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EXCHANGE RATE VOLATILITY AS A BARRIER TO TRADE: NEW METHODOLOGIES AND RECENT EVIDENCE

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ABSTRACT. The analysis of the border effect in a multi-currency framework reveals that volatility accounts for an important part of the border effect in Europe. This paper proposes an explanation of why this methodology yields robust results of the negative effects of volatility on trade, contrary to a three decades-old literature that is characterised by weak and controversial results. The paper maintains that empirical studies carried out at the level of sub-national units and at the finest industry echelon help clarify the actual influence of exchange rate volatility on trade better than aggregate and purely international analyses.

JEL Classification: F12; F15; F17.
Keywords: Exchange Rate Volatility; Trade; Gravity; Border; Sector.

RÉSUMÉ. L'analyse de l'effet-frontière dans un environnement caractérisé par l'existence de plusieurs monnaies révèle que cet effet est en grande partie expliqué par la volatilité monétaire. Cette étude propose une explication des raisons pour lesquelles cette méthodologie attribue d'importants effets négatifs à la volatilité sur le commerce, contredisant ainsi trente années de littérature aux résultats fragiles et controversés. La conclusion de cette étude est que les études empiriques effectuées avec des données desagrégées au niveau géographique et industriel aident à clarifier l'influence de la volatilité des taux de change sur le commerce par rapport aux études portant sur des données aggrégées et purement internationales.

Classification *JEL* : F12 ; F15 ; F17.
Mots-clefs : Volatilité des changes ; Commerce ; Gravité ; Frontière ; Secteur.

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INTRODUCTION

Thirty years of hard work have been deployed in the attempt to quantify the effects of exchange rate volatility on trade. Sadly, the only consensus reached is that the impact, if any, is difficult to estimate. As a result, research in this area has dried out without reaching a firm conclusion. It is now customarily presumed that the adverse effect of exchange rate volatility, if it exists, is certainly not large. Moves towards dollarisation from a number of countries in the American continent and the birth of EMU in Europe, have fuelled the debate after years of consensus. The new angle of attack has its hub on the hypothesis that joining a currency union may have a very different effect than even a radical reduction in exchange rate volatility. This supposition, if confirmed by robust empirical evidence, would call for a new interpretation of the volatility/trade link.

The purpose of this article is to briefly review the literature on the importance of volatility as a barrier to trade, describe the main lines of work within the genre, identify the methodological issues involved in the most recent empirical tests of the relationship and assess the link with the limiting case of permanent zero volatility.

Borders and trade in a multiple currency world

According to gravity models, two opposing forces determine bilateral trade between countries: the level of their economic activity and income, and the extent of impediments to trade. The sharp reduction in trade barriers since World War II, accompanied by a rapid increase in international trade (see Baier and Bergstrand, 2001[2]), suggests that the relevance of national borders as a major impediment to trade has significantly declined. On the other hand, McCallum (1995) found significant impediments to Canada-US trade.

After controlling for distance and size, he found that the level of trade between Canadian provinces is more than twenty times larger than the level with US states. The result was even more astonishing since these are two countries with similar cultures, institutions, language, and whose reciprocal trade is largely liberalized. Until very recently, the observed border-related reductions in trade flows were non-accountable on the basis of estimates of non tariff-barriers computed by means of reasonable values for the elasticity of substitution between domestic and foreign products.

McCallum's initial paper has given rise to a rapidly growing literature aimed at measuring and understanding the trade border effect (BE thereafter). The main references are Evans (1999, 2000), Helliwell (1998), Helliwell and McCallum (1995), Wei (1996), Anderson and Smith (1999a, b) and, for the European case, Nitsch (1997), Chen (2000) and Head and

2. Baier and Bergstrand disentangle the relative empirical contribution of transport-cost reductions, trade liberalisation, income convergence and income growth to the expansion of world trade. Using a dataset of 16 OECD countries over the period 1958-1988, they find that the contribution of tariff-rate reductions and preferential trade agreements to trade growth was three times that of transport costs reductions, other factors held constant. Real GDP growth was also very important while income convergence irrelevant.

Mayer (2000). Although the subsequent literature has both toned down McCallum's empirical results and challenged their interpretation, a balanced interpretation of the BE literature suggests that, even if the bias is not as extreme as the McCallum original estimates suggest, countries do still exhibit a considerable degree of home bias in trade. Three dominant research strategies have characterised the ensuing literature.

The first approach focuses on issues of a technical nature, mainly questioning the existing methods for measuring BEs. Anderson and Van Wincoop (2000), for instance, argue that even though McCallum controls for state and province size in his gravity equation, his paper gives an exaggerated measure of home bias in global trade because it calculates the bias from the perspective of the small country (Canada) instead of the big country (US). Because Canada's economy is so small relative to that of the US, a moderate percentage change in US-Canada trade produces a spectacular percentage change in intra-national Canadian exchanges. Using American interstate trade data, instead of Canadian ones, Anderson and Van Wincoop estimate that the US-Canada border shrinks up to 40 percent. In other words, they demonstrate that while within-Canada trade rises by a factor 6 due to the border, within-US trade rises by a mere 25 percent[3] They also recall that theoretical models tell us that the more resistant to trade with all others a region is, the more it is pushed to trade with a given bilateral partner. They point out that trade-diversion measures used by McCallum and in later literature lack a theoretically appropriate indicator for the average multilateral trade barriers[4].

A second line of attack proposes alternative modelling strategies. Obstfeld and Rogoff (2000) partly justify McCallum's puzzle by means of a simple consumption model, in which two countries are each endowed with a single good. It demonstrates that, in a polarised production framework, the trade barrier does not need to be large, if combined with large elasticities of substitution, to explain substantial home biases in trade. Empirically plausible trade costs, combined with fairly standard estimates of elasticities of substitution across imports and exports, could in such a setting generate a large gap between intra-national and international trade flows.

A third view is to accept the results and to look for possible undetected deterrents to trade. Under this approach, the BE can be thought of as a measure of our ignorance. It quantifies the lack of knowledge about a number of mechanisms entailing unnoticed costs in international trade practices or discouraging cross-border transactions. Given the nature of this black box, it turns out to be a useful tool to "clean" the overall residual level of barriers from

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3. Hillberry (1999), who calculates the bias from the perspective of the large country, however, finds estimates of the aggregate border effect that are surprisingly similar to McCallum's estimates. He uses sectorally disaggregated data covering 142 commodities and reported in the *1993 Commodity Flow Survey*.

4. McCallum, in his study, did not include multilateral resistance variables at all. However most of the subsequent literature does include some form of it by means of theoretic remoteness variables related to distance from all trading partners. Bergstrand (1985, 1989) models the multilateral resistance term but it is unable to deal with its cross-sections aspects, which are crucial for the proper treatment of bilateral trade barriers.

specific impediments to trade. The leading existing explanations as to why borders matter fall across three main groupings:

– unobserved and residual tariff and non-tariff barriers;
– home bias by consumers due to cultural and political factors;
– exchange rates and monetary arrangements.

Among these "real explanations" the focus is usually put on the importance of cultural differences and/or political actions and on the significance of different national institutions in constraining trade (via residual international tariffs and quotas, hidden NTBs and transaction costs, different standards and customs, and regulatory differences).

However, before investigating these two determinants, the researcher should quantify the constraints deriving from a multi-currency framework. Explicit account for it requires the introduction in the equation of two key elements: the "pure" transaction costs – *i.e.* the cost of the passage from one money to the other and all costs linked to hedging activities – and the effects of value uncertainty due to exchange rate fluctuations and volatility on the possible risk aversion of importers and exporters. The logic of gravity models leads to the presumption that both types of transaction costs are negatively correlated with the strength of monetary arrangements and that both ought to diminish with the passage from several to one common currency.

The large body of empirical literature produced in the past thirty years concurs on the view that “pure” transaction costs impact negatively on trade. Nevertheless, it has been unable to prove incontestably the existence of a significant trade-volatility relationship and assumes that the effect of exchange rate variability, if it exists, is certainly not large. Such evidence has led scholars and policymakers to overlook the eventual trade gains arising from a single currency and hence the gains from permanentely eliminating exchange rate volatility (*i.e.* permanent zero volatility)[5]. However, the limiting case of monetary union deserves further inspection.

Since sharing a common currency is a much more serious and durable commitment than a fixed exchange rate, evidence on monetary unions may well capture the effect of other unobserved related factors. A new strand of literature, initiated by Rose (2000), addresses the question of whether countries inside currency unions tend to trade more, holding other factors constant. Given the focus of this paper we will closely analyse this issue later in the text. At the present stage of the discussion we will limit ourselves to a careful analysis of the nature of the volatility-trade link.

5. "Since empirical research has not found any robust relationship between echange rate variability and trade it is not possible to estimate the increase in intra-EC trade that might derive from the irrevocable fixing of the exchange rates", European Commission (1990, p.73).

Exchange rate variability and trade link: past and present

Three types of exchange rate variability are distinguished: volatility, single currency (permanent zero volatility), and misalignment. While exchange rate misalignments – persistent departures of real exchange rates from their equilibrium values – have been conclusively shown to have a negative link with trade (see, inter alia, European Commission (1995)), investigations on the impact of volatility on trade are not so one sided.

On the theoretical side, there are various approaches that have been used to account for the effect of exchange rate variability on trade. The literature on the response of trading firms to exchange rate uncertainty demonstrates that exchange rate uncertainty can affect trade behaviour, but gives no clear predictions as to the net effect on trade volume or trade growth. In most imperfect competition models, expected profit increases with uncertainty (Varian, 1984), but uncertainty reduces its utility. Consequently, exchange rate uncertainty may have either a positive or a negative impact on trade according to the degree of firms'risk aversion.

Under certain conditions, also risk-averse firms It is not only (near) risk neutral firms that may increase trade in response to exchange rate variability. There are two effects on risk-averse firms (De Grauwe, 1988): a substitution effect, whereby greater uncertainty deters them from international trade, and an income effect, whereby the need to offset the decline in total expected utility drives them to increase international trade. In the case of extreme risk aversion, the income effect dominates the substitution effect and increased exchange rate risk leads to a higher rather than a lower level of international trade.

Other approaches demonstrate that the ambiguity concerning the volatility-trade link does not depend upon the assumption of risk aversion. Gros (1987) finds that if firms can adjust output in response to exchange rate movements, uncertainty can increase trade. Viaene and Vries (1992) develop a mean-variance model in which firms'net trade position is the crucial factor in determining potentially positive or negative effects of exchange rate volatility.

Last but not least, the trader's decisions are also likely to be affected by a certain degree of hysteresis. Dixit (1989a and 1989b), Baldwin (1988), Baldwin and Krugman (1989) and Krugman (1989) show that exchange rate fluctuations in the presence of sunk costs can lead risk-neutral competitive firms to make decisions about entry and exit into foreign markets that are not reversed when the exchange rate returns to its previous level.

Yet, intuition and empirical observation suggest that an adverse impact of exchange rate volatility on international trade exists[6]. Unfortunately, most of the empirical evidence doesn't appear to be more conclusive than the theory on the volatility-trade link, as summari-

6. Between 1960 and 1973, the rate of growth of international trade and world GDP was 10% and 4.4%, respectively. Between 1973 and 1986, after the collapse of the Bretton Woods system, they dropped to a low of 5% and 1.7% respectively. The growth of world trade and GDP for the decade 1991-2000 was on the contrary picking up again 6.5% and 2%, respectively (Source: *International Trade Statistics*, World Trade Organization).

zed by IMF (1984), European Commission (1995), and Flam and Jansson (2000). Calmfors *et al.* (1997) states: "The somewhat surprising, but fairly unanimous, conclusion is that these fluctuations seem to influence foreign trade very little, if at all."

Traditional literature has based its analyses either on cross section or time series data. The results based on a utility-maximizing approach and time series analysis report substantially ambiguous, weak or negative results concerning the relationship between international trade and the international monetary regime, while studies based on cross-section analysis may suffer from multicollinearity. Hooper and Kohlhagen (1978), whose theoretical model predicts an unambiguously negative relationship between exchange rate variability and volumes of trade, is not verified at the empirical level, where no significant effect of exchange rate uncertainty on trade is observed. Testing for eleven industrialised countries during the period of floating exchange rates, Kenen and Rodrik (1986) find mostly negative and significant effects. Cushman (1986), which allows for exchange rate uncertainty with third countries, also finds overall negative and significant results. On the contrary Sercu and Vanhulle (1992), considering the effects of exchange rate risk on the relative attractiveness of foreign direct investment versus the development of an export strategy, conclude that exchange rate volatility makes exporting relatively more attractive.

The studies that use a cross-section of countries find significant effects. However, they are relatively small and subject to multicollinearity problems. Among these studies, De Grauwe compares the period of fixed exchange rates in the 1960s with the following two decades of floating currencies and Bini-Smaghi (1991) studies the effect of short-term exchange rate variability on the manufacturing exports among a number of countries joining the EMS.

In the last ten years, a number of empirical contributions, starting with Koray and Lastrapes (1989), employed modern time series methods in order to take into account the integration properties of the time series data. An empirical review of this strand of literature is reported in Flam and Jansson. The results of the studies taking into consideration the trend characteristics of the time-series, appear to be more clear-cut; most suggest a significant negative effect of exchange rate uncertainty on the trade variables. However, at least three studies employing the above mentioned techniques, among which the one from Flam and Jansson, report significantly positive or mixed results[7].

Overall the results seem quite contradictory, but tend in general, to indicate that there is not a systematic link between exchange rate variability and trade flows. There are two possible explanations of the reported facts. Either trading firms are able to entirely hedge against foreign exchange risk and to do it at a relatively bearable cost or the empirical tests are undermined by a series of methodological problems leading to imprecise statistical results.

7. Flam and Jansson find that the long run relations between exchange rate volatility and exports are mostly negative and in several cases insignificantly different from zero. McKenzie (1998) analyses Australian imports and exports at the sectoral level and obtains mixed results. Daly (1998) analyses bilateral trade between Japan and seven other industrialised countries, finding significantly positive results for seven import and five export flows out of fourteen.

As of the first possible conclusion, several surveys and other analyses indicate that firms do not entirely hedge against exchange rate uncertainty (Magee and Rao (1980) and Grassman (1973, 1976), Dornbush and Frankel (1988), European Commission (1990), Frankel *et al.* (1995)). Bini-Smaghi endorses the alternative view and maintains that the lack of evidence on a systematic negative link between exchange rate variability and trade flows hinges upon methodologically wrong strategies.

In order to address some of the problems raised by Bini-Smaghi, such as long-term exchange rate movements (*i.e.* over periods greater than one year) with multicollinearity problems, more recent literature estimates data with panel techniques modelled in a gravity-like functional form. Pugh *and al.* (1999) estimate 16 OECD countries in the period 1980-1992 and find that exchange rate volatility leads to a decrease in the level of trade by about 8 percentage points. Dell'Ariccia (1998) also finds a significant and substantially negative effect of exchange rate volatility on bilateral flows of the fifteen actual EU countries and Switzerland. By taking the standard deviation of the real exchange rate and the forward error as proxies for exchange rate uncertainty, the resulting trade gains from the elimination of the exchange rate volatility are respectively thirteen and ten percent. This strand of literature, however, is liable to be tackling a possibly wrong question.

If sharing a common currency is different from fixing the exchange rates then the whole debate on the exchange-rate volatility link must be examined under a new light and volatility measures have to encompass the case of single currency, *i.e.* permanent zero volatility. As a consequence, the whole contention should be based on a two-fold strategy. By continuing, on the one hand, the search for solutions to problems relating to the existence of theoretical ambiguities, low-cost hedging, and inappropriate techniques and, on the other hand, by exploring and developing methodologies able to depict more effectively and fully the fundamental features of the macroeconomic framework. The debate about the trade increasing effect, specific to a currency union, has gained momentum in the last few years giving rise to a rapidly growing literature which deals with what is becoming customarily known as the *Rose effect.*

The Rose effect

In his recent and controversial paper, Rose, empirically finds that the adoption of a common currency has a very large impact on trade flows. Indeed, he finds that those countries which share a common currency, trade around three times more than countries outside a monetary union. He also finds a clear negative link between volatility and aggregate bilateral trade. However the effect is weak. Rose bases his findings on a "gravity" model of bilateral trade having the following form:

$$\ln(T_{ijt}) = gCU_{ijt} + bZ_{ijt} + e_{ijt} \quad (1)$$

where T_{ijt} is the value of real bilateral trade between "countries" i and j at time t, CU is a dummy variable which is unity if i and j share the same currency at time t, Z is a vector of controls given by an augmented gravity model, *b* are the associated nuisance coefficients, and *e* is a residual. The main result is that the *g* coefficient is large and robust (point estimate $g = 1.2$, implying that a pair of countries using a common currency trade three times more than countries which keep their own currencies, since exp (1.2) = 3).

The results of the paper have been hotly debated. A first wave of papers strongly contests the finding mainly on the basis of the methodology employed, the inaccuracy of the analysis and the chosen dataset[8]. More recently, however, the profession has started accepting the presumption that a *Rose effect* exists, even if not necessarily of the magnitude suggested by Rose. A number of papers, for instance Frankel and Rose (2002) and Flandreau and Maurel (2001) take the *Rose effect* on trade as given, and focus on the implications of this estimate.

The assumption that common membership in a monetary union must have an important effect on trade derives from indirect empirical evidence on the trade effects of bringing closer or further apart two geographic units. Endogenous Optimum Currency Area (OCA) theories also suggest that such a move implies greater synchronisation of business cycles. Furthermore a currency union is likely to be perceived as a signal for a more serious commitment to integration and it definitely entails tighter financial integration among the participants.

Recently Rose has produced a meta-analysis of nineteen studies investigating the effect of currency unions. He brings evidence showing that a monetary union doubles trade, that the hypothesis of lack of effect can be statistically rejected and that results are unconnected with study-specific features. One should keep in mind, however, that the data sample is limited and results may suffer in terms of robustness.

Has the world changed or is it a methodological matter?

The existence of trade increasing effects of currency unions, and, by extension, of administrative and political unions, is definitely in line with intuitive reasoning. However, for long it has been difficult to find supporting empirical evidence. Only a few years back, Frankel (1997, p. 68) was commenting "in an ideal world we would have data on bilateral trade among provinces, or even among smaller geographical units". He mentioned that the most important advantage of using data at the provincial level would be the ability to "ascertain how trade between two geographical entities is affected by their common membership in a political union". Only in recent years, and only for a limited set of countries, systematic measures of internal trade flows became available.

The border effect methodology, a "refinement" of gravity models that we will explore in the ensuing paragraphs, allows to pool together international and intra-national trade flows.

8. For a fairly complete list of all contestation and Rose's replies, refer to Rose's web-page http://faculty.haas.berkeley.edu/arose/RecRes.htm#CUTrade.

This methodology is particularly useful in assessing the effect of exchange rate volatility and monetary regimes such as the single currency because it adds to a dataset observations where volatility is null by definition. A second important element is the use of disaggregated data. An extensive literature on the exchange rate pass-trough, and advances in several other fields of international trade and industrial organisation have in fact demonstrated that aggregate data do not allow to take into account the sector specific nature of production and market structures as opposing effects cancel out.

The empirics of the border effect

The natural framework with which to attack the issues discussed above is, as Helliwell states, "some model giving geography a key role as a determinant of the density of economic linkages, and yet permitting national borders to be additional factors... Without a model that accounts explicitly for the cost of distance, *i.e.* for the extent to which distance increases the cost of finding, negotiating and implementing economic transactions, any border effect would get impossibly mixed up with distance". The so-called gravity equation, which has long been the workhorse for empirical studies in international trade (Bayoumi and Eichengreen, 1995, p. 2), has the appropriate characteristics.

Gravity

Gravity-like modelling techniques have the reputation of being very successful at predicting bilateral trade flows. Improved theoretical foundations, allowing to derive the gravity specification from a variety of leading trade theories, and a new approach, on the part of international economists, to the subject of geography and trade, which treat countries and regions as geographically located at particular places, rather than as intangible entities, have added to their appeal.

A primary advantage of gravity modelling is that it provides a strong foundation to a modelling based on rough indicators. This is particularly useful when the sample to be estimated consists of a large and diversified number of cross-sectional units. It constitutes an empirical tool offering a straightforward yet powerful way for predicting bilateral trade flows since, by controlling for variables such as distance, both in the geographical and figurative sense, and for supply as well as demand it allows, even in its less sophisticated forms, to reliably explain a substantial portion of the variation in bilateral volumes and in the determinants of the nature of trade flows. It customarily produces R-squared estimations of at least 0.7 and provides elasticities of trade with respect to both income and distance that are consistently correctly signed, economically large and statistically significant.

The basic equation

In the Newtonian equation, after which the gravity model is named, attraction of two objects increases with the product of their masses and decreases with the distance between them. Translated into economics this means that the trade volume between two nations, measured either as bilateral imports, exports or total trade, increases with the products of their size (usually measured in terms of GDP or GNP) and decreases with the distance between them. The baseline gravity model only needs these two elements, distance and size, and in its simplest form can be modelled as follows:

$$T_{ij} = Y_i^{\alpha_1} Y_j^{\alpha_2} d_{ij}^{\alpha_3} \quad (2)$$

where T_{ij} stands for the unilateral or bilateral trade flow between country *i* and country *j*, *Y* is GDP (or GNP) and *d* is distance. α_1 and α_2, quantifying demand and supply forces, are positive since it is reasonable to assume that large countries trade more than small ones. A methodological paper by Head (2000), giving indications about the usual results for estimated coefficients, states that obtained values usually range between 0.7 and 1.1, but are often close to unity.

Trade costs increase with geographical distance therefore α_3 is negative. α_3 is negative and normally equal to – 2 meaning that trade decreases in proportion to the square of the distance. Although this is an empirically robust result, the discussion of the distance variable requires some further elaboration. Distance is customarily measured as the mileage between capital cities or economic centres (*i.e.* Shanghai instead of Beijing, Chicago instead of Washington, Koln instead of Berlin, etc.). This implies the assumption that the entire economic activity takes place in one location and forces us to model countries as single points. The already mentioned border effect literature, a refinement of gravity models, which I will develop in subsequent paragraphs, addresses this shortcoming by combining international trade data with internal ones. An uncontested critical issue in the empirics of this strand of literature is the measurement of distances and, in particular, the need to approximate the true region, weighted to relative magnitudes of international and intra-national distances.

A number of solutions have been proposed to overcome data inadequacy regarding the measurement of internal distances. Wei advises to calculate internal distances as one quarter of the distance to the nearest foreign economic neighbour and combine them with standard measures of international distances. Wolf (1997) replaces internal distances with the distance between the two main cities of the state. Leamer (1997) and Nitsch (1997) model internal distances as proportional to the square root of the area of the country[9]. Finally, Head and Mayer identify a method based on two important measurement aspects. First, the relevant distance for a representative product depends on the economic size of the importing and exporting regions. Second, measures of distance should take into account the unequal distribution of a country's economic activity among geographically dispersed sub-national units. From these assumptions they derive an integrated formula for total distance (internal and external) with weights for exporting and importing countries respectively based on 2-

9. They assume that the economic geography of each country can be approximated with a disk in which all production concentrates in the centre and consumers are randomly distributed throughout the rest of the area.

digit employment figures and on GDP (or population). A fairly high correlation exists between Leamer and Head and Mayer methodologies, while Wei and Wolf differ in a large and non-systematic manner from region-weighted distances.

The relationship between trade flows and distance, and the economic meaning and measurement of this latter deserve additional treatment. Several *ex ante* reasons that I will mention in the ensuing text would suggest that available distance measures fail to depict the "real" economic transportation costs. Nevertheless, empirical evidence shows that distance, no matter how roughly measured, dramatically impedes trade. Such discrepancy between theory and fact calls for further investigation. The leading economic explanations on why distance matters so much are either related to its approximation of transportation costs[10] or its focus on the direct and indirect missed opportunities for business that physical, economic and cultural distances imply[11]. The empirical relevance of distance, in any case, calls for accurate measurement and a clear understanding of the problems involved.

A number of measurement methods can be used. Yet, most econometric estimations use "as the crow flies" measures. The technical procedure consists in applying the "great circle" formula between the two latitude-longitude combinations. This formula approximates the shape of the earth as a sphere and calculates the minimum distance across the surface. Distances so measured are potentially subject to a number of miss-estimating problems. First, many air routes avoid the poles even when this would be the shortest trajectory. Second, land and sea transportation modes are subject to a number of geographical and political obstacles. Third, physical distance is only one of many components of transportation costs. Market imperfections and forms of monopolistic and oligopolistic power, characterising a number of segments of the transport industry, draw a wedge between the physical distance and the relative transportation cost. Fourth, estimates of c.i.f. data suggest that measures of transport increase less than linearly with distance implying important shipment fixed costs and small marginal costs for unit of travelled distance. Attempts to distinguish among different modes of transport and to take into account the shipping routes which are actually followed failed to shed much light on the issue.

Economists give at least three reasons in support to the great circle formula for distance measurement. First, a great deal of transport increasingly goes by air. For instance, in the last thirty years the share of air transport in US exports has doubled and nowadays it covers approximately one third of the entire market (US Bureau of Census). Second, air transport seems to be a reasonable way to average costs across different modes of transportation. Finally, empirically, it works well.

10. Distance represents a proxy for transport costs (Bergstrand among others) and it indicates the time elapsed during shipment, which, for perishable goods determines the probability of survival.

11. Greater distances are likely to be associated with larger cultural differences and consequently longer times for the establishment of trust and transmission of information. In addition, they reduce possibilities of informal communication and personal contact thereby increasing informational transaction costs.

Remoteness, which measures each importer's set of alternatives, is an important topic connected with distance. Nevertheless, it has often been overlooked by the empirical literature. A possible reason is that results approximate the theoretically correct remoteness values, but not accurately enough. To my knowledge, the best formalisation is the *inclusive value* proposed by Head and Mayer. It describes the full range of potential suppliers to a given importer, taking into account their size, distance and relevant costs of crossing the border. Less sophisticated measures of the remoteness of each trading partner from other possible partners also exist. Wei, Wolf and Helliwell each adopt different formulations of the remoteness variable involving distance and GDP.

The importance of taking remoteness into account when measuring the trade/distance relationship is better explained by way of exemplifications. The most striking and cited example is the comparison of the bilateral trade flows linking Australia and New Zealand with trade between Austria and Portugal. These two pairs of countries have distances and GDP products comparable in size. Nonetheless, the actual 1993 trade between the two pacific countries was nine times bigger than the one between their European counterparts (Head, 2000). A gravity model neglecting remoteness would erroneously predict a similar bilateral trade for the two country pairs.

Refinements

The basic gravity model, analysed up to this point can be "augmented" in order to account for a variety of factors mitigating or reinforcing the effects of size and distance variables. Refinements to the gravity model include a vast array of quantitative and qualitative indicators. Here I briefly outline the most important examples.

Size variables

The most frequently used specifications of the gravity equation also include a population variable, which gives us a measure of size and self-sufficiency. It can enter the equation in two different, but mathematically equivalent, ways: either directly or through per-capita income:

$$X_{ij} = Y_i^{\beta_1} L_i^{\beta_2} Y_j^{\beta_3} L_j^{\beta_4} d_{ij}^{\beta_5} \tag{3}$$

$$X_{ij} = Y_i^{\gamma_1} y_i^{\gamma_2} Y_j^{\gamma_3} y_j^{\gamma_4} d_{ij}^{\gamma_5} \tag{4}$$

where L is population and y is per capita income ($y = Y/L$). L determines the market size of an economy. Assuming increasing returns to scale, the bigger the home market (L), the bigger will be the absorption of home production, leading to smaller trade volume (Aitken, 1973, p. 882). The coefficients on population (β_2 and β_4) are therefore negative, while the coefficients on per capita income (γ_2 and γ_4) are positive. This prediction contradicts the traditional Heckscher-Ohlin trade model and supports Helpman-Krugman types of theories. According to the latter, richer countries tend to trade more than poorer ones (Baldwin, 1994,

p. 83). Love for variety, innovation processes and more advanced and effective transportation infrastructures are all an increasing function of a country's wealth and all foster trade. Heckscher-Ohlin, on the contrary, assumes that if the only two factors of production are capital and labour, then countries with dissimilar levels of per capita income will trade more than countries with similar levels[12].

Thus, despite the mathematic equivalence, the economic interpretation of population and per-capita GDP variables is very different and their detection calls for different empirical implications and policy measures. To understand the equation in a simple and intuitive way, Baldwin (pag. 82) suggests considering the analogy of an individual family's pattern of purchases as having the choice between two nearby shopping areas. "Factors influencing how much the family buys at each shopping area may be divided into those that concern the family's characteristics and those that relate to the particular shopping area's traits... The richer the family becomes per capita, the more they will tend to spend on goods from both shopping areas." Similarly, holding per capita income constant, but increasing the family's total income, thereby increasing the size of the family, wouldn't change the share of expenditures going to either shopping area. On the other hand, "the division of purchases between the two shopping places would depend primarily on the characteristics of the shopping areas themselves. It is likely that the family would buy relatively more from the area that offered the wider selection of goods. Also, other things being equal, the family will tend to do more of their shopping at the nearest location".

The analogy better clarifies the role of importer and exporter GDP, population and per-capita GDP in determining bilateral trade flows. Frankel suggests a gravity specification that keeps in mind all the factors that may be involved in the relationship.

$$T_{ij} = y_i^{d_1} L_i^{d_2} \; y_j^{d_3} L_j^{d_4} \qquad (5)$$

From the empirical specification above, emerges an improved prediction of the effect on trade growth and the composition of the flows. If a country experiences a relative increase in income which takes the form of an increase in per capita income, then the effect on trade is proportionate, as predicted by the theories of imperfect substitution. Alternatively, if the increase in income is entirely due to an increase in the population size, then the increase in trade is likely to be somewhat less proportionate as economies of scale make the country proportionately less dependent on trade.

Trade cost related variables and "trading block effect" dummies

Once we have incorporated a role for distance in raising the cost of trade, one can also incorporate factors which might also interfere with the determination of trade costs.

12. More precisely countries with dissimilar labour/capital ratios will trade more than countries with similar ones.

The border effect is one such factor. Another widely used refinement is adjacency, which is likely to have a positive impact on trade flows. Near the border, consumers can cross over to shop in the other country and firms can source intermediate inputs in the other country much more readily that it would be possible if the countries did not share a common border. Trans-national economic initiatives such as the Basel International Airport, offspring of a co-operation between Switzerland, Germany and France, are also likely to boost local trade. Landlockedness, on the other hand, is possibly adding to trade costs. A negative coefficient for such a dummy would indicate a negative effect arising from the lack of ocean-ports for a country.

Regional or preferential trade agreements, common language and colonial links are also important variables to take into account. The first reduces political, economic and bureaucratic obstacles while the latter two reduce the cost of unfamiliarity in international trade.

In this brief outline I have overlooked a whole array of factors that should be taken into account. In gravity equations it is vital to model as many factors affecting bilateral trade patterns as we reasonably can, because an omitted variable correlated with one of the factors that we want to study, would give us biased estimations. Frankel, in his 1997 book (chap. 6), provides a comprehensive summary of political and historical factors affecting trade flows as well as of the role of investments and currencies.

Theoretical underpinnings and competing models of trade

The assumption that bilateral trade flows depend positively on the size of the trading countries and negatively on the distance separating them is self-evident. Nevertheless, the gravity model has long been disregarded by international economists due to poor theoretical foundations and the inability to derive it from theories alternative to the Helpman-Krugman imperfect substitutes model. This was a particularly sensitive issue because correspondence between the gravity equation and theoretical models was sought to be used as the basis for empirical tests of alternative theories. Furthermore, while a lot of efforts have gone into finding an appropriate theoretical rationale for the relationship between the product of GDPs and bilateral trade, theoreticians as a whole have disregarded distance, providing, in so doing, frameworks that only partially were able to give foundations to gravity models. The exceptions include Bergstrand (1988), who incorporates a role for shipping costs, proxied by distance, and one of the two Heckscher-Ohlin models developed by Deardoff (1998).

Helpman-Krugman and its child: the standard gravity equation

The best-known theoretical rationale exemplifying the link between bilateral trade and size of GDPs is the study carried out in 1985 by Helpman and Krugman. The prototype of this model describes a market structure determined by consumers'love for variety and firms'fixed requirements for limited productive resources. The authors use a multi-country, multi-sector, multi-factor model in which firms produce two different kinds of products. One subset of industries (I_H) produces a homogenous product with constant returns to scale or increasing returns and contestable markets[13]. The other subset (I_D) produces differentiated products with increasing returns to scale. Each firm, in this second subset, produces a variety for which it is the monopolist, and, with freedom of entry, profits are just sufficient to cover average costs, which are decreasing as output increases. Tastes of consumers are homothetic and the same in all countries. Utility is given by a constant elasticity of substitution utility function. Consumers distinguish varieties of the same type of goods produced by different firms and utility increases when the number of varieties increases. In equilibrium there is factor price equalisation and the total volume of trade (*VT*), equal to the sum of all exports, is:

$$VT = \sum_{j \in J} \sum_{i \in I_H} \max(p_i X_i^j - s^j p_i \overline{X}_i, 0) + \sum_{j \in J} \sum_{i \in I_D} (1 - s^j) p_i X_i^j \qquad (6)$$

where X_i is world production of good *i*, p_i is the price of good *i*, X_i^j is country *j* production of good *i*, and s^j is country *j*'s share of world income and expenditure. The first part of the right hand side of the equation above describes the contribution of homogenous products to world trade. The second term describes the contribution of differentiated products to the volume of trade. In both cases, exports are the difference between a country's production of a good *i* and its own consumption of the good. In the case of homogenous products, a country can be an importer in which case the value is put to zero.

In the case where there is specialisation in the production of homogenous goods – or if all goods are differentiated – the following is true: $i \in I_H$ implies that $X_i^j = 0$ or $X_i^j = X_i$.

We can therefore say that:

$$\max(p_i X_i^j - s^j p_i \overline{X}_i, 0) = \max(p_i X_i^j - s^j p_i X_i^j, 0) = (1 - s^j) p_i X_i^j \qquad (7)$$

Rewriting we obtain:

$$VT = \sum_{j \in J} \sum_{i \in I} (1 - s^j) p_i X_i^j = \sum_{j \in J} (1 - s^j) Y^j = \sum_{j \in J} (1 - s^j) s^j \overline{Y}$$

where Y^j is country *j*'s income and $\overline{Y} = \sum_{j \in J} Y^j$. Since $\sum_{j \in J} s^j = 1$ we have

$$VT = \left(1 - \sum_{j \in J} (s^j)^2\right) \overline{Y} \qquad (8)$$

This states that world trade is a fraction $\left(1 - \sum_{j \in J} (s^j)^2\right)$ of world income. This fraction (and thereby total trade) is largest when countries are of equal size.

13. Contestable markets imply that every good subject to economies of scale is produced by one firm and will be priced at average cost. For more details se Helpman and Krugman (1985), chapter 4.

When we are in presence of complete specialisation, then identical and homothetic preferences and access of all consumers to the same price will imply two things. First that country j consumes a fraction s^j of every good that is produced in the world, and second that it exports a fraction $(1 - s^j)$ of every good that it produces, with a fraction s^k of its output being exported to country k. This implies that country j's exports to country k are:

$$X_{jk} = s^k Y^j \qquad (9)$$

Two country's bilateral trade is positively related to their income levels. In this sense, the equation above is a version of the gravity equation in its traditional multiplicative form. The intuition behind this is simple and straightforward. The larger an economy, the more varieties of differentiated goods it will produce. Since all goods are exported in this model and love for variety holds, then trade increases with the rise in the number of varieties.

A generalised gravity equation

Bergstrand (1988) develops a general equilibrium model of international trade, nesting inter-industry trade with modern intra-industry trade models. The model is one with two differentiated-product industries and two factors of production. Demand of the two goods is found by maximising the consumer's utility function (a Cobb-Douglas-CES-Stone-Geary utility function) subject to an income constraint. The thereby found bilateral import demand functions depend both on nominal and per capita GDP. Specifically, the national income elasticity of demand for manufactured goods will be greater than one if per capita income rises. On the supply side, each firm in each of the two industries produces a uniquely differentiated good, using capital and labour inputs, in a market that is characterised by monopolistic competition. Technology takes a linear form and is the same for each firm in every country. Each firms' output is distributed among domestic and foreign markets according to the constant-elasticity-of-transformation function. Output shipped to foreign markets is scaled by the "c.i.f./f.o.b. factor", which is always greater than one. This implies that only a portion of the shipment actually arrives in the foreign market (iceberg-type costs). The transformation curve between domestic and foreign markets as well as among foreign markets is concave. Therefore, firms' behaviour can be described as a two-stage process. First, the firm produces a differentiated good under increasing returns to scale. In a second stage, it distributes the product to all markets including the home market under diminishing returns.

Solving this system for the value of bilateral trade flows, one obtains what Bergstrand calls the "generalised" gravity equation[14]. It explicitly contains exporter's and importer's nominal and per capita GDPs. Distance enters the equation through the c.i.f./f.o.b. ratio, which is a measure of transport costs. Two of the gravity equation variables have unambiguous effects.

14. The author characterises his version of the gravity model as "generalised" because, besides volumes, it also includes trade prices.

Importer's income enters positively and bilateral distance negatively.[15] It is also shown that when the elasticity of substitution in consumption for a given industry is greater than one, exporter's income is expected to have a positive coefficient. Under the same condition it is true that exporter's per capita GDP has a positive effect on trade in capital-intensive goods[16]. As I have already mentioned, importer's per capita GDP is related to income elasticity of demand. It is therefore expected to observe coefficients greater than unity for luxury goods and smaller than unity for necessities. Bergstrand also argues that adjacency has an unambiguous, positive effect, but he does not provide theoretical support to this statement.

Solving for the presumed theoretical inconsistency of the Heckscher-Ohlin factor endowments theory with the gravity model

Until the appearance of Deardoff (1995), it was frequently stated that the Heckscher-Ohlin theory was incapable of providing a foundation to the gravity model. Since the data does have the property that bilateral trade depends upon the product of incomes, this was taken as evidence against Heckscher-Ohlin. Deardoff shows that this theory permits to derive the gravity equation almost as easily as from the imperfect substitutes framework.

He uses two alternative settings of analysis, *frictionless trade* and trade *in presence of trade impediments,* to characterise two extreme cases of trade. In a frictionless world, it is indifferent to serve home or foreign markets. Thus, Heckscher-Ohlin and other models based solely on comparative advantages and perfect competition can account for a gravity equation in a frictionless form without a role for distance. In a background of bilateral impeded trade, the same holds under the assumption that each good is produced only by one country. In both cases, the extreme specialisation hypothesis is central to the reasoning.

On theories explaining the success of gravity equations

Similar to Deardoff, most models used to underpin gravity equations, have one characteristic in common: perfect specialisation, where each commodity is produced in only one country. Evenett and Keller (2002) empirically find that perfect specialisation models, imposing a strict proportionality of trade to GDP, over-predict, by a large amount, the volume of trade to what is actually observed. As a consequence, it suggests to go a step ahead in fine-tuning the theoretical basis of gravity models and identifying which theory actually accounts for the success of the gravity equation in a given data sample.

The paper advances that this "model identification problem" can be solved by conditioning bilateral trade relations on factor endowment differences and on the share of intra-industry trade. The authors single out and test four archetypal models – combining perfect and imperfect specialisation models alternatively with increasing returns to scale (*IRS*) and

15. Bergstrand also argues that adjacency has an unambiguous, positive effect, but he does not provide any theoretical basis to this statement.
16. Since the trading partners in our sample are exclusively rich nations it is reasonable to assume that a large fraction of trade among them is in capital intensive goods.

Heckscher-Ohlin. In so doing, they show that the two trade theories explain different components of the international variation of production patterns and trade volumes and demonstrates that while north-south trade is mainly of a Heckscher-Ohlin nature, the north-north one is truly mixed.

The measurement of internal trade flows

As previously mentioned, data availability on intra-national trade flows is the main difficulty in testing for the border effect. Some papers have tried to find alternative sources of statistical information. Hillberry, for instance, exploits the sub-national characteristics of a different set of data that can be assimilated to trade. He uses the 1993 US commodity flow survey (CFS) in order to check over 136 commodities by gravity methods. CFS data consists of freight shipments originating in mining, manufacturing, wholesale and selected retail establishments in the US so that data for 142 commodities between 48 contiguous US states and between them and 7 Canadian provinces become available. However, important shortcomings of using proxies to trade data must be kept in mind and controlled for. For example, in Hillberry, the inclusion of wholesale shipments in the survey sample entails the risk of overstating the local intensity of trade flows.

Other papers apply methodologies aimed at relaxing the constraints deriving from the need for trade data on sub-national units. Wei defines a country's imports from self as the domestically made goods that are exported to domestic consumers. He proposes a residual value for imports from self obtained by subtracting total exports from total production. More precisely *GGDP = (GDP – services – transport – total exports) = goods part of GDP*. Since then, it has become customarily for this strand of literature to calculate trade from self by applying Wei's methodology.

More recently Head and Mayer derive a relative specification able to sidestep completely the need for domestic data. By moving from first principles, these authors derive a monopolistic competition specification which predicts that imports from a particular country for a specific industry are related to the alternative sources in the whole world. They manage to overcome an apparently intractable data problem by working with log odds ratios. Through exploitation of the *Independence from Irrelevant Alternatives (IIA)* property of constant elasticity of substitution (CES) demand functions, they obtain a formulation in which relative demand for a given foreign country depends only on ratios of explanatory variables for that country and the home country.

Other data issues

Geographically and sectorally disaggregated data

The importance of using bilateral data stems from the fact that differences exist, across national marketplaces, affecting the exposure of traders to foreign exchange risk and the design of a typical contract. However, traditionally, aggregate data were used, due to the unavailability of bilateral data for trade volumes and values, something which became widespread only in the last fifteen years. Part of the literature, aware of the necessity to draw on bilateral data, constructed proxy series on the basis of product consumption of bilateral trade (for instance Hooper and Kolhagen). However, as Kemp signalled already in 1962, such procedures entailed the risk of severely biased results in the case of measurement errors.

Bilateral data, although geographically disaggregated, are to be considered macoeconomic data and, as such, do not take into consideration the different nature of the markets in which trade occurs. One of the main conclusions of the extensive literature on exchange rate pass-through was that a sector's market structure has an important effect on firms'pricing behaviour in international markets. Features such as the extent of vertical differentiation, the magnitude of economies of scale, the degree of industrial concentration, non-tariff barriers, the relative location of reference markets and competitors are all explanatory variables found at an aggregate level which can only be taken into consideration by emphasising the data at the industry level.

A number of papers have recently investigated economic interaction at the finest geographical and commodity level of detail in order to identify the primary causes of the remaining obstacles to international trade. Hillberry uses commodity and industry specific data to test the size of the border effect in 136 distinct industries. He verifies 7 hypotheses that are intended to explain cross-commodity variation in the border effect. Chen studies the behaviour of prices across EU countries and industries by means of multi-variate unit-root tests, to identify a number of potential explanations for the differing behaviour of relative prices in the continent. Rogoff (1996), in a survey of international price behaviour, states that "international goods markets, though becoming more integrated at all time, remain quite segmented, with large trading frictions across a broad range of goods… As a consequence of various adjustment costs, there is a large buffer within which nominal exchange rates can move without producing an immediate proportional response in relative domestic prices."

In a previous paper of mine (Taglioni, 2001), I inspect the likely effects of exchange rate volatility on 120 different manufacturing sectors in 12 European Union countries during the period 1976-1995. I observe how volatility is particularly harmful for some primary products, ingestible goods and utilities. I register positive results, on the other hand, for a few and diverse sectors such as telecommunications, office machinery, musical instruments and shipbuilding. By testing for differences in factor intensities, production conditions, technology requirements, market structure and labour skills, I find that, *ceteris paribus*, volatility harms most mature products and traditional sectors, characterised by medium-low technology and non-skilled labour. To note, these findings are in line with the deductions of the pass-through literature.

Why is it necessary to estimate disaggregated trade relationships rather than concentrating on overall trade flows? If the effects of the determining variables were exactly the same between aggregated and disaggregated data, or if the relationship between the disaggregated coefficients and the overall ones were a stable one, then it would be indifferent to focus on either type of data. However, if these conditions are not satisfied, as it is often the case, estimating aggregate data is equivalent to constraining the specific elasticities to be equal across countries and sectors determining specification biases. Furthermore goods (or countries) with relatively low elasticity can display the largest variation in prices and thereby exert a dominant effect on the overall estimation, thus entailing the risk of downward biased estimations (Goldstein and Kahn, 1985).

One setback of using disaggregated trade data is the large number of data points in which there is no observed commodity flow between a given pair of locations. Estimation problems linked to the existence of zero observations increase with the increase of the number of zeroes. Therefore the higher the level of disaggregation and the degree of industrial specialisation are, the more problematic the estimation using formal panel regression models. The risk of non-linearities and selection biases, implied by non-randomly missing and multiple zero observations, calls for sample selection models and two-parts models[17]. Examples are the Heckman two-stages procedure, as used by Head and Mayer, or a combination of ordered probit regressions and truncation models (used by Hillberry).

Pooled data and panel techniques

The best way to avoid dispersing information on cross sectional units observed over time is to employ pooled data and panel techniques. By using them, one can simultaneously exploit the cross-country and time-series dimension of the data. A major advantage of their use is that one can control for institutional, economical, cultural time-invariant or population-invariant factors, which are not specifically modelled. Time-series or cross-country studies cannot control for such variables and run the risk of obtaining biased results. Furthermore, panels are free of possible problems generated by multicollinearity (Baltagi, 1995, p. 4). Pooling data on a panel gives more information, more variability, more degrees of freedom and more efficiency in the parameter estimates produced. Last but not least, Dell'Ariccia draws attention to their usefulness in dealing with simultaneous causality problems which are likely to arise while testing for the volatility-trade link. For example, if central banks make an effort to stabilise the exchange rate with their main trade partners, a negative correlation between exchange rate volatility and trade would appear from the data, when in fact, the two may not be linked by causality. In other words, it would appear from the data that stable exchange rates induced greater trade and instable exchange rates are detrimental to trade flows. The use of panel data explicitly takes into account the behaviour of central banks by means of fixed effect models. If the central bank strategy is invariant over the observed period, it can be treated as a country-pair specific effect.

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17. The appropriate treatment and interpretation of zero observations is rather contentious. The main issue is the interpretation of the relationship between the zeroes and the positive observations. Two classes of models are employed: *sample selection models* and *two-parts models.* The first class of models assumes that the zero observations represent "latent" negative values of the dependent variable. They estimate such values and fit a line passing through the entire sample of observed and latent values. The second class of models, prefers not to rely on assumptions about the relationship between the zeroes and positive observations. Rather, estimates and interprets two distinct equations. Normally the latter type of models is preferred when the number of zero is large.

EMPIRICAL EVIDENCE

What do the latest contributions to the debate on the exchange rate volatility-trade relationship, which systematically report a negative and statistically robust coefficient, have in common? Can we detect features that are able to better characterise the volatility-trade linkage? In this section we will review the methodology employed by four papers and look for regularities and differences in the strategies used. The works under review are the already mentioned (Dell'Ariccia,1998; Pugh *et al.*, 1999; Rose, 2000; Taglioni, 2001). All the papers under review test a gravity model in its augmented version (TABLE 1).

Table 1 - Empirical specifications from selected literature on the volatility-trade link

	Dell'Ariccia (1998)	Pugh *et al.* (1999)	Rose (2000)	Taglioni (2001)
Dependent variable	Log $(X + M)_{ijt}$	Log X_{ijt}	Log $(X + M)_{ijt}$	Log (M_{ijt}/M_{iit})
Size variables				
GDP	log $(Y_{it}Y_{jt})$	$\beta_1$log (Y_{it}) + $\beta_2$log (Y_{jt})	log (Y_iY_j)	
Per Capita GDP			log $(Y_iY_j/\text{pop}_i\text{pop}_j)$	
Population	$\beta_3$log $(\text{pop}_{it}\text{pop}_{jt})$	log (pop_{it}) + $\beta 4$ (pop_{jt})		
Production V.A.	log $(\text{Prod}_j/\text{Prod}_i)$			
Prices	log (P_j/P_i)			
Distance	Great circle formula	c.i.f. imports less f.o.b. exports	Great circle formua	Weighted sub-national log $(\text{Dist}_{ijt}/\text{Dist}_{iit})$
Remoteness				Inclusive value
Exchange rate vol.	yes	yes	yes	yes
Dummies				
Common border	yes	yes	yes	
Language	yes	yes	yes	yes
EU	yes	yes		yes
Non-ERM		yes		yes
FTA		yes	yes	
NTBs				yes
Home bias				yes
Common nation (*i.e.* French overseas dept. s)			yes	
Common colonizer			yes	
Colony/colonizer			yes	
Currency union			yes	

Trade is measured at a bilateral level, and in one case disaggregated by industry (3-digit level of detail). A summary table is reported below (TABLE 2). The dependent variable in Dell'Ariccia and Rose is total bilateral trade while in Pugh it is exports. In Taglioni, imports are used and preference is given to a relative specification of the equation where all bilateral values are measured relative to domestic values. Imports from self are defined as total production less exports, in accordance with Wei (1997)[18]. The theoretical model, which uses the methodology proposed by Head and Mayer justifies the chosen relative specification[19]. Other differences between Taglioni's econometric specification and the other three papers are the use of production data instead of GDP and the inclusion of relative prices, which

Table 2 - A summary table of results

Author	Dell'Ariccia (1998)	Pugh *et al.* (1999)	Rose (2000)	Taglioni (2001)
Area	15 EU countries and Switzerland	16 OECD countries	186 countries worldwide	The 12 EU countries before 1995 enlargement
Estimating model/models	Gravity model	Aggregate import demand equation and gravity model	Gravity model	Gravity model with border effect
Estimating technique	Panel with fixed effects	Panel and OLS	OLS for separate years and panel with year controls	Panel
Disaggregation of data	Gross bilateral trade	Gross bilateral trade	Gross bilateral trade	3-digit industry specific bilateral trade
Period covered	1975-1994	1980-1992 for the import dem. fcn 1984-1990 for the gravity model	5 different years: 1970, 1975, 1980; 1985; 1990	1976-1995
Exchange rate volatility specification	3 different specifications of both nominal and real monthly data	2 different specifications: log std dev of annual% changes exchange rate variability slope dummy in logs	std dev. of the first diff. of monthly nat. log of bil. nom. exch. rate.	std dev. of the first diff. of monthly nat. log of bil. nom. exch. rate.
Coefficients for volatility	using: nom std. dev. *– 2.84 (0.608)* real std. dev. *– 4.15 (0.645)* forward error *– 0.25 (0.034)*	using: log std dev annual% change *– 0.59 (– 4.10)* exch. rate var. slope dummy log *0.48 (2.46)*	using nom std. dev. 1970 *– 0.062 (0.012)* 1975 *– 0.001 (0.008)* 1980 *0.060 (0.010)* 1985 *– 0.028 (0.005)* 1990 *– 0.009 (0.002)* pooled *– 0.017 (0.002)*	using: unconstrained panel *– 19.64 (1.1)* Heckit procedure *– 21.26 (2.5)*

18. Wei's definition of country's imports from itself is GGDP = goods part of GDP = (GDP – services – transport – total exports).
19. Head and Mayer's value-added lies in the fact that this paper develops the estimating equation from first principles, deals very carefully with the measurement of distance and with the fact that the prices of third nation goods can affect bilateral trade flows.

derives from the monopolistic competition setting. Specific dummies account for regional monetary arrangements. Pugh *et al.* split the effect by including two dummies: ShiftDV and SlopeDV, which, for intra ERM-trade, take respectively, value 1 and value equal to the bilateral volatility (ER_{ijt}). They both amount to zero otherwise. The other dummies included reflect specific aims of the papers.

Dell'Ariccia and Taglioni focus on European countries, Pugh on sixteen OECD countries and Rose tests 186 countries, dependencies, territories, colonies, etc. for which the UN statistical office gathers international trade data.

The volatility coefficient

Exchange rate volatility is measured in various manners. This reflects the fact that when it comes to measures of exchange rate volatility and variability as a proxy for risk, the specification depends on the type of exchange rate risk relevant to the importer and/or exporter. This in turn depends on the model of trading firm that is examined and the nature of its trading activities.

Pugh uses moving standard deviations from annual levels of the real effective exchange rate for the panel and two different specifications for the gravity equation estimated by OLS: the standard deviation of annual percentage changes in the nominal bilateral exchange rates and the average absolute annual percentage changes. Dell'Ariccia, Rose and TaglioniI use the standard deviation of the first difference of the monthly natural logarithm of the bilateral nominal exchange rate. Empirical findings in Anderton and Skudelny (2001) support the use of this specification. This paper shows that importers are most likely to "remember" past episodes of significant exchange rate volatility that took place during the previous five years. By experimenting with various moving average measures of volatility ranging from one to nine years, it finds that the five-year specification registers both the highest t-statistics and the highest adjusted R-squared. Dell'Ariccia, checks also two more proxies: the sum of the square of the forward errors and the percentage difference between the maximum and the minimum of the nominal spot rate[20]. It finds that all the volatility variables tested give similar results. Furthermore volatility in nominal and real terms turns out to be highly correlated.

As previously mentioned, all studies report correctly signed and significant volatility coefficients using bilateral trade data, panel techniques and the gravity modelling, which allow for depiction of otherwise overlooked elements of the relationship between volatility and trade. However, with the exception of Taglioni, the effect is rather small. Our next step will be, therefore, to propose an explanation of this difference in magnitude. There are two elements of discrepancy between Taglioni and the other three papers. Taglioni tests a border effect model instead of a simple gravity specification and uses disaggregated data instead of

20. The advantage of the first measure is that, under target zone regimes, or pegged but adjustable exchange rates, it would unveil the presence of a "peso problem" or the lack of credibility of the official parity. As for the second measure, on the other hand, it is deemed to stress the importance of medium run uncertainty (Dell'Ariccia).

total trade. Since Taglioni finds a statistically robust, large and negative parameter for volatility on bilateral imports it is worth discussing these two characteristics of the paper.

A nation is after all a monetary union

Head and Mayer measure the border effect in Europe and found that, for the average industry in 1985, Europeans purchased 14 times more from domestic producers than from equally distant foreign ones and that the tariff equivalent of the border for the period 1984-1986 was at least 36 percent. In an attempt to find the causes of such a large BE, they decomposed it into government actions that impede trade and unspecified consumer preferences. They found that NTBs, before the launch of the European Single Market, were responsible for at most 10 percent of the total effect. On the other hand, the coefficients on the consumer bias were systematically positive and statistically significant in half the regressions. This led the authors to identify the consumer bias as the main explanation for the BE in Europe. They advanced that such a strong consumer bias could be "the outcome of cultural differences or the legacy of past protection that caused domestic suppliers to adapt their product offerings to suit local tastes" (p. 285).

I believe that a valid alternative explanation is the simple fact that trade between two geographical entities is strongly affected by their common membership in political, administrative or monetary unions. Speculations on the importance of the geopolitical links for trade can be derived, for example, from the trade effects of free trade areas or from historical events such as political unions that formed or split apart[21]. A nation, after all, is a limiting example of political union, and single currency is a primary feature of all nation-states. By measuring volatility in a border effect framework, one can compare intra-national with international data. In so doing, it provides us with a virtually complete dataset, with observations crossing the whole range of possible values, including permanent zero volatility. Thus we can expect more reliable results.

Closely following Head and Mayer's procedure, Taglioni estimated the magnitude of the border effect before the implementation of the single market, and found estimates of volatility able to account for more than half of the overall Head and Mayer's BE.

TABLE 3 reports both the benchmark results from Head and Mayer – in columns (1) to (3) – and from Taglioni – in columns (4) to (6). Their comparison shows how exchange rate volatility contributes to explain the overall border effect. Column (1) and (4) report OLS estimations for pooled years 1984-1986 and column (2) and (5) report results obtained using Heckman (1979) two stages procedure aimed at avoiding the generation of selection bias, by testing for non-randomly missing observations. Finally, in column (3) and (6) relative production is forced to be one as predicted by the Dixit-Stiglitz model.

21. Flanderau and Morel (2001) for empirical evidence from 19th century Europe.

Table 3 - Border effects in the EU, 1984-1986

Dependent variable: Ln (partner imports/own imports)	Head and Mayer (2000)			Taglioni (2001)		
	(1)	(2)	(3)	(4)	(5)	(6)
Border	– 2.75*	– 2.97*	– 2.48*	– 2.42*	– 2.49*	– 2.07*
	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)
Ln rel. production	0.85*	0.80*	0.83*	0.83*		
	(0.01)	(0.01)	(0.01)	(0.01)		
Ln rel. distance	– 1.29*	– 1.06*	– 1.45*	– 1.2*	– 1.15*	– 1.47*
	(0.03)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)
Ln rel. price	– 0.75*	– 0.82*	– 1.18*	– 0.66*	– 0.68*	– 1.02*
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Volatility	– 22.57*	– 21.26*	– 21.34*			
	(2.3)	(2.5)	(2.49)			
Non-EU Member	– 0.52*	– 0.39*	– 0.41*	– 0.42*	– 0.39*	– 0.41*
	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
Common Language	1.57*	1.58*	1.47*	1.57*	1.58*	1.47*
	(0.09)	(0.09)	(0.09)	(0.08)	(0.09)	(0.09)
Mills ratio	– 2.30*	– 0.31*	– 0.61*	0.92*		
	(0.25)	(0.23)	(0.024)	(0.22)		
No. observations	12 892	12 892	12 892	12 892	12 892	12 892
R-squared	0.417	0.421	0.24	0.414	0.241	

Note : standard errors in parentheses with (*) denoting significance at 1 percent.

Specific account of volatility in equation (5), using Heckman, reduces the border effect measured by Head and Mayer calculated using the same methodology (equation 2) from 19.49 (exp. 2.97) to 12.06 (exp. 2.49), *i.e.* after controlling for volatility, the border effect is reduced in size by more than half.

The high volatility coefficients are indirect evidence of the *Rose effect* even if, at a first sight, it would seem exactly the opposite. Rose's results in TABLE 4 show very low coefficients for exchange rate volatility. In my opinion the divergence in results between the two papers lies in the methodology chosen. When using a non-relative specification, which corresponds to excluding intra-national data from estimation, Taglioni's volatility coefficients have little significance.

In order to provide a direct comparison between Taglioni and Rose's results, TABLE 4, reports the results of non-relative estimations run for the same years. The coefficient for volatility is non significant for three of the five years tested and significant at the 10 percent level in the remaining two years. It turns out to be significant only for the pooled sample but its coefficient is four times smaller than when using the border effect technique.

The importance of industry level data

In the past, at least one other paper testing for the home bias (Wei, 1996), has directly controlled for volatility. This author tests for two types of exchange rate volatility: direct bilateral volatility between importing and exporting country, which is expected to have a trade depressing effect and the average volatility for both importer and exporter[22] to entertain the

22. Average volatility is defined as the average of volatility of all the country's bilateral exchange rates weighted by the partners' GDP.

Table 4 - A Comparison with Rose (2000)

	Rose (2000)						Taglioni 2001)					
	1975	1980	1985	1990	Pooled		1976	1980	1985	1990	1995	Panel
Currency	1.28	1.09	1.4	1.51	1.21							
Union	(0.41)	(0.26)	(0.27)	(0.27)	(0.14)							
Exchange	0.001	– 0.06	– 0.028	– 0.009	– 0.017	Exchange	– 16.79**	**7.42**	**– 2.00**	**– 0.90**	– 10.07**	– 5.91
rate vol.	(0.008)	(0.01)	(0.005)	(0.002)	(0.002)	rate vol.	(6.96)	(5.54)	(4.21)	(3.74)	(4.49)	(2.10)
Output	0.81	0.81	0.80	0.83	0.80	Exporter's	0.79	0.67	0.71	0.75	0.77	0.75
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	output	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
						Importer's	0.43	**– 0.01**	0.11	0.27	0.25	0.18
						output	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
Output per	0.66	0.61	0.66	0.73	0.66							
Capita	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)							
						Exporter's	**– 0.30**	– 1.07	**0.33**	0.61	**0.13**	0.66
						prices	(0.21)	(0.26)	(0.21)	(0.11)	(0.09)	(0.08)
						Importer's	**– 0.23**	– 1.26	**0.12**	0.30 (**)	– 0.60	0.18**
						prices	(0.21)	(0.31)	(0.31)	(0.12)	(0.09)	(0.08)
Distance	– 1.15	– 1.03	– 1.05	– 1.12	– 1.09	Distance	– 1.83	– 2.41	– 2.21	– 1.99	– 2.00	– 1.83
	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)		(0.12)	(0.11)	(0.09)	(0.07)	(0.06)	(0.04)
FTA	1.02	1.26	1.21	0.67	0.99	Non	drop	– 0.67	**0.06**	drop	drop	**– 0.04**
	(0.21)	(0.16)	(0.17)	(0.14)	(0.08)	EU member		(0.12)	(0.09)			(0.06)
Common	0.36	0.28	0.36	0.50	0.40	Common	0.34**	**– 0.22**	**0.12**	**0.05**	**– 0.06**	0.14**
language	(0.1)	(0.09)	(0.08)	(0.08)	(0.04)	language	(0.17)	(0.17)	(0.17)	(0.16)	(0.16)	(0.08)
Obs.	4474	5092	5091	4239	22,984	Obs.	2363	3673	4129	5460	5460	15625
R-sq	0.59	0.62	0.65	0.72	0.63	R-sq	0.48	0.48	0.50	0.51	0.51	0.48
RMSE	2.18	2.03	1.94	1.75	2.02	RMSE	1.82	2.00	1.95	1.86	1.86	1.94

Notes: ** Significant at 10 percent level.
Numbers in bold are non significant.

possibility of cross-currency volatility causing substitution among trading partners. The underlying assumption is that a rise in either exporter's or importer's average volatility, holding the volatility of the direct exchange rate constant, may increase the pair's trade. Unfortunately, the volatility measures show "incorrect", but statistically significant, signs. Furthermore, the estimated home bias appears to be only slightly affected. I believe that these "disappointing" results concerning volatility derive from the choice to test aggregate data. My statement is based on the findings of the pass-through literature and on the line of reasoning of section 2.2.1.

Wei's other findings are the following. At aggregate level, imports from self (*i.e.* a nations production less its exports) are 2.5 times more than from abroad. The welfare consequences of the observed home bias are rather small and a slow but steady decline of the border effect across years takes place. TABLE 5 provides a synthetic comparison of the two papers.

Table 5 - A Comparison with Wei (1996)

Wei (1996)	Taglioni (2001)
Dataset covers 19 OECD countries members of the European Union before the last enlargement of 1995	**Dataset** covers 12 European countries *i.e.* the 12
Period 4 separate years: 1982, 1986, 1990, 1994	**Period** 1976-1995
Basic gravity model augmented with • remoteness • common border • adjacency • common language	Gravity model explanatory variables are: • relative/non relative production • distance measure encompassing remoteness • bilateral exchange rate volatility • non-EU membership • common language
Variables: • Bilateral trade • GDP • Population (to instrument GDP) • Distance: Greater circle distance between countries, within countries average distance is assumed to be half of the distance from the economic centre to the border (0.25*distance between the two international economic centres) • Remoteness: arithmetic weighted average of its distances from all trading partners with trading partners – incomes as weights • $\text{Remote} = \sum_h w_h \text{Distance}_{hi}$ where w_h is the country h's share in OECD total GDP. • Direct bilateral volatility between importing and exporting country • Average volatility for both importer and exporter	**Variables**: • Bilateral imports (3-digit industry level) • Production (3-digit industry level) • Prices • Distance from Head and Mayer (2000): between two regions calculated as the weighted distance between the main city of each region, taking the longitude and latitude of each city and applying the greater circle formula. Internal distances are approximated to 0.376 the square root of the area according to the formula $d_u = \frac{2}{3} \quad R = \frac{2}{3}\sqrt{\frac{A}{\pi}} = 0.376R$

Conclusion

Research on the volatility-trade link has moved from a utility maximising approach to models where geography plays a key role as a determinant of the density of economic linkages and where additional trade-influencing factors can be tested. With each generation of studies, the economic interpretation of the relationship has become more focused.

Aggregate and purely international analyses might jeopardize an unbiased interpretation of the causes and effects in the field of international economics. On the other hand, studies on specific products and regions run the risk of being unrepresentative and their results may not hold theoretically with generality. The conclusion from this investigation, which ought to affect the way we think, is that empirical studies carried out at the level of sub-national units and at the finest industry echelon help clarify the actual influence of exchange rate volatility on trade.

Yet, the lack of a comprehensive and fairly large set of bilateral trade data among provinces or, ideally, among smaller geographical units, represents a serious statistical constraint. It can, however, be bypassed by measuring volatility in a border effect framework. When employing such methodology, we obtain a description of the world "as if" we were allowed to directly compare intra-national with international data. In so doing, border effect techniques enable us to take into consideration the whole range of possible values of exchange rate volatility, including permanent zero volatility (intra-national data).

Accordingly, border effect estimations carried out in a multi-country, multi-currency context reveal a strongly negative influence of volatility on trade, whereas traditional gravity specifications fail to identify this. Such evidence indirectly confirms the existence of a *Rose effect* of monetary union on trade. Exchange rate volatility matters, but it matters relative to situations of monetary union which give support to the view that, holding a single currency within a given area entails a dramatic drop in intra-area trade costs.

Bilateral data, although geographically disaggregated, are still macroeconomic data and, as such, do not take into consideration the different nature of the markets in which trade occurs. One of the main conclusions of the extensive literature on exchange rate pass-through is that a sector's market structure has an important effect on firms'pricing behaviour in international markets. The interplay of a multi-currency framework with industry-specific features such as the degree of industrial concentration and non-tariff barriers, the relative location of reference markets and competitors, the extent of vertical differentiation and the magnitude of economies of scale greatly influences the effects found at an aggregated international level.

We mentioned in the paper that only in exceptional cases, the relationship between the disaggregated coefficients and the overall ones is stable and that industry specific trade data specifications might fail to produce results in line with those at the macro level. Holding this true, estimations based on aggregate flows, which are equivalent to constraining the specific elasticities to be the same across sectors, lead to misspecification problems. Moreover, downward biased results become a concrete risk because goods with relatively low elasticity can display the largest variation in prices and thereby exert a dominant effect on the overall estimation.

Empirical evidence reported in the paper confirms the sensitivity of exchange rate volatility to differences in market structures and emphasises the benefits of using industry level data in empirical investigations. However, disaggregated trade data have one important drawback. The existence of zero observations (no observed commodity flow) between pairs of locations, directly proportional to the number of zeroes, leads to severe estimation caveats. Consequently, the higher the level of disaggregation and the degree of industrial specialisation are, the more problematic the estimation using formal panel regression models is likely to be. The risk of non-linearities and selection biases, implied by non-randomly missing and multiple zero observations, calls for *ad hoc* estimations procedures still under refinement.

Improved data availability and continued effort to upgrade the techniques of measurement will help improve the estimation of the role played by currencies in favouring or hindering market integration. These will also help in determining the extent to which they constitute a trade barrier or a cause of segmentation[23].

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