system, suggesting that land area may not be suitable as an instrument.

Last, the focus of most of the theoretical literature is on the role that the invoicing currency plays because prices are set before the exchange rate is observed. Therefore, the invoicing currency determines who bears the exchange rate risk. Note that in this setup uncertainty arises between the time in which prices are set and the time final payment is made, which is usually a short period.⁸ We depart from this tradition and focus on the market entry decision of exporting firms. There are no price rigidities in this model.

The chapter proceeds as follows. Section 3.2 contains our trade model. Section 3.3 discusses the implications of that model for exchange rate volatility. Section 3.4 develops our empirical model and identification strategy. Section 3.5 describes our data. Section 3.6 presents the main results of the chapter and the comparisons with the exchange rate regime literature. Section 3.7 presents robustness checks. Section 3.8 concludes.

3.2 A Four-Country, Two-Sector Trade Model

3.2.1 Model Description

The model has four countries and two sectors, manufacturing and commodities. The manufacturing sector is an adaptation of the Krugman (1980) model of intraindustry trade driven by scale economies and product differentiation. The adaptation is that to serve an export market, manufacturers must incur an additional fixed cost in each period before observing that period's exchange rates. After making the entry decision and observing the exchange rate, the manufacturer can set prices optimally for that period. Manufacturers' assumptions about the distribution of exchange rates will affect the entry decision. Exchange rates are affected by productivity shocks that are external to this model. Commodity producers do not face a fixed cost of entry; they are always ready to sell in a market. The realized price levels affect where commodities are sent; exchange rate volatility has no independent effect on commodity trade. Finally, we add "iceberg" trans-

8. Informal evidence suggests that this can take between one and six months.

port costs. The transport costs affect the distribution of exchange rates and affect manufacturers' decisions to export. Detailed assumptions are set out as follows:

1. There are four countries $i = 1, \dots, 4$ on two continents; countries one and two on one continent and three and four on the other.
2. Each country has its own currency that can be freely exchanged for that of another. The price of country i 's currency in terms of the currency of country one, which we call the dollar, is s_i .
3. There is one factor of production, labor, supplied inelastically. Labor earns a factor reward of $w_i = 1$ unit of local currency. The total labor supply in each country is one.
4. Trade is always balanced. It is essential to have some long-run trade balance condition, though it need not take this simple and extreme form. Since the model is used to motivate an empirical specification, we do not see this as an important limitation. We will not be estimating deep parameters of our model.
5. Exchange rate movements are driven by shocks to labor productivity $\theta_i^{-1} \in (0,1)$. Any exogenous cause of real exchange rate movements would suffice for our purposes.
6. All consumers in all countries are assumed to maximize identical constant-relative-risk-aversion preferences in each period over a composite manufactured good M and a composite commodity C , with the fraction of income spent on M being b (equation [1]).

$$(1) \quad U = \frac{1}{a} (M^b C^{1-b})^a.$$

7. Commodity sector. The commodity C is a composite good. Perfectly competitive firms in country i produce an identical commodity under constant returns to scale, requiring θ_i units of labor to produce one unit of the commodity. Each country produces a different commodity. For instance, country one might produce wheat while country two produces copper. What is essential for our model is that some commodities are internationally traded between some countries. Commodity C can be interpreted as a subutility function that depends on the quantity of each commodity consumed. We choose the constant elasticity of substitution (CES) function with elasticity of substitution between two different commodities being σ_c . Let q_i^D denote the quantity consumed of the commodity produced in country i . Commodity C is defined by equation (2):

$$(2) \quad C = \left(\sum_{i=1}^4 (q_i^D)^{(\sigma_c-1)/\sigma_c} \right)^{\sigma_c/(\sigma_c-1)}.$$

8. Monopolistic competition in manufacturing. In manufacturing, there are economies of scale in production, and firms can costlessly differentiate

their products. The output of manufacturing consists of a number of varieties that are imperfect substitutes for one another. The quantity produced of variety v is denoted by q_v^S , the quantity consumed by q_v^D . Variable V is the endogenously determined set of varieties produced, and M can be interpreted as a subutility function that depends on the quantity of each variety of M consumed. We choose the symmetric CES function with elasticity of substitution $\sigma_m > 1$:

$$(3) \quad M = \left(\int_{v \in V} (q_v^D)^{(\sigma_m-1)/\sigma_m} dv \right)^{\sigma_m/(\sigma_m-1)}, \quad \sigma_m > 1.$$

All manufacturers must serve their domestic market. Manufactures are produced using labor with a marginal cost $w_e \theta_v$, and a per-period fixed cost. The fixed cost must be paid before manufacturers observe the exchange rates for the period. Average costs of production decline at all levels of output, although at a decreasing rate. Production technology for a firm in country e selling q_v units in the domestic market is represented by a total cost function TC that is assumed to be identical for all firms selling in their domestic market:

$$(4) \quad TC_e(q_v^S) = w_e (\alpha_1 + q_v^S \theta_e).$$

Manufacturers enter foreign markets through exports only.⁹ To export to a foreign market, the manufacturer must incur a per-period fixed cost for market development, which must be paid before observing exchange rates for that period.¹⁰ The manufacturer's cost for market development and producing x_v units for export from country e (exporter) to country i (importer) is represented by the Free On Board (FOB) export cost function XC .

$$(5) \quad XC_{ei}(x_v^S) = w_e (\alpha_2 + x_v^S \theta_e).$$

9. Costly international trade. There may be a transport cost for international trade. To avoid the need to model a separate transport sector, transport costs are introduced in the convenient but special iceberg form. The τ_{1m} units of a manufactured good must be shipped for one unit to arrive in the country on the same continent, and τ_{2m} units must be shipped for one unit to arrive in a country on a different continent ($\tau_{2m} \geq \tau_{1m} \geq 1$). The equivalent transport costs for commodities are τ_{1c} and τ_{2c} .

3.2.2 Equilibrium in Commodity Sectors

In general, equilibrium consumers maximize utility, firms maximize profits, all factors are fully employed, and trade is balanced. Productivity determines exchange rates s_e . The equilibrium for commodity sectors

9. If they produce in a foreign country, their cost structure is identical to a domestic firm's.

10. The critical assumption is not the fixed cost α_1 for commencing domestic production, but how large the fixed cost α_2 for entering each export market is relative to α_1 .

is straightforward. Firms always price at marginal cost. For their domestic market, marginal cost in local currency is simply equal to the wage rate, one. For export markets, marginal cost is higher due to the transport cost. The price, in dollars, of a commodity produced in country e (exporter) and sold in country i (importer) is given by equation (6).

$$(6) \quad p_{ei} = \begin{cases} s_e \theta_e & e = i \quad \text{domestic sales} \\ s_e \theta_e \tau_{1c} & e \neq i \quad e, i, \text{ on same continent} \\ s_e \theta_e \tau_{2c} & e \neq i \quad e, i, \text{ on different continents.} \end{cases}$$

Consumers spend a fixed proportion of their income on commodities. They demand some of each commodity. Income in country i in dollars is simply s_i . Maximizing equation (1) yields the following demand functions in country i for commodities produced in e :

$$(7) \quad q_{ei}^D = \frac{(s_e \theta_e \tau_{eic})^{-\sigma_c}}{\sum_{e'} (s_{e'} \theta_{e'} \tau_{e'ic})^{1-\sigma_c}} (1 - b) s_i,$$

where $\tau_{eic} = 1, \tau_{ic}$, or τ_{2c} , according to model assumption 9. Note how trade costs involving third countries e' directly affect the trade between e and i . It is convenient to define the ideal price index for commodities in country i , P_{ic} :

$$(8) \quad P_{ic} = \left(\sum_e (s_e \theta_e \tau_{eic})^{1-\sigma_c} \right)^{1/(1-\sigma_c)}.$$

Equations (6) through (8) can be solved for log of the value of commodity exports from country e to country i :

$$(9) \quad \ln p_{ei} q_{ei}^D = (1 - \sigma_c) \ln s_e \theta_e + (1 - \sigma_c) \ln \tau_{eic} + \ln (1 - b) s_i - (1 - \sigma_c) \ln P_{ic}.$$

We can eliminate country i specific effects, such as its commodity price index P_{ic} and income spent on commodities $(1 - b) s_i$, by differencing. In particular, the log value of country i 's imports of commodities from country e , $\ln C_{ei}$ less the log value of country i 's imports of commodities from country e' is:

$$(10) \quad \ln C_{ei} - \ln C_{e'i} = (1 - \sigma_c)(\ln s_e \theta_e - \ln s_{e'} \theta_{e'}) + (1 - \sigma_c)(\ln \tau_{eic} - \ln \tau_{e'ic}).$$

3.2.3 Equilibrium in Manufacturing Sectors

The equilibrium in manufacturing sectors is more involved. The crucial difference is that some manufacturers may not end up exporting to some or all foreign markets, and that this proportion will depend on the perceived volatility of exchange rates. The properties of the model's demand structure for manufactures have been analyzed in Helpman and Krugman (1985).¹¹ Let $p_{ei,v}$

11. See sections 6.1, 6.2, and 10.4 in particular.

be the price paid by consumers in country i , inclusive of transport costs, for a variety v produced in country e , expressed in dollars. Maximization of equation (1) yields the following demand functions for variety v in country i :

$$(11) \quad q_{ei,v}^D = \frac{p_{ei,v}^{-\sigma_m}}{\int_{v' \in V} p_{ei,v'}^{1-\sigma_m} dv'} b s_i; \quad \forall v \in V.$$

A firm's share of industry revenues depends on its own price and on the prices set by all other firms in that industry. It is convenient to define the ideal price index for manufactures in country i , P_{im} :

$$(12) \quad P_{im} = \left(\int_{v \in V} p_{ei,v}^{1-\sigma_m} dv \right)^{1/(1-\sigma_m)}.$$

Each firm produces a different variety of the product. Each country produces different varieties. Consumers demand some of every variety made available to them. Profit maximizing firms perceive a demand curve that has a constant elasticity, and therefore, set price at a constant markup over marginal cost.¹² An individual firm in country e sets a single factory gate dollar price $\hat{p}_{e,v}$:

$$(13) \quad \hat{p}_{e,v} = \frac{\sigma_m}{\sigma_m - 1} s_e \theta_e.$$

For export markets, marginal cost is higher due to the transport cost. The consumer price $p_{ei,v}$ in dollars, of a manufactured good v produced in country e and sold in country i , is given by equation (14):

$$(14) \quad p_{ei,v} = \hat{p}_{ei,v} \tau_{eim}.$$

Country e 's products sell in its own domestic market at the factory gate price $\hat{p}_{e,v}$, but in export markets the transport cost raises the price to $\hat{p}_{ei,v} \tau_{eim}$. The ideal manufacturing industry price index for country i , P_{im} , is given in equation (15). We assume a symmetric equilibrium if each country faces the same distribution of shocks to productivity, which affects exchange rates. Prior to the realization of the productivity shock, all countries are alike with n firms manufacturing in each country, and that $n f_{ei}$ manufacturing firms from country e export to country i . Let $f_{ei} = f_1$ if e and i are on the same continent, and $f_{ei} = f_2$ if e and i are on different continents. Note that $f_{ei} = 1$ if $e = i$ (domestic sales). The free entry conditions for f_1 and f_2 are examined below.

$$(15) \quad P_{im} = \left[\sum_e n f_{ei} \left(\frac{\sigma_m}{\sigma_m - 1} s_e \theta_e \tau_{eim} \right)^{1-\sigma_m} \right]^{1/(1-\sigma_m)}.$$

12. The demand curve faced by a firm has a constant elasticity if there are an infinite number of varieties.

Equation (16) gives real profits for sales in country i for a manufacturer based in country e : $1/\sigma_m$ is the profit margin; $\alpha_i s_e$ is the fixed market development cost in dollars, where $\alpha_i = \alpha_1$ if $e = i$ (domestic sales) and $\alpha_i = \alpha_2$ if $e \neq i$ (export sales); the remainder of the term in brackets are sales revenues in dollars; while $P_e = (P_{em})^b (P_{ec})^{1-b}$ is the ideal price index in country e .

$$(16) \quad \frac{\pi_e}{P_e} = \left[\frac{1}{\sigma_m} \left(\frac{(\sigma_m / \sigma_m - 1) s_e \theta_e \tau_{eim}}{P_{im}} \right)^{1-\sigma_m} b s_i - \alpha_i s_e \right] \frac{1}{P_e}.$$

With free entry, manufacturers establish themselves in each country e and make decisions to export to each other country i until for each manufacturer:

$$(17) \quad \text{Max}_{I_{ei}} \left[E \left(\sum_i I_{ei} \left(\frac{\pi_e}{P_e} \right)^a \right) \right] = 0,$$

where I_{ei} is an indicator variable that takes a value of 1 if a manufacturer exports from e to i and is 0 otherwise, and a is the parameter governing risk aversion. Profitability in each market is a declining function of the number of domestic firms n and the number of foreign firms $n(f_1 + 2f_2)$ that export to that market, since the price index P_{im} declines with entry and because $\sigma_m > 1$. In general, the proportion of manufacturers that export to nearby markets, f_1 , and the proportion, f_2 , that export to distant markets will depend on transport costs, market entry costs, risk aversion, and the distribution of exchange rates. The proportion f_2 will in general differ from f_1 , directly due to the higher transport cost (which reduces willingness to enter), and indirectly through the impact of transport costs on the distribution of exchange rates.

Proportions f_1 and f_2 are, therefore, different functions of expected exchange rate volatility. The first two equations of our empirical specification will come directly from equations (10) and (19), recognizing that f_1 and f_2 are a function of exchange rate volatility. Let V_e be the set of all manufacturing varieties produced in country e . Equations (11) through (15) solve for the log of the value of manufacturing imports into country i from country e :

$$(18) \quad \ln \int_{v \in V_e} p_{eiv} q_{eiv}^D = \ln n f_{ei} + (1 - \sigma_m) \ln s_e \theta_e + (1 - \sigma_m) \ln \tau_{eim} + \ln b s_i - (1 - \sigma_m) \ln P_{im}.$$

We again employ differencing to eliminate country i specific effects. Equation (19) gives the log value of country i 's manufacturing imports from country e , $\ln M_{ei}$, less the log value of country i 's manufacturing imports from country e' :

$$(19) \quad \ln \frac{M_{ei}}{M_{e'i}} = \ln \frac{f_{ei}}{f_{e'i}} + (1 - \sigma_m) \ln \frac{s_e \theta_e}{s_{e'} \theta_{e'}} + (1 - \sigma_m) \ln \frac{\tau_{eim}}{\tau_{e'im}}.$$

Equation (19) for manufacturing trade depends on the difference in the proportions f_{ei} and $f_{e'i}$ of manufacturers who choose to pay the fixed cost to enter country i 's market, which will depend on the distribution of exchange rates and attitudes to risk.

3.3 Endogenous Exchange Rate Volatility

In most of the existing theoretical literature, the exchange rate process is purely driven by exogenous shocks. The earlier literature relied on a partial equilibrium approach in which the exchange rate was assumed to be an exogenous random variable (see Ethier 1973; Viaene and de Vries 1992; Hooper and Kohlhagen 1978). More recently, Obstfeld and Rogoff (1998) and Bacchetta and van Wincoop (2000) have focused on general equilibrium models of exchange rate fluctuations. They highlight the importance of having fundamentals such as monetary, fiscal, and productivity shocks drive exchange rate fluctuations. However, in these models, real exchange rates are unaffected by other endogenous variables, and are purely driven by exogenous shocks.

In our model, trade acts as an automatic stabilizer of real exchange rates. The model implies that, *in equilibrium*, proximate countries have more similar consumption baskets than more distant countries. More similar consumption baskets, in turn, reduce real exchange rate volatility. The intuition for this result is simple. Since real exchange rates are commonly measured as the ratio of price levels P_i across countries (denominated in a common currency), a shock to the price of one country's output shifts the relative price level between itself and more proximate countries less than it shifts the relative price levels between itself and more distant countries. Hau (2002) obtains a similar cross-country prediction using a small open economy model by assuming that the share of tradable goods in preferences vary by country. Our model differs from his in two dimensions. First, Hau assumes different consumption baskets across countries, while in our setup they are endogenously determined by trading and searching costs. Second, in our multicountry framework, the bilateral pattern of real exchange rate volatility can differ across countries even though the distribution of underlying shocks to each country are identical. Third, we argue that his instrument for openness, land area, is effectively a proxy for variables that belong directly in the system of equations such as trade costs and aggregate price indexes, and is therefore not a valid instrument.

Figure 3.2 illustrates the impact that trade costs have on real exchange rate volatility in the model. In particular, it shows the relationship between intercontinental trading costs and the relative real exchange rate volatility between countries that share the same continent and between countries on different continents. We assume that the distribution of productivity shocks hitting each individual country are identical; $\sigma_m = \sigma_c = 5$; intracontinental

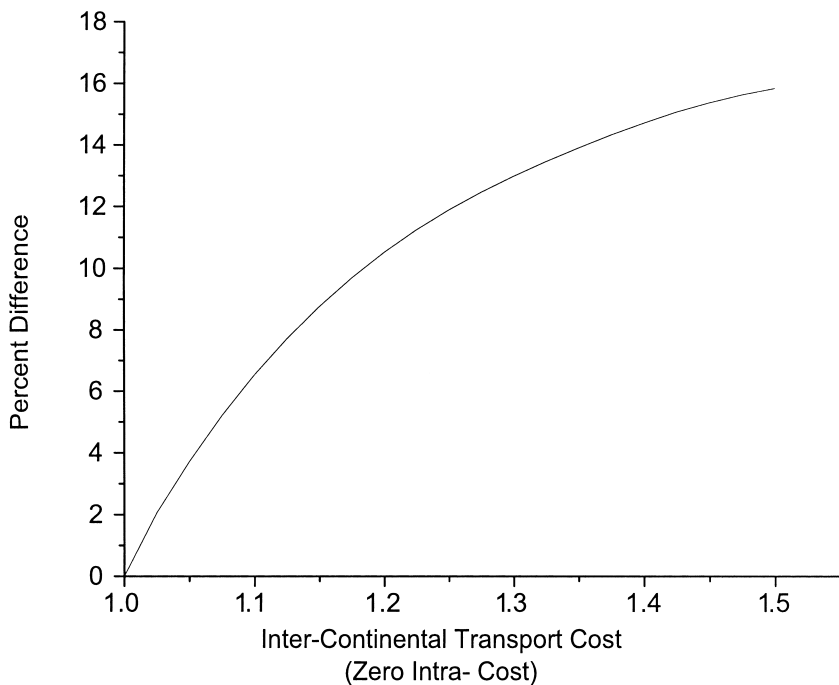


Fig. 3.2 Difference between intercontinental and intracontinental, real exchange rate volatility

trading costs $\tau_{1m} = \tau_{1c} = 1$; intercontinental trading costs are $\tau_{2m} = \tau_{2c} = \tau_2$; firms are risk neutral; and the fixed cost of entering foreign markets is sufficiently low that manufacturers export to all markets. The figure shows that with $\tau_2 > 1$, real exchange rate volatility with distant countries is larger than with proximate countries. It also shows that when the trading costs between continents increase, the intercontinental bilateral real exchange rate volatility rises relative to the intracontinental volatility. For the empirical section that follows, this means that we face a system of simultaneous equations. The OLS regressions of trade on exchange rate volatility will be biased toward finding depressing effects of real exchange rate volatility on trade, because trade itself depresses real exchange rate volatility.

But what does this other equation look like? Suppose that productivity in country e rises. At preexisting exchange rates, there is an incipient trade surplus in country e . Every country's demand shifts toward country e 's output because the prices of country e 's products falls. Country e 's exchange rate appreciates. How much it appreciates is negatively related to how substitutable country e 's output is for the output of other countries, which is determined by σ_e and σ_m . But what happens to real exchange rates? In the appendix, it is shown that the sensitivity of country i 's real exchange rate

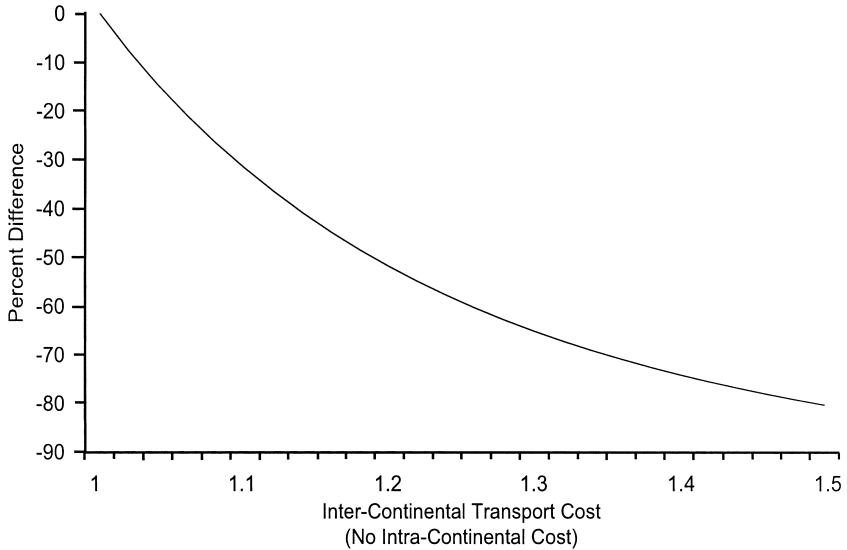


Fig. 3.3 Difference between intercontinental and intracontinental trade

with country e , in response to a small movement in country e 's exchange rate, is given by:

$$(20) \quad \frac{d \ln(P_i/P_e)}{d \ln s_e} = \frac{M_{ei} + C_{ei}}{\text{GDP}_i} - \frac{M_{ee} + C_{ee}}{\text{GDP}_e},$$

where M_{ei} (C_{ei}) is the dollar value of manufactures (commodities) produced in country e and consumed in country i . The terms on the right of equation (20) are simply the dollar value of country e 's goods sold in countries i and e , respectively, divided by aggregate income in those countries. How much the real exchange rate moves depends on the difference in the importance of country e 's goods in country i 's and country e 's consumption baskets. The more that country e exports to country i , the more similar their consumption baskets will look. This is consistent with figures 3.2 and 3.3; the less trade there is between countries, the greater the volatility of their real exchange rate. Trade in both manufactures and commodities is important. Without a closed-form solution, we assume that the way that exports from e to i affect bilateral real exchange rate volatility between e and i is given by:

$$(21) \quad \ln V_{ei} = \gamma + \beta \left(\ln \frac{M_{ei} + C_{ei}}{\text{GDP}_i} - \ln \frac{M_{ee} + C_{ee}}{\text{GDP}_e} \right).$$

3.4 Empirical Model

We base our empirical specification in equations (10), (19), and (21). In order to better assess the identification structure suggested by the model, we first present this system of equations in its most general format. We include importer-exporter and time fixed effects to account for the direct effect of bilateral trade costs, and model the proportion of manufacturers that export to foreign markets, f_{ei} , as a simple linear function of expected exchange rate volatility between countries e and i . Thus we obtain the following system:

$$(22) \quad \ln \frac{M_{eit}}{M_{e'it}} = \gamma_{ei}^m + \delta_i^m + \alpha^m \ln \frac{V_{eit}}{V_{e'it}} + \theta^m \ln \frac{s_{et}\theta_{et}}{s_{e't}\theta_{e't}} + \varepsilon_{ee'it}^m$$

$$(23) \quad \ln \frac{C_{eit}}{C_{e'it}} = \gamma_{ei}^c + \delta_i^c + \alpha^c \ln \frac{V_{eit}}{V_{e'it}} + \theta^c \ln \frac{s_{et}\theta_{et}}{s_{e't}\theta_{e't}} + \varepsilon_{ee'it}^c$$

$$(24) \quad \ln \frac{V_{eit}}{V_{e'it}} = \gamma_{ei}^v + \delta_i^v + \beta \left(\ln \left[\frac{M_{eit} + C_{eit}}{M_{e'it} + C_{e'it}} \right] - \ln \left[\frac{M_{eet} + C_{eet}}{GDP_{et}} \right] + \ln \left[\frac{M_{e'e't} + C_{e'e't}}{GDP_{e't}} \right] \right) + \theta^v \ln \frac{s_{et}\theta_{et}}{s_{e't}\theta_{e't}} + \varepsilon_{ee'it}^v$$

The first identification assumption suggested by the model in the previous section is that $\alpha^c = 0$. This assumption suggests that commodity trade is unaffected by exchange rate volatility. Producers of commodity products are always ready to export their product, only today's price levels matter for how much they export. This assumption is not testable as our model is exactly identified. The second identification assumption, implicit in equation (24) suggests that the impact of trade on exchange rate volatility is the same regardless of the product being traded (we relax this assumption later as a robustness check). We also assume that our model is rich enough such that $E(\varepsilon^m \varepsilon^c) = E(\varepsilon^c \varepsilon^v) = 0$. These four assumptions allow us to identify the coefficients of interest, (α^m, β) without making any assumption about $E(\varepsilon^m \varepsilon^c)$. We estimate the system using generalized method of moments (GMM), imposing these restrictions. Commodity trade is in effect being used as an instrument for the function of trade in equation (24); the only way commodity trade affects real exchange rate volatility is through its effect in making consumption bundles more similar. With equation (24) identified, GMM uses the estimated residual $\hat{\varepsilon}_{ee'it}$ as an instrument for $\ln(V_{eit}/V_{e'it})$ in equation (22). This residual is a shock to real exchange rate volatility that is not caused by trade.

This system is general enough to understand the biases introduced by other identifying procedures. In particular, estimating equation (22) while

ignoring the existence of equation (24) introduces the following simultaneity bias to the estimate of α_m :

$$(25) \quad E \hat{\alpha}_m - \alpha_m = \frac{\beta}{1 - \alpha_m \beta} \frac{\sigma_{\varepsilon^m}^2}{\sigma_{dV}^2},$$

where $d\bar{V} = \bar{V}_{eit} - \bar{V}_{e'it}$ and \bar{V}_{eit} is the real exchange rate volatility variable purged of the fixed effects and exogenous variables. In the case where $\beta < 0$ and $\alpha < 0$, then $|\alpha| > |\alpha|$, which implies that the estimate of the effect of trade on exchange rate volatility overestimates the true effect when the reverse causality channel is assumed away. If, in addition, the econometrician is lax in controlling for bilateral trade costs, it can easily be shown that the simultaneity bias gets exacerbated by omitted variables bias, because these trade costs depress trade and the omitted costs will be positively correlated with real exchange rate volatility. In this situation, adding additional proxies for trade costs may reduce the omitted variables bias, but may have no effect on the simultaneity bias. We argue that this is precisely what happens in Rose (2000) and Frankel and Rose (2002). Note how in Frankel and Rose (2002) the estimated impact of currency unions declines as they better control for a broad conception of trade costs. Better controlling for trade costs is necessary to reduce omitted variable bias, but does nothing to address simultaneity bias. Hau's (2002) instrument for openness, land area, is a proxy for trade cost and price index variables that belong in the system; hence, land area will be correlated with the error term in his regression.

We adapt the model to estimate the relationship between exchange rate regimes and trade. The underlying idea is very similar to the exchange rate volatility case. Countries are more likely to bind their exchange rate to that of their major trading partners, which may have the effect of promoting trade between those countries. We use the methodology described earlier to identify how trade affects the exchange rate regime and how that exchange rate regime affects trade. In this case, $\ln V_{eit}$ is replaced by a simple indicator variable indicating the presence of a currency union or a currency board (CU_{eit}), or a fixed exchange rate (F_{eit}). This adaptation is open to the criticism that if the monetary authority is interested in promoting trade and realizes that volatility has no impact on commodity trade, it may seek to peg the exchange rate with large manufacturing-trade partners. This criticism can be addressed by reducing the weight given to commodity trade in equation (24).

3.5 Trade and Real Exchange Rate Data

Rauch (1999) provides a categorization of SITC Revision 2 industries according to three possible product types following an extensive search for published reference prices: differentiated, reference priced, and commodity. The Rauch classification is widely used in empirical international trade stud-

ies, but has not been updated to cover more recent trade classifications. The lack of a reference price distinguishes differentiated products from the rest. Those industries with reference prices can be further divided into those whose reference prices are quoted on organized exchanges (commodities) and those whose reference prices are quoted only in trade publications (reference priced). The classification is fixed; products do not migrate from one classification to the other. Most elaborate manufactures usually belong to fairly broad SITC classifications, and get classified as differentiated products even if they are effectively reference priced (for example, computer memory chips). The trade data consists of annual flows of exports from a given country to different importing countries. For instance, lead (SITC 685) is listed on an organized exchange and, therefore, treated as a commodity while footwear (SITC 851) is not and is treated as a differentiated product. Bilateral trade data for each SITC industry is available for a large number of developed and developing countries during the period 1970 to 1997. The data consists of annual flows of exports from a given country to different importing countries. Table 3A.1 shows the share of each type of product for different regions and time periods. A summary of the sample used in the estimation is listed in table 3A.1 in the appendix.

Another essential part of the estimation is to obtain a measure of exchange rate volatility. We use monthly data on real exchange rate series from the *International Financial Statistics (IFS)* to compute standard deviations. We detrend these series using a Hodrick-Prescott filter and take standard deviations of the filtered data in five-year periods.¹³ Table 3A.1 also shows the descriptive statistics of these series. The additional data needed for the main specifications are taken from the World Development Indicators, except for export prices $s_e\theta_e$, which are computed using detailed unit export price data in U.S. trade statistics described in Feenstra (1997) and Feenstra, Romalis, and Schott (2002) after extracting product-by-year fixed effects.

We source data on currency unions and currency boards from Frankel and Rose (2002). The chapter also uses data on other fixed exchange rate regimes. The basic reference for classification of exchange rate regimes is the International Monetary Fund's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER).¹⁴ This classification is a de jure classification that is based on the publicly stated commitment of the authorities in the country in question. The IMF report captures the notion of a formal commitment to a regime, but fails to capture whether the actual

13. We identify the trend from the monthly log real exchange rate data using a smoothing parameter of 1,000,000. Our volatility measure is the standard deviation of the detrended series over the previous five years. For robustness checks, the detrended series is further decomposed into short-term volatility and medium-term volatility, by smoothing these deviations using a smoothing parameter of 400.

14. The AREAER classification consists of nine categories, broadly grouped into pegs, arrangements with limited flexibility, and more flexible arrangements, which include managed and pure floats. This description is based on the AREAER (IMF 1996).

policies were consistent with the stated commitment. Since we mainly use bilateral data in the chapter, we use the currency to which a country is pegged to create a fixed exchange rate regime dummy that takes the value of one if one country's currency is pegged to the other country's currency, or if two countries are pegged to the same currency. While a *de jure* classification like the IMF's captures the formal commitment to a regime, it fails to capture whether the actual policies were consistent with this commitment. For instance, *de jure* pegs can pursue policies inconsistent with their stated regime and require frequent changes in the nominal exchange rate, making the degree of commitment embedded in the peg, in fact, similar to a float. The problems that arise from a pure *de jure* classification have prompted researchers to use different criteria to classify regimes. Reinhart and Rogoff (2002) classify exchange rate regimes using information about the existence of parallel markets combined with the actual exchange rate behavior in those markets. Levy-Yeyati and Sturzenegger (2000) analyze data on volatility of reserves and actual exchange rates. A similar bilateral fixed exchange rate dummy is constructed from the Reinhart and Rogoff and Levy-Yeyati and Sturzenegger database. We source data on currency unions and currency boards from Rose (2000) and Frankel and Rose (2002).

3.6 Results

The main results of the chapter are reported in tables 3.1, 3.2, and 3.3. The first two columns of table 3.1 present OLS estimates of equations (22) and (24). A 10 percent increase in volatility depresses differentiated product trade by 0.7 percent, while a 10 percent increase in trade reduces exchange rate volatility by 0.3 percent. The next two columns present GMM estimates of equations (22) and (24). The OLS estimate of the effect of volatility on trade is reduced by 70 percent. This reduction is because the model attributes much of the correlation between trade and volatility to the effect that trade has in depressing volatility. A 10 percent increase in the intensity of a bilateral trading relationship reduces the volatility of the associated exchange rate by 0.3 percent. Although the estimate is statistically significant, the magnitude of the effect does not at first appear to be that large. But, it must be remembered that the typical bilateral trading relationship is very small (the median was under \$8 million in 1997, whereas the median GDP was \$32 billion), while the typical real exchange rate is quite volatile (typically 11 percent from its trend). A trading relationship that is 1 percent of GDP greater than the median trade relationship implies that the volatility of the bilateral real exchange rate associated with the intense trading partner is 12 percent smaller than with the less intense partner. Though most trade relationships are much smaller than this, intense relationships of this size or greater are very numerous, especially between proximate countries. For example, the Canada-United States trade relationship in 1997 is equal to

Table 3.1 Exchange rate volatility and trade

Model	Left-hand side variable							
	Log differentiated product trade (1) OLS	Log exchange rate volatility (1) OLS	Log differentiated product trade (1) GMM	Log exchange rate volatility (1) GMM	Log differentiated product trade (2) OLS	Log exchange rate volatility (2) OLS	Log differentiated product trade (2) GMM	Log exchange rate volatility (2) GMM
Right-hand side variable								
Log real exchange rate volatility	-0.077 (0.012)		-0.032 (0.015)		-0.059 (0.012)		-0.015 (0.015)	
Log total trade		-0.034 (0.005)		-0.033 (0.008)		-0.022 (0.005)		-0.033 (0.008)
Log export price level	-0.595 (0.056)	-0.165 (0.026)	-0.588 (0.056)	-0.165 (0.026)	-0.699 (0.064)	0.041 (0.025)	-0.701 (0.064)	0.038 (0.025)
Log product real GDP					X	X	X	X
Log product real GDP/capita					X	X	X	X
Log exporters' real GDP					X	X	X	X
Log exporters' real GDP/capita					X	X	X	X
Importer-exporter fixed effects	X	X	X	X	X	X	X	X
Year fixed effects	X	X	X	X	X	X	X	X
Observations	47,521	47,521	47,521	47,521	47,521	47,521	47,521	47,521

Notes: Each variable has been differenced as follows: from log differentiated product imports of country i from country e we have subtracted log differentiated product imports of country i from the United States. The reason, derived in the model, is to eliminate country i specific effects. All variables are equivalently differenced. Standard errors corrected for heteroscedasticity and autocorrelation are reported in parentheses. X indicates that the explanatory variable has been included as a control in the regression, but due to the differing employed in the regression specification, the estimated regression coefficient has no obvious economic meaning and has been suppressed.

23 percent of the GDP using our measure: U.S. exports to Canada equal 21 percent of Canada's GDP, while Canadian exports to the United States equal 2 percent of the U.S. GDP. Our results predict that this intense relationship reduces the volatility of the United States dollar-Canadian dollar (USD-CAD) real exchange rate by 38 percent, compared with the typical exchange-rate pair. The estimated effect of trade on exchange rate volatility in table 3.1, columns (5) through (8), is barely changed by the addition of more explanatory variables that often appear in gravity models of trade, though the estimated effect of volatility on trade declines.

Table 3.2 presents estimates from the adaptation of our identification strategy to estimating the effect of currency unions and currency boards on trade. In our sample there are very few instances of a change in currency union or currency board status, so we drop the fixed effects for each importer-exporter relationship and instead include exporter fixed effects and importer fixed effects. Extension of the data to more recent years would be helpful here due to EMU. The OLS result is again presented in column (1), with the typically large estimate that a currency union increases trade by 250 percent, consistent with Rose (2000), Frankel and Rose (2002), and Glick and Rose (2002). Columns (2) and (3) present the GMM estimates. We find that controlling for reverse causality reduces the estimate of the currency union effect to 25 percent; the estimate is one-tenth the size of the OLS estimate and just as precise. Almost all of the correlation between trade and the presence of a currency union or a currency board is attributed to the fact that countries are much more likely to adopt the exchange rate of a major trading partner. The addition of explanatory variables that are often used to explain trade in the presence of currency unions does not change the basic story. The OLS estimates are always above 50 percent, the GMM estimates are always small, ranging between 10 and 25 percent, with very little loss in precision relative to their OLS counterparts. The OLS estimates are usually outside 95 percent confidence intervals for the GMM estimates.

Table 3.3 presents estimates from the adaptation of our identification strategy to estimating the effect of fixed exchange rates on trade. The fact that many countries have changed their exchange rate regime allows us to reintroduce fixed effects for every importer-exporter relationship. The coefficient on the fixed exchange rate variable is only identified because countries have changed their exchange rate regime. All estimates, be they OLS or GMM, suggest only modest effects of fixed exchange rates on trade. The GMM estimates for the two de facto measures of exchange rate regime both suggest that a fixed exchange rate regime increases differentiated product trade by 6 percent.

3.6.1 Robustness Checks

We check the robustness of our results to a number of changes to our empirical model. Table 3.4 reports sensitivity of our results to alternative mea-

Table 3.2 Currency unions, currency boards, and trade

	Left-hand side variable											
	Log differentiated product trade (1)		Log differentiated product trade (2)		Log differentiated product trade (3)		Log differentiated product trade (4)		Log differentiated product trade (5)		Log differentiated product trade (6)	
Model	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM	OLS	GMM
Right-hand side variable												
Currency union/board	1.246 (0.206)	0.219 (0.214)	1.282 (0.230)	0.185 (0.212)	0.423 (0.169)	0.094 (0.201)						
Log total trade							2.35E-03 (5.51E-04)	2.51E-03 (5.53E-04)				1.29E-03 (7.51E-04)
Log export price level	1.877 (0.108)	1.879 (0.108)	2.280 (0.121)	2.282 (0.121)	2.267 (0.102)	2.268 (0.102)	-2.07E-03 (3.68E-03)	-1.81E-03 (4.33E-03)				1.47E-03 (4.06E-03)
Log product real GDP			X	X	X	X	X	X	X	X	X	X
Log product real GDP/capita			X	X	X	X	X	X	X	X	X	X
Log exporters' real GDP			X	X	X	X	X	X	X	X	X	X
Log exporters' real GDP/capita			X	X	X	X	X	X	X	X	X	X
Log distance												
Preferential trade agreement												
Common language												
Common land border												
Exporter fixed effects	X	X	X	X	X	X	X	X	X	X	X	X
Importer fixed effects	X	X	X	X	X	X	X	X	X	X	X	X
Year fixed effects	X	X	X	X	X	X	X	X	X	X	X	X
Observations	48,808	48,808	48,808	48,808	48,808	48,808	48,808	48,808	48,808	48,808	48,808	48,808

Notes: Each variable has been differenced as follows: from log differentiated product imports of country i from country j we have subtracted log differentiated product imports of country i from the United States. The reason, derived in the model, is to eliminate country i specific effects. All variables are equivalent differenced. Standard errors corrected for heteroscedasticity and autocorrelation are reported in parentheses. X indicates that the explanatory variable has been included as a control in the regression, but due to the differencing employed in the regression specification, the estimated regression coefficient has no obvious economic meaning and has been suppressed.

Table 3.3 Fixed exchange rate regimes and trade

	Left-hand side variable									
	Log differ-entiated product trade IMF OLS	Log differ-entiated product trade IMF GMM	Fixed exchange rate IMF GMM	Log differ-entiated product trade RogoffDF OLS	Log differ-entiated product trade RogoffDF GMM	Fixed exchange rate RogoffDF GMM	Log differ-entiated product trade LYS OLS	Log differ-entiated product trade LYS GMM	Fixed exchange rate LYS GMM	
Exchange rate regime data Estimation technique										
Right-hand side variable										
Fixed exchange rate	0.017 (0.022)	-0.037 (0.026)		-0.002 (0.023)	0.064 (0.031)		0.114 (0.015)	0.069 (0.019)		1.65E-02 (4.69E-03)
Log total trade			1.35E-02 (4.59E-03)			-6.68E-03 (-2.65E-03)				
Log export price level	-0.648 (0.061)	-0.649 (0.061)	-0.012 (0.019)	-0.751 (0.063)	-0.750 (0.063)	-0.013 (0.007)	-0.747 (0.063)	-0.734 (0.063)		0.300 (0.021)
Log product real GDP	X	X	X	X	X	X	X	X	X	X
Log product real GDP/capita	X	X	X	X	X	X	X	X	X	X
Log exporters' real GDP	X	X	X	X	X	X	X	X	X	X
Log exporters' real GDP/capita	X	X	X	X	X	X	X	X	X	X
Preferential trade agreement	X	X	X	X	X	X	X	X	X	X
Importer-exporter fixed effects	X	X	X	X	X	X	X	X	X	X
Year fixed effects	X	X	X	X	X	X	X	X	X	X
Observations	45,061	45,061	45,061	48,791	48,791	48,791	45,568	45,568	45,568	45,568

Notes: Each variable has been differenced as follows: from log differentiated product imports of country i from country e we have subtracted log differentiated product imports of country i from the United States. The reason, derived in the model, is to eliminate country i specific effects. All variables are equivalently differenced. Standard errors corrected for heteroscedasticity and autocorrelation are reported in parentheses. X indicates that the explanatory variable has been included as a control in the regression, but due to the differencing employed in the regression specification, the estimated regression coefficient has no obvious economic meaning and has been suppressed.

Table 3.4 Sensitivity to different volatility measures

Exchange volatility Measure Estimation technique	Left-hand side variable									
	Log differ-entiated product trade	Log real exchange rate volatility	Log differ-entiated product trade	Log real exchange rate volatility	Log differ-entiated product trade	Log real exchange rate volatility	Log differ-entiated product trade	Log real exchange rate volatility	Log differ-entiated product trade	Log real exchange rate volatility
	Long OLS	Long OLS	Medium OLS	Medium OLS	Medium GMM	Medium GMM	Medium GMM	Short OLS	Short OLS	Short GMM
Right-hand side variable										
Log real exchange rate volatility	-0.016 (0.006)		-0.027 (0.009)	-0.001 (0.001)	-0.134 (0.015)	-0.039 (0.005)	-0.071 (0.020)			
Log total trade		-0.014 (0.008)	-0.012 (0.014)	-0.014 (0.006)	-0.032 (0.010)					
Log export price level	-0.700 (0.064)	0.079 (0.044)	-0.699 (0.064)	-0.701 (0.042)	0.092 (0.032)	-0.086 (0.027)	-0.707 (0.064)			
Log product real GDP	X	X	X	X	X	X	X	X	X	X
Log product real GDP/capita	X	X	X	X	X	X	X	X	X	X
Log exporters' real GDP	X	X	X	X	X	X	X	X	X	X
Log exporters' real GDP/capita	X	X	X	X	X	X	X	X	X	X
Importer-exporter fixed effects	X	X	X	X	X	X	X	X	X	X
Year fixed effects	X	X	X	X	X	X	X	X	X	X
Observations	47,521	47,521	47,521	47,521	47,521	47,521	47,521	47,521	47,521	47,521

Notes: Each variable has been differenced as follows: from log differentiated product imports of country i from country e we have subtracted log differentiated product imports of country i from the United States. The reason, derived in the model, is to eliminate country i specific effects. All variables are equivalently differenced. Standard errors corrected for heteroscedasticity and autocorrelation are reported in parentheses. X indicates that the explanatory variable has been included as a control in the regression, but due to the differencing employed in the regression specification, the estimated regression coefficient has no obvious economic meaning and has been suppressed.

asures of exchange rate volatility. We construct four measures to capture volatility at different frequencies by adjusting the smoothing parameters used in the Hodrick-Prescott filters. The data is filtered to isolate very low-frequency movements that we term “long-run” volatility, very high-frequency movements that we term “short-run” volatility, and all other movements that we term “medium-run” volatility. The estimates based on short-run volatility are higher than the other estimates. Trade is both more sensitive to short-run volatility and has a greater effect in dampening short-run volatility.

Table 3.5 performs our basic regression for different regions. In particular, we are interested if our results depend on whether the exporting country is developed or developing. All of the depressing effect of volatility on trade comes from developing country exporters. Developed country exporters are not adversely affected by exchange rate volatility. This suggests that developing country exporters are more risk-averse or are less able to hedge the real exchange rate risk. For both groups of exporters, trade depresses the volatility of the exchange rate.

Table 3.6 reports the effect of adding information on capital controls and capital flows to each equation. Gross private capital flows sourced from the World Development Indicators is the sum of gross private capital flows as a percentage of the GDP for the exporting and the importing country. Capital control data sourced from the IMF’s AREAER is the sum of the dummy variables indicating the presence or absence of capital controls in the exporting and importing countries. The results barely change.

Figures 3.4, 3.5, 3.6, and 3.7 illustrate the effect of reducing the relative effect of commodity trade in reducing real exchange rate volatility or in affecting the likelihood of entering into a currency union. This is done by introducing a parameter β_c to equation (21) describing how trade affects volatility and the equivalent equations describing the formation of exchange rate regimes:

$$(26) \quad \ln V_{ei} = \gamma + \beta \left(\ln \frac{M_{ei} + \beta_c C_{ei}}{\text{GDP}_i} - \ln \frac{M_{ee} + \beta_c C_{ee}}{\text{GDP}_e} \right).$$

This new parameter has to be imposed since the model is otherwise unidentified. As this parameter is reduced from the value of 1 used in all prior regressions, the model attributes even more of the correlation between trade and volatility or currency union to the effect that trade has in depressing volatility or leading to a currency union. Exchange rate volatility and currency unions appear to have little impact on trade.

3.7 Conclusion

Most of the studies of the effect of exchange rate volatility on trade assume that the volume of trade has no impact on exchange rate volatility, thus assuming away an endogeneity problem. We present evidence that this

Table 3.5 **Developing vs. developed country exporters**

Exporter	Left-hand side variable							
	Log differentiated product trade Developing GMM	Log real exchange rate volatility Developing GMM	Log differentiated product trade Developing GMM	Log real exchange rate volatility Developing GMM	Log differentiated product trade Developing GMM	Log real exchange rate volatility Developing GMM	Log differentiated product trade Developing GMM	Log real exchange rate volatility Developing GMM
Right-hand side variable								
Log real exchange rate volatility	-0.053 (0.019)		-0.037 (0.019)	-0.020 (0.009)	0.036 (0.020)	-0.042 (0.028)	0.071 (0.020)	-0.088 (0.029)
Log total trade		-0.028 (0.009)						
Log export price level	-0.615 (0.070)	-0.101 (0.030)	-0.884 (0.080)	0.109 (0.031)	-0.496 (0.072)	-0.057 (0.068)	0.218 (0.095)	0.109 (0.087)
Log product real GDP			X	X			X	X
Log product real GDP/capita			X	X			X	X
Log exporters' real GDP			X	X			X	X
Log exporters' real GDP/capita			X	X			X	X
Importer-exporter fixed effects	X	X	X	X	X	X	X	X
Year fixed effects	X	X	X	X	X	X	X	X
Observations	27,481	27,481	27,481	27,481	20,040	20,040	20,040	20,040

Notes: Each variable has been differenced as follows: from log differentiated product imports of country i from country e we have subtracted log differentiated product imports of country i from the United States. The reason, derived in the model, is to eliminate country i specific effects. All variables are equivalently differenced. Standard errors corrected for heteroscedasticity and autocorrelation are reported in parentheses. X, indicates that the explanatory variable has been included as a control in the regression, but due to the differencing employed in the regression specification, the estimated regression coefficient has no obvious economic meaning and has been suppressed.

Table 3.6 Robustness to inclusion of capital controls and capital flows

Model/data estimation Technique	Left-hand side variable											
	Log differ-entiated product trade Volatility OLS	Log real exchange rate volatility OLS	Log differ-entiated product trade Volatility GMM	Log real exchange rate volatility GMM	Log differ-entiated product trade CU OLS	Log differ-entiated product trade CU GMM	Currency union or board CU GMM	Log differ-entiated product trade RogoffDF OLS	Log differ-entiated product trade RogoffDF GMM	Fixed exchange rate RogoffDF GMM	Log differ-entiated product trade LYS GMM	Fixed exchange rate LYS GMM
Right-hand side variable												
Log real exchange rate Volatility (0.013)	-0.040 (0.016)											
Currency union/board			0.356 (0.173)	0.080 (0.212)								
Fixed exchange rate												
Log total trade	-0.020 (0.005)	-0.037 (0.009)			1.20E-03 (8.63E-04)		0.021 (0.023)	0.061 (0.032)	-4.39E-03 (2.83E-03)		0.109 (0.016)	0.051 (0.019)
Log export price level	-0.581 (0.066)	-0.002 (0.030)	-0.582 (0.066)	2.174 (0.109)	6.00E-06 (4.68E-03)		-0.623 (0.064)	-0.622 (0.064)	-3.26E-02 (7.14E-03)		-0.704 (0.065)	-0.688 (0.065)
Log product real GDP	X	X	X	X	X	X	X	X	X	X	X	X
Log product real GDP/capita	X	X	X	X	X	X	X	X	X	X	X	X
Log exporters' real GDP	X	X	X	X	X	X	X	X	X	X	X	X
Log exporters' real GDP/capita	X	X	X	X	X	X	X	X	X	X	X	X
Log distance												
Preferential trade agreement												
Common language												
Common land border												
Gross private capital flows	X	X	X	X	X	X	X	X	X	X	X	X
Capital controls	X	X	X	X	X	X	X	X	X	X	X	X
Importer-exporter fixed effects	X	X	X	X	X	X	X	X	X	X	X	X
Exporter fixed effects												
Importer fixed effects												
Year fixed effects	X	X	X	X	X	X	X	X	X	X	X	X
Observations	39,979	39,979	39,979	39,979	41,265	41,265	41,258	41,258	41,258	41,258	40,304	40,304

Notes: Each variable has been differenced as follows: from log differentiated product imports of country i from country e we have subtracted log differentiated product imports of country i from the United States. The reason, derived in the model, is to eliminate country i specific effects. All variables are equivalently differenced. Standard errors corrected for heteroscedasticity and autocorrelation are reported in parentheses. X indicates that the explanatory variable has been included as a control in the regression, but due to the differencing employed in the regression specification, the estimated regression coefficient has no obvious economic meaning and has been suppressed.

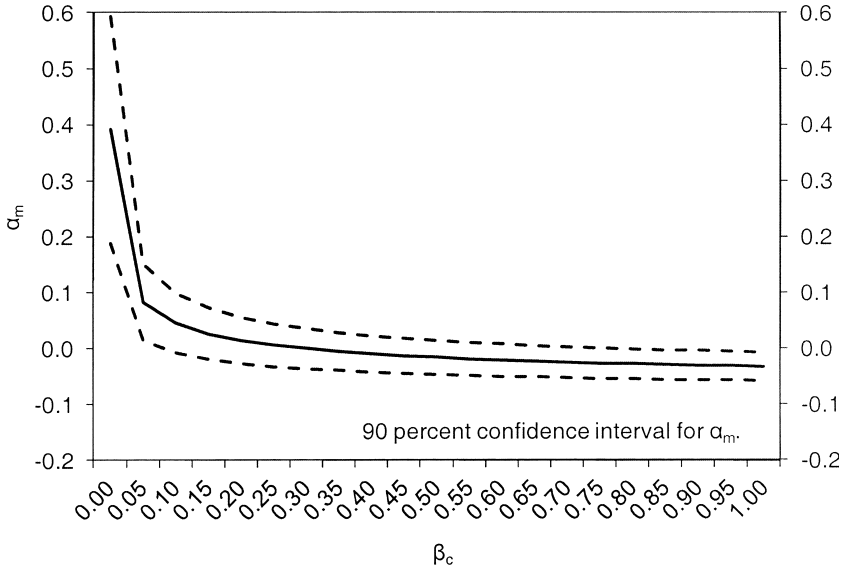


Fig. 3.4 Exchange rate volatility and trade

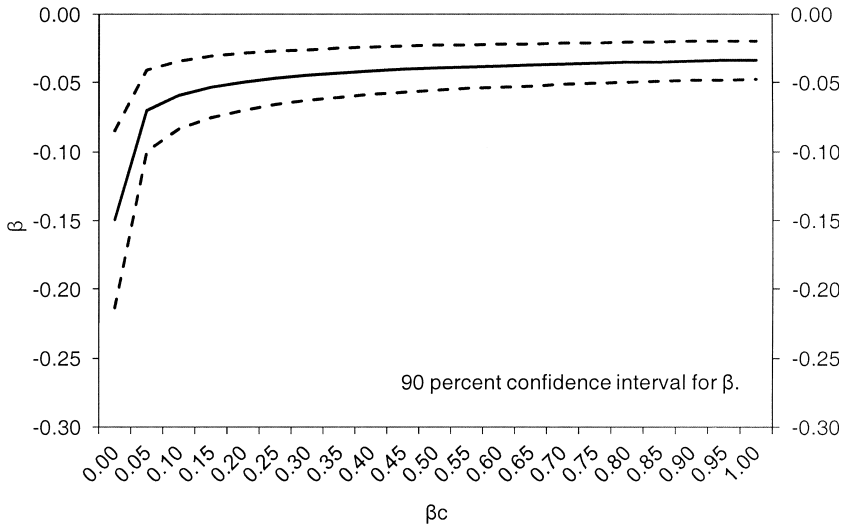


Fig. 3.5 Trade and exchange rate volatility

problem is severe. We develop a model in which both directions of causality are considered, and that allows us to structurally identify the impact of exchange rate volatility on trade. We exploit our identification structure by using disaggregate product trade data for a large number of countries for the period 1970 to 1997. We find that deeper bilateral trading relations dampen

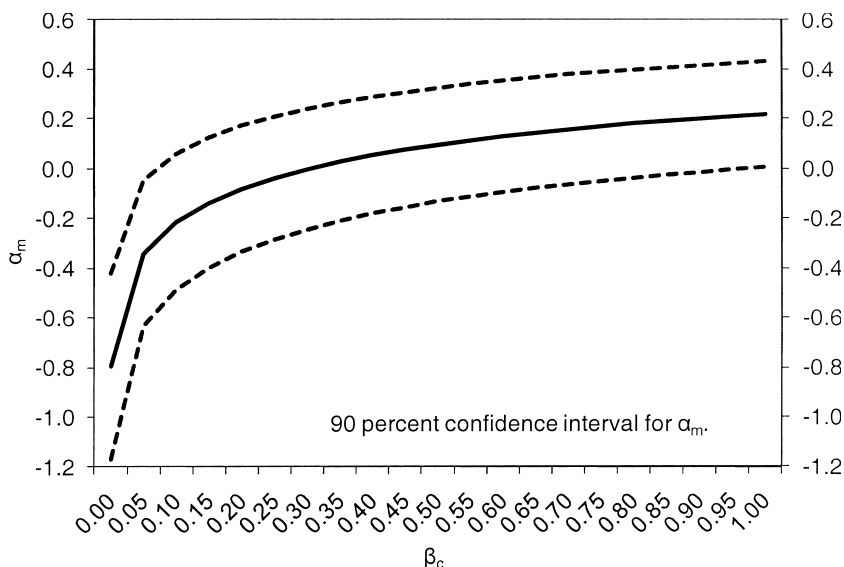


Fig. 3.6 Currency unions and trade

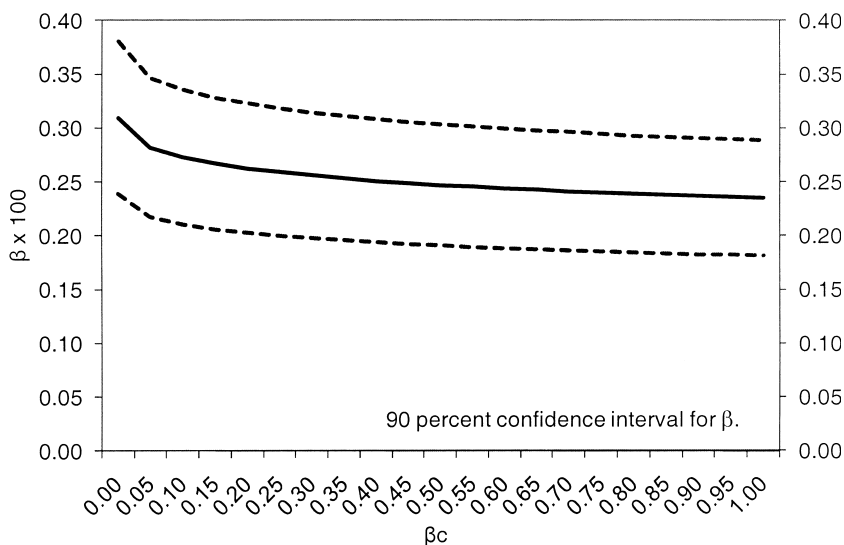


Fig. 3.7 Trade and currency unions

real exchange rate volatility and are much more likely to lead to a currency union. In fact, our empirical model attributes most of the correlation between trade and volatility to the effect that trade has in depressing volatility. It is this effect that had been assumed away in the previous literature. The chapter finds some evidence that real exchange rate volatility depresses trade

in differentiated goods. The size of the effect is fairly small and unevenly distributed. A doubling of real exchange rate volatility decreases trade in differentiated products by about 2 percent. Developing country exports of manufactures may be much more greatly affected due to a combination of greater exchange rate volatility and greater sensitivity of their exporters to that volatility. We find that controlling for reverse causality, the estimates of the effect of currency unions on trade are much smaller than OLS estimates and similarly precise. Currency unions enhance trade by 10 to 25 percent rather than the 300 percent estimates previously obtained.

Appendix

Derivation of equation (20). The log of the price index for country i is:

$$(27) \quad \ln P_i = [b \ln P_{im} + (1 - b) \ln P_{ic}],$$

where P_{im} is defined in equation (15) and P_{ic} is defined in equation (8). Differentiating:

$$(28) \quad \frac{d \ln P_i}{d \ln s_e} = s_e \left[\frac{b}{P_{im}} \frac{dP_{im}}{ds_e} + \frac{(1 - b)}{P_{ic}} \frac{dP_{ic}}{ds_e} \right].$$

Substituting out dP_{im}/ds_e and dP_{ic}/ds_e :

$$(29) \quad \frac{d \ln P_i}{d \ln s_e} = s_e \left[\frac{b}{P_{im}} P_{im}^{\sigma_m} n f_{ei} \left(\frac{\sigma_m}{\sigma_m - 1} s_e \theta_e \tau_{eim} \right)^{1 - \sigma_m} s_e^{-1} + \frac{1 - b}{P_{ic}} P_{ic}^{\sigma_c} \tau_{eic}^{1 - \sigma_c} s_e^{-\sigma_c} \right].$$

Substituting using equations (6) and (14):

$$\frac{d \ln P_i}{d \ln s_e} = b n f_{ei} \frac{P_{ei,v}^{1 - \sigma_m}}{P_{im}^{1 - \sigma_m}} + (1 - b) \frac{P_{ei}^{1 - \sigma_c}}{P_{ic}^{1 - \sigma_c}}.$$

The first term on the right side of equation (30) is the proportion of country i 's income spent on manufactured goods produced in country e , while the second term is the proportion spent on commodities from country e . For small shocks to s_e , the price index in country i changes in line with the share of country e 's goods in country i 's consumption basket. Equation (20) follows from our definition of the real exchange rate as the ratio of two price indexes.

Table 3A.1 Descriptive statistics

Exporter from	Number of pairs	Share of exports in differentiated products	Share of exports in reference products	Share of exports in commodity products	Real exchange rate volatility (medium-term) (%)	Real exchange rate volatility (short-term) (%)	IMF fixed exchange rate regime pairs (1) (%)	Rogoff-Reinhardt fixed exchange rate regime pairs (1) (%)
					<i>1970s</i>			
Africa	4,260	0.17	0.17	0.66	7.0	4.6	11.7	3.7
N. America	1,191	0.59	0.20	0.21	6.1	3.5	0.4	0.3
C. America and S. America	6,977	0.11	0.15	0.73	8.1	6.0	20.5	9.7
Asia	4,921	0.60	0.17	0.23	7.6	4.6	14.4	3.6
Europe	9,081	0.65	0.24	0.12	5.7	3.8	3.5	6.1
All	26,430	0.58	0.21	0.21	6.9	4.6	11.6	5.9
					<i>1980s</i>			
Africa	5,332	0.17	0.18	0.66	13.6	7.0	3.7	1.8
N. America	1,341	0.63	0.20	0.17	10.1	4.8	0.0	0.0
C. America and S. America	8,327	0.20	0.17	0.63	15.2	8.2	10.4	1.2
Asia	7,085	0.73	0.11	0.17	10.2	5.0	2.5	0.1
Europe	10,820	0.66	0.21	0.13	10.8	5.1	3.5	0.6
All	32,905	0.62	0.19	0.19	12.2	6.2	4.9	0.8
					<i>1990s</i>			
Africa	7,514	0.24	0.23	0.53	11.1	7.6	2.8	1.1
N. America	1,346	0.70	0.18	0.12	8.1	5.1	0.0	0.0
C. America and S. America	9,143	0.41	0.20	0.39	11.8	8.0	1.4	0.2
Asia	8,346	0.76	0.10	0.14	8.5	5.2	1.0	0.4
Europe	12,197	0.71	0.20	0.09	8.8	5.7	1.1	1.4
All	38,546	0.69	0.17	0.13	9.8	6.5	1.4	0.8

Notes: Pairs are included only if real exchange rate volatility data is available. For exchange rate regimes, not all number of pairs have data.

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Comment Chaiyasit Anuchitworawong

Previous research has investigated the relationship between exchange rate volatility and international trade. The literature in this area dated back several decades and the issue has been recently and rigorously reexamined, given some improvements in analytical methods, and the quantity and quality of data used to explore the relationship. Most existing studies focus on the effect of exchange rate volatility on trade, despite the fact that there are two major lines of research that differently identify the direction of relationship between the two. The main line of causality runs from exchange rate volatility to international trade, as well as the other way around, which is motivated by the early and most influential paper by Mundell (1961) on the theory of optimal currency areas, which suggested that trade flows reduce exchange rate volatility. If one adds the two strands of literature together, it becomes obvious that the exchange rate process is not exogenously given, but may, in fact, be endogenous to the level of international trade among other factors.

Most of the past studies were based on models in which the direction of causality was assumed to run from exchange rate volatility to trade, implying that the exchange rate process is driven by exogenous shocks. The findings also varied widely depending on the data and empirical methodologies being