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On the trade impact of nominal exchange rate volatility

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Abstract

What is the effect of nominal exchange rate variability on trade? I argue that the methods conventionally used to answer this perennial question are plagued by a variety of sources of systematic bias. I propose a novel approach that simultaneously addresses all of these biases, and present new estimates from a broad sample of countries from 1970 to 1997. The estimates indicate that nominal exchange rate variability has no significant impact on trade flows.

JEL classification: C21; F10; F11; F12; F15
Keywords: Exchange rate volatility; Trade; Gravity equation; Heteroskedasticity; Poisson regression; Instrumental variable

1. Introduction

Major changes are reshaping the international monetary system. The Communist Party in China is considering the idea of floating the Chinese yuan and so are several Asian governments.[1] In the same direction, although prompted by the drastic collapse of its currency board, Argentina has moved towards a (managed) float. On the other extreme, and after the recent institution of the euro, many countries in Eastern Europe are joining while others are expected to join the euro area. El Salvador and Guatemala have reinforced their peg to the dollar, and Ecuador has dollarized its economy.

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[1] Currently, the Malaysian ringgit is pegged to the US dollar and the Hong Kong dollar is tied to the US dollar through a currency board. Other Asian countries are officially floating, but the facto, central banks have been intervening to keep their currencies fixed to the US dollar.

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These recent developments have reinvigorated the policy debate over the pros and cons of different exchange rate systems. One of the issues in the debate is the trade effect of nominal exchange rate variability.[2] Proponents of fixed exchange rates have long argued that the risks associated with exchange rate variability discourage economic agents from trading across borders. Opponents have maintained that there are good instruments to hedge against this type of nominal volatility, and hence this effect should be immaterial. The question of the magnitude of the trade effect of exchange rate variability is an empirical one, and the subject of this investigation.[3]

The economics literature has provided at best mixed results. Most early studies, including Abrahms (1980) and Thursby and Thursby (1987), document a large negative effect of nominal variability on trade.[4] Studies from the 1990s, including Frankel and Wei (1993), Eichengreen and Irwin (1996), and Frankel (1997) report negative, albeit quantitatively small effects.[5] More recent studies on the effect of currency unions and unilateral dollarizations on trade, however, document large effects. (See, for example, Rose, 2000; Engel and Rose, 2000; Frankel and Rose, 2002; Alesina et al., 2002; Tenreyro and Barro, 2002). Frankel and Rose (2002) extend the analysis to currency boards, also finding significantly large effects. It could be argued that currency unions involve more than the mere elimination of exchange rate variability, although the case is less clear for currency boards. Furthermore, some critics have contended that countries that have historically been part of a currency union are too small and too poor to make generalizations about the effect of currency unions (boards) in larger countries. These interpretations and criticisms reinforce the need for a second look at the data that is not limited to this extreme type of exchange rate regime.

This paper argues that there are several estimation problems in previous studies of the impact of nominal variability (and more generally, of exchange rate regimes) on trade that cast doubt on previous answers. These studies have typically been framed in the context of the "gravity equation" model for trade.[6] In its simplest form, the empirical gravity equation states that exports from country i to country j, denoted by T_{ij}, are proportional to the product of the two countries' GDPs, denoted by Y_i and Y_j, and inversely proportional to their distance, D_{ij}, broadly construed to include all factors that might create trade resistance. Importer and exporter specific effects, s_j and s_i, are added to account for multilateral resistance.[7] The gravity

[2] Three other important issues are part of the debate: one is the relevance (or irrelevance) of monetary policy independence to dampen business cycle fluctuations. Another is the effect of exchange rate variability on financial markets. And a third issue is the ability of different regimes to stabilize inflation.

[3] The focus on nominal exchange rate variability (as opposed to real exchange rate variability) owes to the fact that the nominal rate is a priori the monetary instrument that policy makers can directly affect. In practice, however, nominal and real exchange rates move very closely, so, learning about the implications of nominal variability amounts to learning about the implications of real variability.

[4] The exception is Hooper and Kohlhagen (1978), who find no significant effects on trade volumes but a big effect on prices.

[5] See also De Grauwe and Skudelny (2000), who focus on European trade flows, and find statistically significant negative effects. See Côté (1994) and Sekkat (1997) for recent surveys on the literature.

[6] For theoretical foundations of the gravity equation model, see, for example, Anderson (1979), Helpman and Krugman (1985), Bergstrand (1985), Davis (1995), Deardoff (1998), Haveman and Hummels (2001), Feenstra et al. (1999), Barro and Tenreyro (2006), Eaton and Kortum (2001), and Anderson and van Wincoop (2003).

[7] See Anderson and van Wincoop (2003) for a formulation of the concept of multilateral resistance, and Rose and van Wincoop (2000) for a related empirical implementation.

equation is then augmented to account for the resistance, α_4, created by exchange rate variability, δ_{ij}, with $\delta_{ij} \geq 0$, that is:

$$T_{ij} = \alpha_0 \cdot Y_i^{\alpha_1} \cdot Y_j^{\alpha_2} \cdot D_{ij}^{\alpha_3} \cdot \exp(\alpha_4 s_i + \alpha_5 s_j + \alpha_6 \delta_{ij}) \cdot \varepsilon_{ij}, \tag{1}$$

where ε_{ij} is an error term, typically assumed to be statistically independent of the regressors, with $E(\varepsilon_{ij}|Y_i, Y_j, D_{ij}, \delta_{ij}, s_i, s_j)=1$, and the α's are parameters to be estimated. The standard practice consists of log-linearizing Eq. (1) and estimating the parameters of interest, in particular α_4, by ordinary least squares (OLS) using the equation

$$\ln(T_{ij}) = \ln(\alpha_0) + \alpha_1 \ln(Y_i) + \alpha_2 \ln(Y_j) + \alpha_3 \ln(D_{ij}) + \alpha_4 s_i + \alpha_5 s_j + \alpha_4 \delta_{ij} + \ln(\varepsilon_{ij}). \tag{2}$$

There are at least four problems with this procedure. First, it is very unlikely that the variance of ε_{ij} in (1) will be independent of the countries' GDPs and of the various measures of distance. In other words, the error term ε_{ij} is generally heteroskedastic. Since the expected value of the logarithm of a random variable depends both on its mean and on higher order moments of its distribution, whenever the variance of the error term ε_{ij} in Eq. (1) depends on the regressors, the expected value of $\ln(\varepsilon_{ij})$ will also depend on the regressors, violating the condition for consistency of OLS. This is simply the result of Jensen's inequality: $E(\ln \varepsilon) \neq \ln E(\varepsilon)$, and $E(\ln \varepsilon)$ depends on the whole distribution of ε. In particular, if ε is log-normal, $E(\ln \varepsilon)$ is a function of the mean and variance of ε. Santos Silva and Tenreyro (in press) find this to be a serious source of bias in practical applications of the gravity equation.

Second, pairs of countries for which bilateral exports are zero have to be dropped out of the sample, as a result of the logarithmic transformation. In a typical data set, this leads to the loss of over 30% of the data points. This massive sample selection can cause additional biases in the estimation.

Third, with a few exceptions, previous studies assume that exchange rate variability is exogenous to the level of trade. Standard endogeneity problems, however, are likely to confound the estimates. For example, two countries willing to increase their bilateral trade through lower exchange rate volatility might undertake additional steps to foster integration (such as lowering regulatory barriers, harmonizing standards of production, and so on). To the extent that these steps cannot be measured in the data, simple OLS estimates will tend to produce a bias.

Fourth, there is significant measurement error in official statistics on nominal exchange rates, and hence in the corresponding measures of variability.[8]

In this paper, I argue that partial corrections of the different biases can lead to misleading answers, and that all biases should be tackled simultaneously. I hence propose an approach to estimation that simultaneously addresses all of these problems.

In a nutshell, my approach deals with the problems generated by heteroskedsasticity and zero-trade observations by estimating the trade-volatility relation in levels, instead of logarithms, as is usually done. More specifically, I use a pseudo-maximum likelihood (PML) technique whose efficiency and robustness in the context of gravity equations has been established by Santos Silva and Tenreyro (in press). To deal with the endogeneity and the measurement error of exchange rate variability I then develop an instrumental-variable (IV) version of the PML estimator.

The idea behind the IV is as follows. For a variety of reasons (which I review below) many countries find it useful to peg their currency to that of a large, and stable "anchor" country (e.g.,

[8] See the discussion on reporting errors by Reinhart and Rogoff (2004).

the US, France). Two countries that have chosen to peg to the same anchor will therefore experience low bilateral exchange rate variability. I turn this observation into an identification strategy by first estimating the probability that two countries are pegged to the same anchor, and then using this probability as an instrument for their bilateral exchange rate volatility. Crucially, I estimate this "propensity to share a common anchor" by using exclusively information on the relationship between the anchor country and each individual "client" country, so that my instrument only captures reasons for pegging to the anchor country other than the desire to increase bilateral trade among the two clients. In Section 3.2 I elaborate further on this point.

Using a broad sample of countries from 1970 to 1997, and after accounting for all sources of bias, the analysis leads to the conclusion that exchange rate variability has no significant impact on trade. The absence of any significant effect goes against the view that stabilization of exchange rates is necessary to foster international trade. As later explained, this result can be rationalized by the fact that exchange rate fluctuations not only create uncertainty or risks, which tend to discourage trade across borders, but they also create profitable opportunities. This finding might also suggest that the availability of forward contracts, currency options, and other alternatives for risk diversification provide sufficient hedging to reduce the potential drawbacks of exchange rate variability on trade. The absence of a significant effect is also consistent with the model proposed by Bacchetta and van Wincoop (2001), who show that in a general equilibrium context, exchange rate stability may have no impact on trade.

The remainder of the paper is organized as follows. Section 2 discusses in further detail the problems raised by log-linearization in the presence of heterogeneity, the exclusion of zeroes, and the endogeneity of the regressors. It then presents the PML-IV method to address the various econometric problems. Section 3 studies the effect of exchange rate variability on trade, using different methodologies. Section 4 contains concluding remarks.

2. Estimation issues

2.1. Sources of bias

As mentioned in the Introduction, there are various potential sources of bias in standard estimations of the effect of nominal exchange rate variability. The first one comes from log-linearizing the gravity equation, given the heteroskedastic nature of trade data. (In fact, any non-linear transformation of the dependent variable in the presence of heteroskedasticity will generally lead to inconsistent estimators.) It may appear that one could simply assume in Eq. (2) that $E\ln(\varepsilon_{ij})=0$, as has been implicitly done in previous studies. This, however, would still not solve the problem if $\ln(\varepsilon_{ij})$ is heteroskedatic.[9] To see why, note that, ultimately, we are interested in the change in the expected value of bilateral exports, $E(T_{ij})$, due to changes in volatility, that is, $\frac{\partial E(T_{ij})}{\partial \delta_{ij}}$. If the variance of $\ln(\varepsilon_{ij})$ depends on the regressors x_{ij}, then, by Jensen's inequality, the expected value of ε_{ij}, $E(\varepsilon_{ij}|x_{ij})=E(\exp(\ln \varepsilon_{ij})|x_{ij})$ will in general be a function of the regressors. The semi-elasticity of trade flows with respect to variability will then be given by:

$$\frac{\partial E(T_{ij})}{\partial \delta_{ij}}\frac{1}{E(T_{ij})}=\alpha_4+\frac{\partial E(\varepsilon_{ij}|x_{ij})}{\partial \delta_{ij}}\frac{1}{E(T_{ij})},$$

[9] This is indeed the case in bilateral trade regressions: The null hypothesis of homoskedasticity is generally rejected.

which is different from α_4. So, while OLS consistently estimates α_4 in this case, the estimated coefficient will be a biased estimate of the true semi-elasticity of exports with respect to volatility. The extent of the bias is given by $\frac{\partial E(\varepsilon_{ij}|x_{ij})}{\partial \delta_{ij}} \frac{1}{E(T_{ij})}$.

Hence, even if $E\ln(\varepsilon_{ij}|x_{ij})=0$, when $\ln(\varepsilon_{ij})$ is heteroskedastic we cannot retrieve the true elasticity of expected exports with respect to volatility using OLS, unless we know the distribution of ε_{ij}.

The second source of bias stems from the existence of observations with zero values for bilateral exports. While these zero-valued observations pose no problem for the estimation of gravity equations in their multiplicative form, they create an additional problem for the use of the log-linear form of the gravity equation. Several methods have been developed to deal with this problem (see Frankel, 1997 for a description of the various procedures). The approach followed by most empirical studies is simply to drop the pairs with zero exports from the data set and estimate the log-linear form by OLS. This truncation makes the OLS estimator of the slope parameters inconsistent, even in the absence of heteroskedasticity.[10]

The third source of bias relates to the potential endogeneity of exchange rate variability. The underlying assumption in most studies is that exchange rate regimes, and, therefore, the implied exchange rate variability, are randomly assigned among countries.[11] In practice, however, unmeasured characteristics might create spurious links between exchange rate variability and bilateral exports. Two countries willing to lower their exchange rate volatility might also be prone to foster integration and trade through other channels, for example, by reducing or eliminating regulatory barriers or by encouraging the harmonization of product standards to enhance competition and exchange. These unmeasured characteristics might lead to negative biases in simple estimations of the gravity equation. The bias may also go in the other direction, as in the model by Barro and Tenreyro (2006). In this model, higher levels of monopoly distortions imply higher markups, which tend to deter trade. At the same time, higher markups lead to higher inflation rates under discretion and therefore increase the need for external commitments (such as currency boards, currency unions, or strong pegs) in order to reduce inflation. This mechanism may, therefore, lead to a positive correlation between exchange rate variability and trade.[12]

[10] My econometric approach implicitly assumes that the determinants of the volume of trade coincide with the determinants of whether a country trades in the first place. An alternative approach is the one followed by Hallak (2006) and Helpman et al. (2004), who use a two-part estimation procedure, with a fixed-cost equation determining the cut-off point above which a country exports, and a standard gravity equation for the volume of trade conditional on trade being positive. Their results, however, rely heavily on both normality and homoskedasticity assumptions, the latter being a particular concern of this paper; a natural topic for further research is to develop and implement an estimator of the two-part model that, like the PPML developed here, is robust to distributional assumptions.

[11] One exception is Frankel and Wei (1993), who use the variability in relative quantities of money as an instrument for nominal exchange rate volatility. One objection to this IV is that movements in money demand and supply are driven by factors that are also likely to affect trade flows directly. A second exception is Broda and Romalis (2003), who estimate the effect of exchange rate variability on the composition of trade and then back out the effect of exchange rate variability on total trade relying in two assumptions. First, exchange rate variability is exogenous to the composition of trade flows and second, volatility does not affect homogeneous-goods trade. While ingenious, the two assumptions seem potentially debatable. These studies are based in the log-specification, and hence also suffer from the heteroskedasticity biases discussed before.

[12] Tenreyro and Barro (2002) and Alesina et al. (2002) use a "triangular" IV similar in spirit to the one in this paper to assess the trade effect of currency unions (as opposed to the more general effect of exchange rate variability, which is the focus here). It is clear from the results of this paper that the findings from currency unions do not generalize to other regimes with low variability.

A fourth potential source of bias is measurement error. As Reinhart and Rogoff (2004) demonstrate, official statistics on exchange rates are particularly contaminated by reporting errors.[13] And, therefore, so is the measure of variability used in empirical studies. In general, measurement error will lead to inconsistency of the estimators, which is yet an additional reason to prefer the use of IV. However, as it will soon be argued, the IV should be applied to the multiplicative form of the gravity equation, since the logarithmic version can lead to further biases.

2.2. Correcting the biases

2.2.1. The PML-IV methodology

To develop the PML-IV methodology, I build on Santos Silva and Tenreyro (in press), who propose a Poisson PML (PPML) estimator that allows for consistent estimation of the conditional expectation function. To simplify notation, I write the gravity equation throughout the paper in its exponential form:[14]

$$T_{ij} = \exp(x_{ij}\beta) + \xi_{ij} \tag{3}$$

where the vector x_{ij} includes (the log of) the countries' GDPs, (the log of) geographical distance, and a set of dummy variables indicating whether the countries share a common border, language, and colonial history. x_{ij} also includes the term δ_{ij}, to reflect the impact of exchange rate variability. To account for multilateral resistance, x_{ij} includes importer- and exporter-specific effects.

In the absence of endogeneity, that is, if $E(\xi_{ij}|x)=0$, the PPML estimator is defined by

$$\tilde{\beta} = \arg\max_{b} \sum_{i,j}^{n} \{T_{ij} \cdot (x_{ij}b) - \exp(x_{ij}b)\},$$

which is equivalent to solving the following set of first-order conditions:

$$\sum_{i,j}^{n} [T_{ij} - \exp(x_{ij}\tilde{\beta})]x_{ij} = 0. \tag{4}$$

The form of (4) makes clear that all that is needed for this estimator to be consistent is for the conditional mean to be correctly specified, that is, $E[T_{ij}|x_{ij}]=\exp(x_{ij}\beta)$. Note that, terminology aside, this is simply a Generalized Method of Moments (GMM) estimator that solves the moment conditions in Eq. (4).[15]

[13] Reinhart and Rogoff (2004) find big disparities between what countries report (basically the exchange rate regime of the country) and what they actually do.

[14] Note that whether the error term enters additively or multiplicatively is irrelevant, since both representations are observationally equivalent. For further discussion on this, see Santos Silva and Tenreyro (in press) and the references therein. The subscripts for time have been omitted for simplicity.

[15] An alternative would be to use a simple non-linear least square estimator (NLS). The NLS estimator of β is defined by

$$\hat{\beta} = \arg\min_{b} \sum_{i,j}^{n} [T_{ij} - \exp(x_{ij}b)]^2,$$

which implies the following set of first order conditions:

$$\sum_{i,j}^{n} [T_{ij} - \exp(x_{ij}\hat{\beta})]x_{ij}\exp(x_{ij}\hat{\beta}) = 0.$$

These equations give more weight to observations where $\exp(x_i\hat{\beta})$ is large. Note, however, that these are generally also the observations with larger variance, which implies that NLS gives more weight to noisier observations. Thus, this estimator may be very inefficient, depending heavily on a small number of observations. Santos Silva and Tenreyro (in press) perform a series of Monte Carlo experiments in gravity equations, which show that the PML approach is significantly more efficient than NLS in trade data models.

Turning now to the IV estimation, suppose that one or more of the regressors are no longer exogenous, that is, $E(\xi_{ij}|x_{ij})\neq 0$. If z_{ij} is a set of instruments such that $E(\xi_{ij}|z_{ij})=0$, the consistent PPML estimator will solve the following moment conditions:

$$\sum_{i,j}^{n} [T_{ij}-\exp(x_{ij}\bar{\beta})]z_{ij} = 0. \tag{5}$$

Note that this moment (or orthogonality) condition has the same form as that stated in Eq. (4), and the condition $E(\xi_{ij}|z_{ij})=0$ ensures the consistency of the estimator.[16]

It is important to point out that an IV that is appropriate for the equation in levels is not necessarily appropriate for the log specification. To see this, observe that Eq. (3) can be written as $T_{ij}=\exp(x_{ij}\beta)(1+u_{ij})$, where $u_{ij}=\xi_{ij}/\exp(x_{ij}\beta)$. Assuming that T_{ij} is strictly positive, the log-linear version will be given by $\ln T_{ij}=x_{ij}\beta+\eta_{ij}$, with $\eta_{ij}=\ln(1+u_{ij})$. If ξ_{ij} in (3) is heteroskedastic, z_{ij} will generally fail to satisfy the condition $E[\eta_{ij}|z_{ij}]=0$, and hence IV estimates in the log form will generally be inconsistent.[17] Needless to repeat, the requirement that T_{ij} be strictly positive already conflicts with the facts. Hence, in the presence of heteroskedasticity and/or zero-valued bilateral exports, the IV approach has to be applied to the multiplicative version of the gravity equation for it to produce a consistent estimator, which makes a strong case for the use of the PPML-IV estimator.

2.2.2. The propensity to anchor the currency as instrument

Alesina and Barro (2002) provide a formal model for the anchor–client relationship in the context of the currency-union decision, which can be generalized to the choice of nominal anchors. The model shows that countries with lack of internal discipline for monetary policy stand to gain more from pegging their currencies, provided that the anchor country is able to commit to sound monetary policy. This commitment is best protected when the anchor is large and the client is small (otherwise, the anchor may find it advantageous to change the conduct of monetary policy). In addition, the model shows that, under reasonable assumptions, client countries benefit more from choosing an anchor with which they would naturally trade more, that is, an anchor with which trading costs–other than the ones associated to high exchange rate variability–are small. These features of the relation between clients and anchors are used to guide the instrumentation.

To construct the instrument, I use a logit analysis for all country pairings from 1970 to 1997 with five potential anchors that fit the theoretical characterization of Alesina and Barro (2002) and whose currencies have served as "reference" for other countries, according to Reinhart and Rogoff (2004) classification. Two important characteristics here are country size (GDP) and a record of low and stable inflation. The group of anchors in my analysis includes France, Germany, South Africa, the United Kingdom, and the United States.[18,19] I

[16] See Windmeijer and Santos Silva (1997) for further discussion.

[17] In general, $E[\eta_{ij}|z_{ij}] = E\left[\ln\left(1+\frac{\xi_{ij}}{\exp(x_{ij}\beta)}\right)|z_{ij}\right]$ is different from zero (and, it typically will be a function of the regressors, x_{ij}). If ξ_{ij} is heteroskedastic, that is, if its variance is a function of the regressors x_i, since the expected value of the non-linear transformation $\ln\left(1+\frac{\xi_{ij}}{\exp(x_{ij}\beta)}\right)$ depends on higher-order moments of the distribution of ξ_{ij}, then, $E\left[\ln\left(1+\frac{\xi_{ij}}{\exp(x_{ij}\beta)}\right)|z_{ij}\right]$ generally will be a function of x_{ij}, violating the condition for consistency.

[18] The Australian dollar has played a reference role for some of the Pacific islands, but the islands are not included in this study; the same note goes for the Indian rupee, which has served as an anchor for Bhutan, which is not in the sample. See Table A1 in the appendix for a list of the countries included in this study.

[19] Note also that in the first year of the analysis, the anchors were themselves pegs, following the gold standard. Still then, one can identify, following Reinhart and Rogoff (2004), what countries were serving as anchors for the rest. To give an example, the ex-French colonies in Africa are classified by Reinhart and Rogoff as tracking the French franc, rather than independently following some or all of the other anchors. As a robustness check, I repeated the exercises eliminating the first years of the sample (1970–1973) and the main findings remained unchanged.

consider effectively anchored currencies those characterized by the following regimes in Reinhart and Rogoff (2004)'s classification: no-legal-tender (including currency unions), currency boards, pegs, and bands. By exclusion, freely floating, managed floats, moving bands, crawling bands, and crawling pegs are not considered nominally anchored, since they allow for significant departures from initial nominal parities (Table A5 in the appendix). The logit regressions include various measures of distance between clients and anchors (to proxy for trading costs) and the sizes of potential clients and anchors.

To make the methodology more transparent, consider a potential client country i, deciding whether or not to anchor its currency to one of the five reference currencies k ($k=1, 2, \ldots, 5$). The logit regression determines the estimated probability $p(i, k, t)$ that client i anchors its currency to that of anchor k at time t. If two clients, say i and j, anchor their currencies to the same anchor independently, then the joint probability that countries i and j have the same nominal anchor k at time t is given by:

$$P^k(i,j,t) = p(i,k,t) \cdot p(j,k,t).$$

The probability $P^k(i, j, t)$ will be high if anchor k is attractive for both countries. The joint probability that at time t, countries i and j use the same anchor (among the five candidates considered in this analysis) is given by the sum of the joint probabilities over the support of potential anchors:

$$P(i,j,t) = \sum_{k=1}^{5} P^k(i,j,t) = \sum_{k=1}^{5} p(i,k,t) \cdot p(j,k,t). \tag{6}$$

The variable $P(i, j, t)$ can be used as an instrument for exchange rate variability in the regressions of bilateral trade. The key point is that the propensity to share a common anchor exclusively uses information on the relationship between the anchor country and each individual client country, so that the instrument only captures reasons for pegging to the anchor country other than the desire to increase bilateral trade among the two clients.

Bilateral variables involving third countries affect the likelihood that clients i and j share a common reference currency and thereby influence bilateral trade between i and j through that channel. The assumption requires that these factors do not influence the bilateral trade between i and j through other channels.

A question one might ask is to what extent the bilateral variables between each client and the third anchor-countries convey new information beyond the bilateral variables between two potential clients. More concretely, consider whether the joint probability of pegging to a common anchor's currency, $P(i, j, t)$, adds information, given that the regressions control separately for the bilateral characteristics of the two clients, i and j. The key point is that the bilateral relations are not transitive. As a first example, the geographical distance from client i to anchor k and that from client j to anchor k do not pin down the distance between i and j. This distance depends on the location of the countries. Similarly, because the language variable recognizes that countries can speak more than one main language, the relation is again non-transitive. For example, if anchor k speaks only French and country i speaks English and French, k and i speak the same language. If another country, j, speaks only English, it does not speak the same language as k. Nevertheless, i and j speak the same language.

3. The effect of variability on trade

This section presents the estimated impact of exchange rate variability using different methods. The analysis considers 87 countries, which are listed in Table A1 in the appendix.[20] The regressions use annual data from 1970 to 1997 for all pairs of countries. Data on bilateral exports come from Feenstra et al. (1997). Data on GDP come from the World Bank's World Development Indicators (2002).[21] Information on geographical area, geographical location, and dummies indicating contiguity, common language, colonial ties, and access to water come from the Central Intelligence Agency's World Factbook (2002). Bilateral distance is computed using the great circle distance algorithm provided by Gray (2001). Finally, information on free-trade agreements comes from Frankel (1997), complemented with data from the World Trade Organization. Table A2 in the appendix presents the free-trade agreements considered in the study. Data on monthly exchange rates come from the IMF's International Financial Statistics (2003), provided by Haver Analytics. Exchange rate variability between countries i and j in year t, denoted by δ_{ijt}, is measured as the standard deviation of the first difference of (the logarithm of) the monthly exchange rate between the two countries, $e_{ijt,m}$:

$$\delta_{ijt} = \text{Std. dev.}[\ln(e_{ijt,m}) - \ln(e_{ijt,m-1})], \quad m = 1 \ldots 12.$$

Table A3 in the appendix provides a description of the variables and displays the summary statistics. The first two columns show, respectively, the means and standard deviations for all country-pairs. The third and fourth columns present the means and deviations for country-pairs with positive bilateral flows.

3.1. Linear vs. non-linear estimation

Table 1 presents the benchmark estimation outcomes using OLS and PPML. The first two columns report OLS estimates using the logarithm of trade as the dependent variable. The regression in the first column controls for importer and exporter specific effects; the regression in the second column allows for time-varying importer and exporter effects, as suggested in Anderson and van Wincoop (2004). As noted before, log-linear OLS regressions leave out pairs of countries with zero bilateral exports (only 139,313 country pairs, or 66% of the sample, exhibit positive export flows). The third and fourth columns report the PPML estimates restricting the sample to positive-export pairs, in order to compare the results with those obtained using OLS (the two columns differ in that the fourth controls for time-varying importer and exporter effects). Finally, the last two columns show the PPML results for the whole sample.

A few observations regarding the estimates of the coefficients of the control variables are in order. First, PPML-estimated coefficients are remarkably similar using both the whole sample and the positive-export subsample. However, most coefficients differ–often significantly–from those generated by OLS. This suggests that, in this case, heteroskedasticity can distort results in a material way, whereas truncation, as long as the model is estimated non-linearly, leads to no significant bias. OLS significantly exaggerates the roles of geographical proximity and

[20] The sample hence consists of 209,496 (=87 × 86 × 28) year-pair observations.

[21] Both exports and GDP are expressed in current U.S. dollars.

Table 1
Exchange rate volatility and exports

	Sample: exports>0				Sample: all country-pairs	
	Dependent variable					
	Log of exports		Exports		Exports	
	OLS		PML		PML	
Exchange rate variability	−0.358**	0.431	−0.572**	−1.780	−0.589**	−1.863
	(0.072)	(0.433)	(0.191)	(1.344)	(0.196)	(1.358)
Log of distance	−1.216**	−1.225**	−0.799**	−0.809**	−0.796**	−0.806**
	(0.035)	(0.008)	(0.053)	(0.054)	(0.052)	(0.053)
Contiguity dummy	0.371*	0.363**	0.333**	0.330**	0.332**	0.330**
	(0.160)	(0.033)	(0.116)	(0.112)	(0.116)	(0.112)
Common-language dummy	0.264**	0.282**	0.347**	0.316**	0.342**	0.309**
	(0.079)	(0.019)	(0.111)	(0.109)	(0.113)	(0.111)
Colonial-tie dummy	0.685**	0.693**	0.102	0.134	0.112	0.144
	(0.087)	(0.022)	(0.164)	(0.159)	(0.169)	(0.163)
Free-trade agreement dummy	−0.609**	−0.608**	0.365**	0.276**	0.362**	0.272**
	(0.124)	(0.027)	(0.078)	(0.070)	(0.079)	(0.071)
Log of importer's GDP	0.738**		0.655**		0.659**	
	(0.029)		(0.039)		(0.041)	
Log of exporter's GDP	0.749**		0.716**		0.724**	
	(0.035)		(0.050)		(0.053)	
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer–exporter fixed effects	Yes	na	Yes	na	Yes	na
Time-varying importer–exporter effects	No	Yes	No	Yes	No	Yes
Observations	139,313	139,313	139,313	139,313	209,496	209,496
Adj. R-squared	0.76	0.40	139,313	139,313	209,496	209,496

The equations use annual data from 1970 to 1997 and allow for clustering of the error terms over time for country pairs. In OLS regressions the gravity equation is estimated in its logarithmic form. In PML the gravity equation is estimated in its multiplicative form. Results for the restricted sample (with positive exports) and the whole sample are reported. Clustered standard errors in parentheses. *Significant at 5%; **significant at 1%; na (not applicable).

colonial links: the distance-elasticity under PPML is about two thirds of that estimated under OLS and the common-colony dummy, while highly significant under OLS, is insignificant under PPML. Also, and against intuition, OLS estimates suggest that free-trade agreements are negatively related to trade.[22] In contrast, PPML indicates a significant and positive relationship: Trade between countries that share a free-trade agreement is, on average, between 20% and 30% larger than trade between countries without a free-trade agreement. Language and contiguity are statistically and economically significant under both estimation procedures. Controlling for time-varying importer and exporter effects does not significantly affect the coefficients on the gravity controls, however, as we mention later, it has an impact on the effect of exchange rate variability.

Turning to the main focus of this paper, the effect of exchange rate variability appears to be more negative under PPML than under OLS. Both under OLS and PPML, the coefficients are significantly different from zero when controlling for importer and exporter fixed effects. Eq. (3)

[22] This is not an unusual result in log-linearized regressions. For example, Frankel (1997) finds that over many years the European community has had a significantly negative effect on the bilateral trade flows of its members (see Table 6.4, p. 136, and Table 6.5a, p. 141 in Frankel, 1997).

indicates that, absent endogeneity concerns, the elasticity of (expected) trade with respect to δ_{ij} will be given by:

$$\frac{\partial E(T_{ijt}|x_{ijt})}{\partial \delta_{ijt}} \cdot \frac{\delta_{ijt}}{T_{ijt}} = \hat{\alpha}_{\delta}\delta_{ijt}, \tag{7}$$

where $\hat{\alpha}_{\delta}$ is the estimated coefficient on the regressor on δ_{ijt}. The values for $\hat{\alpha}_{\delta}$ are -0.36 (OLS), -0.57 (PPML on the positive-trade sample), and -0.59 (PPML on the whole sample) controlling for importer and exporter effects. At the mean value of δ_{ijt} (which is approximately 0.05), OLS generates an elasticity of -0.02, and PPML an elasticity of -0.03. To illustrate the economic significance (or insignificance) of these numbers, the OLS estimate implies that, as a result of an increase in δ from its mean value to one standard deviation above the mean $(0.05+0.10=0.15)$, bilateral trade should decrease by 4% $(=-0.02\times 2\times 100\%)$. PPML, instead, predicts a decrease of 6%. In terms of standard deviations, these estimates indicate that a 1-standard deviation increase in exchange rate volatility from its mean value leads to about 1/10th through 1/9th of a standard-deviation decrease in bilateral trade from its mean value under OLS and Poisson, respectively.

Allowing for time-varying importer and exporter effects renders the estimates statistically insignificant both under OLS and PPML. The point estimate of α_{δ} turns out to be positive under OLS and negative under PPML.[23]

For comparability with the IV results reported in the next section, Table 2 reports the same regressions excluding anchor countries. The only noticeable change is that, under OLS, the coefficient on the free-trade agreement dummy becomes insignificant. The coefficient on exchange rate variability is, as before, quantitatively small or statistically insignificant. In particular, under PPML using the whole sample it is always statistically insignificant, regardless of the inclusion of time-varying fixed effects.

3.2. IV estimation

In order to compute the propensity to share a common anchor, I first use logit regressions to calculate the probability that a potential client anchors its currency to one of the main reference currencies. The logit regressions are shown in Table A4 of the appendix. I present a set of different specifications. The final computation makes use only of the regression presented in the last column which excludes statistically insignificant terms. The final IV results, however, are not quantitatively sensitive to their inclusion.

The probability of anchoring the currency to one of the main anchors increases when the client is closer to the anchor, and when they share a common colonial past. Also, the propensity to anchor the currency increases with the size of the anchor, among the five considered, where size is measured by real GDP per capita and geographical area. The population of the anchor does not seem relevant, although it is likely that this insignificance is due to the high correlation between population and geographical area. Finally, the larger the difference in size (as gauged by per capita GDP and population) between anchor and client, the larger the propensity to anchor the currency. In other words, relative size seems to matter (although the difference in areas is virtually irrelevant). Note also that free-trade agreements, common

[23] To implement the PPML with time-varying country effects I resort to partitioned regressions.

Table 2
Exchange rate volatility and exports

	Sample: exports>0				Sample: all country-pairs	
	Dependent variable					
	Log of exports		Exports		Exports	
	OLS		PML		PML	
Exchange rate variability	−0.303** (0.078)	1.227 (0.831)	−0.388* (0.197)	−0.331 (1.538)	−0.398 (0.233)	−0.184 (1.581)
Log of distance	−1.262** (0.038)	−1.262** (0.037)	−0.833** (0.064)	−0.834** (0.064)	−0.830** 0.065)	−0.832** (0.065)
Contiguity dummy	0.603** (0.171)	0.593** (0.170)	0.530* (0.219)	0.521* (0.207)	0.547* (0.224)	0.539* (0.211)
Common-language dummy	0.243** (0.083)	0.244** (0.082)	0.101 (0.145)	0.073 (0.139)	0.082 (0.150)	0.051 (0.142)
Colonial-tie dummy	0.616** (0.092)	0.617** (0.091)	−0.027 (0.197)	0.008 (0.192)	0.018 (0.202)	0.051 (0.196)
Free-trade agreement dummy	−0.260 (0.143)	−0.151 (0.148)	0.364** (0.101)	0.350** (0.099)	0.350** (0.102)	0.336** (0.100)
Log of importer's GDP	0.742** (0.031)		0.611** (0.054)		0.615** (0.057)	
Log of exporter's GDP	0.757** (0.038)		0.810** (0.070)		0.820** (0.077)	
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer–exporter fixed effects	Yes	na	Yes	na	Yes	na
Time-varying importer–exporter effects	No	Yes	No	Yes	No	Yes
Observations	117,554	117,554	117,554	117,554	185,976	185,976
R-squared	0.71	0.40				

Excluding anchor countries.

The equations use annual data from 1970 to 1997 and allow for clustering of the error terms over time for country pairs. In OLS regressions the gravity equation is estimated in its logarithmic form. In PML the gravity equation is estimated in its multiplicative form. Results for the restricted sample (with positive exports) and the whole sample are reported. Clustered standard errors in parentheses. *Significant at 5%; **significant at 1%; na (not applicable).

language, contiguity, and access to water seem not to matter for the decision to anchor a country's currency.

From the estimated probabilities in the logit regressions, I use the formula in Eq. (6) to compute for each pair of countries the likelihood that they share a common anchor.

Table 3 presents the results of the IV estimation, using both the logarithmic and the multiplicative specifications of the gravity equation. Panel A displays the outcomes from the first-stage regressions, both for the positive-export sample and for the whole sample. The regressions control for importer and exporter fixed effects (first and third columns) and for time-varying importer and exporter effects (second and fourth columns). The instrument exhibits a strong explanatory power. The propensity variable passes the F-test of excluded instruments and is significantly above the cut-offs specified by Staiger and Stock (1997). To make a quantitative assessment one can ask what happens when the likelihood that two countries anchor their currencies to a common anchor changes from 0 to 1. In such case, exchange rate variability decreases, on average, by around 80%.[24]

The first and second columns in Panel B display the IV estimates of the impact of exchange rate variability on trade in the log-specification, controlling, respectively, for importer and exporter fixed effects (first column) and for time-varying importer and exporter effects (second column). The third and fourth columns show the corresponding effects in the multiplicative specification for the positive-export subsample and the last two columns show the results for the whole sample.

The key message from Panel B in Table 3 is that exchange rate variability does not have a statistically significant impact on trade. Interestingly, the log-specification tends to generate highly unstable estimates, being particularly sensitive to the inclusion of time-varying importer and exporter effects: the point estimate is positive when controlling for exporter and importer specific effects and negative when allowing for time-varying specific effects. Under PPML, the point estimates are systematically positive, albeit, as before, the estimates are statistically insignificant. Note that the point estimates (as well as the standard deviations) are considerably bigger in the IV specification, but, still, in terms of economic impact, the point estimates imply a relatively small effect (a 1-standard deviation increase in volatility from its mean value leads to less than a fifth of a standard-deviation increase in trade flows from its mean level).[25]

3.2.1. Comparison of the estimates

Under the assumption that δ_{ij} is exogenous, the PPML elasticity is systematically more negative than that obtained by OLS in the log-linear form. Even under the exogeneity assumption,

[24] Note, though, that this is an out-of-sample prediction, since the values of the propensities are strictly between 0 and 1; the purpose of this calculation is simply to illustrate that the partial relationship between the propensity and the exchange rate is not only statistically, but also quantitatively strong. The decrease in variability is computed at the average value $\overline{\delta}=0.05$ using the following approximation:

$$\frac{\delta^{P=0}-\delta^{P=1}}{\delta^{P=0}} \cdot 100\% = \frac{0.05-\hat{\gamma}}{0.05}$$

where $\hat{\gamma}$ is the estimated coefficient in Table 3, Panel A.

[25] The remaining variables have the expected signs, except for the free-trade agreement dummy, which, as before, has a negative effect in the logarithmic specification (though statistically insignificant) and a significantly positive effect in the specification in levels.

Table 3
Exchange rate volatility and trade

Panel A. First stage regressions

	Sample: exports > 0		Sample: all country-pairs	
	Dependent variable: exchange rate variability			
Common-anchor probability	−0.082** (0.009)	−0.073** (0.007)	−0.092** (0.007)	−0.090** (0.008)
Log of distance	0.004** (0.000)	0.003** (0.000)	0.003** (0.000)	0.003** (0.000)
Contiguity dummy	0.005** (0.001)	0.002* (0.001)	0.000 (0.001)	0.000 (0.001)
Common-language dummy	−0.001 (0.001)	−0.002** (0.000)	−0.002** (0.000)	−0.001** (0.000)
Colonial-tie dummy	0.002** (0.001)	0.001* (0.001)	0.000 (0.001)	0.000 (0.001)
Log of importer's GDP	−0.032** (0.001)		−0.032** (0.001)	
Log of exporter's GDP	−0.031** (0.001)		−0.032** (0.001)	
Year effects	Yes	Yes	Yes	Yes
Importer–exporter fixed effects	Yes	na	Yes	na
Time-varying importer–exporter effects	No	Yes	No	Yes
Observations	117,554		185,976	185,976
Adj. *R*-squared	0.30	0.29	0.28	0.28

Panel B. Second stage regressions

	Sample: exports > 0				Sample: all country-pairs	
	Dependent variable					
	Log of exports		Exports		Exports	
	IV		PML-IV		PML-IV	
Exchange rate variability	1.630 (11.223)	−16.281 (13.168)	9.902 (17.392)	20.702 (17.836)	9.245 (17.680)	15.318 (14.173)
Log of distance	−1.269** (0.057)	−1.200** (0.060)	−0.875** (0.102)	−0.915** (0.101)	−0.869** (0.104)	−0.889** (0.088)
Contiguity dummy	0.595** (0.176)	0.621** (0.171)	0.483* (0.227)	0.477* (0.212)	0.503* (0.232)	0.529* (0.211)
Common-language dummy	0.245** (0.084)	0.209* (0.086)	0.114 (0.153)	0.116 (0.152)	0.093 (0.157)	0.082 (0.151)
Colonial-tie dummy	0.619** (0.092)	0.571** (0.094)	−0.024 (0.197)	0.030 (0.192)	0.021 (0.201)	0.088 (0.196)
Free-trade agreement dummy	−0.257 (0.143)	−0.164 (0.149)	0.373** (0.099)	0.359** (0.098)	0.358** (0.100)	0.344** (0.099)
Log of importer's GDP	0.803* (0.353)		0.924 (0.564)		0.908 (0.575)	
Log of exporter's GDP	0.816* (0.342)		1.110 (0.527)		1.105* (0.534)	
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Importer–exporter fixed effects	Yes	na	Yes	na	Yes	na
Time-varying importer–exporter effects	No	Yes	No	Yes	No	Yes
Observations	117,554	117,554	117,554	117,554	185,976	185,976

The equations use annual data from 1970 to 1997 and allow for clustering of error terms over time for country pairs. The gravity equation estimated in its logarithmic form is reported in the IV column and in its multiplicative form in the PML-IV columns. Clustered standard errors in parentheses. *Significant at 5%; **significant at 1%; na (not applicable).

Log-linear IV estimation.

it is not clear a priori what the direction of the bias should be, as it depends on the complex relationships among all regressors and the distribution of the error terms. To better understand how the bias can affect the estimate, consider the following simple bivariate model:

$$y = x^{\gamma}\varepsilon \tag{8}$$

where (i) ε is log-normal, with (ii) conditional mean $E(\varepsilon|x)=1$, and (iii) conditional variance $V(\varepsilon|x)=\phi(x)$. Assuming $y>0$, the logarithmic formulation is given by:

$$\ln y = \gamma \ln x + \ln\varepsilon \tag{9}$$

and the OLS coefficient is given by $\hat{\gamma} = \gamma + \frac{\sum \ln x \cdot \ln\varepsilon}{\sum \ln^2 x}$. By the log-normality assumption, $E(\ln\varepsilon|x) = -\frac{1}{2}\ln[1+\phi(x)]$, that is, the expected value of the log-linearized error term depends on the regressors, and hence the OLS coefficient will be generally biased. One may conjecture that higher exchange rate variability will tend to increase the variance of export flows. In this simple model, if y is trade and x is variability, this assumption implies that $\phi'(x)>0$. And this causes OLS to be biased downwards, as is the case in the empirical estimation. However, others may argue as well that if variability indeed harms trade links, higher variability will be associated with less trade, and, potentially, with lower variance, that is, $\phi'(x)<0$. This example illustrates that the bias is the result of numerous factors and, even in this extremely simplified model, its direction is hard to predict. In the more complex multivariate model presented in this paper, the task becomes impossible, as both the underlying distribution of errors and the interrelations among all variables, are unknown.

A main result here is that, under the exogeneity assumption, truncation does not seem to bias the coefficient of exchange rate variability when the relationship is estimated in levels.

The previous discussion neglected the possibility that ε could be correlated with x, for example, because of the omission of relevant characteristics, reverse causality, or measurement error. Table 3 shows that the estimated elasticities, in all cases, are insignificantly different from zero. The point estimates are positive or negative under the log-specification, depending on whether we allow for time-variation in importer and exporter fixed effects, and systematically positive under PPML. The IV-estimator on the log-specification leads to highly unstable estimates, depending crucially on the inclusion of time-varying country effects. The contrast between the IV results under the logarithmic and the multiplicative specification confirms the conjecture that a similar instrument can generate drastically different elasticities depending on whether the estimation is performed in levels or in logs.

As expressed throughout the paper the estimates generated by the PPML-IV method (when controlling for time-varying fixed effects) are invariably superior in the presence of heteroskedasticity and endogeneity. The results of this estimation method point to the absence of any statistically significant causal effect from exchange rate variability to trade. The reason for the lack of a significant effect can be rationalized by the fact that not only exchange rate fluctuations create uncertainty or risks, which tend to discourage risk-averse

[26] See, for example, Varian (1992), and Bachetta and van Wincoop (2001).

agents from trade across borders, but they might also create profitable opportunities. For example, if an exporting firm faces a randomly fluctuating price for its products, given the convexity of the profit function, the average profits with fluctuating price will be higher than the profits at the average price.[26] Higher exchange rate volatility might then lead to a larger volume of trade. This positive effect will tend to counteract the negative effects usually cited in the discussion, leading to no significant effect on net. In addition, the availability of forward contracts, currency options, and other derivatives might provide substantial hedging to reduce the uncertainty associated with exchange rate fluctuations.

4. Concluding remarks

Does exchange rate variability harm trade? This paper takes a long road to say "no." However, the long road is not futile: in the quest for an answer, the process uncovers the problems associated with the techniques typically used in empirical applications of the gravity equation. Moreover, the methodological points raised in the paper and the proposed solution can be extended to other contexts where log-linearizations (or, more generally, non-linear transformations) coupled with heteroskedasticity and/or endogeneity threaten the consistency of simple estimators. Examples include production functions and Mincerian regressions for earnings.

I argue that all potential sources of bias should be tackled simultaneously and that partial corrections can be highly misleading. I hence develop an IV PPML approach that addresses the various potential biases highlighted in this paper.

The instrument I use relies on the fact that many countries find it useful to peg their currency to that of a large, and stable "anchor" country in order to reduce inflation. Hence, two countries that have chosen to peg officially or de facto to the same anchor will tend to experience low bilateral exchange rate variability. This observation motivates the use of the probability that two countries peg their currencies to the same anchor as an instrument for their bilateral exchange rate volatility. Importantly, the propensity to share a common anchor-currency uses information on the relationship between the anchor country and each individual client country so that my instrument only captures reasons for pegging to the anchor country other than the desire to increase bilateral trade between any two clients.

The results show that the probability that a client-country pegs its currency to one of the main anchors increases when the client is closer to the anchor, and when they share a common colonial past. Also, the propensity to anchor the currency increases with the size of the anchor and the difference in size between the anchor and the potential client.

The paper contributes to the international policy debate by showing that exchange rate variability does not harm export flows. The elimination of exchange rate variability alone, hence, should not be expected to create any significant gain in trade in the aftermath of the recent waves towards stronger pegs.

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Appendix A

Table A1
List of countries

Anchor countries		
France	South Africa	US
Germany	UK	
Client countries		
Algeria	Gabon	Nepal
Argentina	Gambia	Netherlands
Australia	Ghana	New Zealand
Austria	Greece	Niger
Belgium	Guatemala	Nigeria
Benin	Guyana	Norway
Bolivia	Haiti	Pakistan
Brazil	Honduras	Panama
Burkina Faso	Hong Kong	Paraguay
Burundi	Hungary	Peru
Cameroon	Iceland	Philippines
Canada	India	Portugal
Central African Republic	Indonesia	Saudi Arabia
Chad	Ireland	Senegal
Chile	Israel	Singapore
China	Italy	Spain
Colombia	Jamaica	Sri Lanka
Congo Democratic Rep.	Japan	Suriname
Congo	Korea	South Sweden
Costa Rica	Madagascar	Switzerland
Cote d'Ivoire	Malawi	Syria
Denmark	Malaysia	Thailand
Dominican Republic	Mali	Togo
Ecuador	Malta	Turkey
Egypt	Mauritania	Uruguay
El Salvador	Mexico	Venezuela
Finland	Morocco	Zambia
		Zimbabwe

Table A2
List of countries in free-trade agreements (1970–1997)

EU	
Austria	1995–
Belgium	1967–
Denmark	1973–
Finland	1995–
France	1967–
Germany	1967–
Greece	1981–
Ireland	1973–

(continued on next page)

Table A2 (*continued*)

EU	
Italy	1967–
Netherlands	1967–
Portugal	1986–
Spain	1986–
Sweden	1995–
United Kingdom	1973–
EFTA (European Free Trade Association)	
Austria	1960–1995
Denmark	1960–1972
Norway	1960–
Portugal	1960–1985
Sweden	1960–1995
Switzerland	1960–
Iceland	1970–
Finland	1986–1995
UK	1960–1972
EEA (European Economic Area)	
Iceland	1994–
Norway	1994–
Austria	1994–
Finland	1994–
Sweden	1994–
EU	1994–
CEFTA (Central Europe Free Trade Area)	
Hungary	1992–
Poland	1992–
NAFTA	
Canada	1989–
Mexico	1994–
US	1989–
Group of three	
Colombia	1995–
Mexico	1995–
Venezuela	1995–
Andean community	
Bolivia	1992–
Colombia	1992–
Ecuador	1992–
Venezuela	1992–
Caricom (Caribbean Community)	
Jamaica	1968–
Dominica	1968–
Guyana	1995–
Suriname	1995–

Table A2 (*continued*)

Mercosur (Mercado Comun del Sur)	
Argentina	1991–
Brazil	1991–
Paraguay	1991–
Uruguay	1991–
Bolivia	1996–
Australia–New Zealand CER	
Australia	1983–
New Zealand	1983–
Customs Union of West African States	
Benin	1994–
Burkina Faso	1994–
Cote d'Ivoire	1994–
Mali	1994–
Niger	1994–
Senegal	1994–
Togo	1994–
Israel/US	
Israel	1985–
US	1985–
Israel/EU	
Israel	1996–
EU	1996–
Israel/EFTA	
Israel	1993–
EFTA	1993–
Israel/Canada	
Israel	1997–
Canada	1997–

Table A3
Summary statistics

	All country-pairs		Positive-export pairs	
	Mean	Standard deviation	Mean	Standard deviation
Exchange rate variability	0.046	0.081	0.084	0.167
Trade	256,129	2,268,339	527,587	3,334,265
Log of distance	8.756	0.757	8.714	0.791
Contiguity dummy	0.028	0.164	0.031	0.174
Common-language dummy	0.209	0.406	0.215	0.411
Colonial-tie dummy	0.151	0.358	0.160	0.367
Free-trade agreement dummy	0.020	0.140	0.029	0.167
Log of GDP per capita	23.468	2.193	23.250	2.036
Probability of common anchor	0.042	0.056	0.037	0.051
Observations	209,496		185,976	

Table A4
Propensity to adopt the currency of main anchors

Dependent variable: common-anchor dummy							
Log of distance	−0.493**	−0.458**	−0.739**	−0.768**	−1.149**	−1.235**	−1.094**
	(0.137)	(0.153)	(0.210)	(0.232)	(0.244)	(0.280)	(0.232)
Contiguity dummy		0.213	−0.974	−0.383	−0.858	−0.567	
		(0.592)	(0.909)	(0.822)	(0.867)	(0.839)	
Common-language dummy			1.960**	0.600	0.577	0.558	
			(0.385)	(0.650)	(0.646)	(0.622)	
Colonial-tie dummy				1.635**	1.877**	1.703**	2.143**
				(0.609)	(0.627)	(0.614)	(0.343)
Free-trade agreement dummy				−0.267	−0.509	−0.179	
				(0.509)	(0.497)	(0.522)	
Log of anchor's GDP per capita					2.186**	1.930**	1.990**
					(0.483)	(0.477)	(0.474)
Log of anchor's GDP population					−1.263*	−1.295*	−1.424*
					(0.596)	(0.589)	(0.612)
Log of anchor's area					0.938**	1.004**	1.019**
					(0.233)	(0.254)	(0.259)
Log of ratio of anchor's GDPpc to client's GDPpc						0.213	0.219
						(0.116)	(0.112)
Log of ratio of anchor's population to client's population						0.205	0.232
						(0.121)	(0.124)
Log of ratio of anchor's area to client's area landlocked-client dummy						−0.104	−0.092
						(0.108)	(0.107)
Observations						−0.130	
						(0.387)	
Pseudo R-squared	0.02	0.13	0.15	0.26	0.27	0.27	0.27

Logit estimation.
The sample consists of country-pairs that include the five candidate anchors: France, Germany, South Africa, United Kingdom, and United States. The equations are for annual data and allow for clustering over time for country pairs. Clustered standard errors in parentheses. *Significant at 5%; **significant at 1%.

Table A5
Anchor–client relations

Indicators: 0, no peg; 1, peg to US dollar; 2, peg to French Franc; 3, peg to Pound Sterling; 4, peg to DM; 5, peg to South African Rand; *other or na

Ind.	Country	Start	End	Ind.	Country	Start	End	Ind.	Country	Start	End	Ind.	Country	Start	End
0	Albania	1970	1998	2	Congo	1970	1998	9	Georgia	1991	1992	0	Iraq	1982	1998
2	Algeria	1970	1971	0	Congo, Dem Rep	1970	1998	0	Georgia	1993	1998	3	Ireland	1970	1978
0	Algeria	1972	1998	1	Costa Rica	1970	1970	1	Germany	1970	1970	0	Ireland	1979	1996
1	Argentina	1970	1970	0	Costa Rica	1971	1974	0	Germany	1971	1971	4	Ireland	1997	1998
0	Argentina	1971	1991	1	Costa Rica	1975	1979	1	Germany	1972	1972	0	Israel	1970	1998
1	Argentina	1992	1998	0	Costa Rica	1980	1998	0	Germany	1973	1998	1	Italy	1970	1972
9	Armenia	1970	1992	2	Cote d'Ivoire	1970	1998	3	Ghana	1970	1970	0	Italy	1973	1996
0	Armenia	1993	1998	0	Croatia	1970	1994	0	Ghana	1971	1998	4	Italy	1997	1998
3	Australia	1970	1971	4	Croatia	1995	1998	1	Greece	1970	1974	3	Jamaica	1970	1972
1	Australia	1972	1981	3	Cyprus	1970	1972	0	Greece	1975	1989	1	Jamaica	1973	1982
0	Australia	1982	1998	0	Cyprus	1973	1992	4	Greece	1990	1998	0	Jamaica	1983	1998
4	Austria	1970	1970	4	Cyprus	1993	1998	3	Grenada	1970	1976	1	Japan	1970	1970
0	Austria	1971	1998	0	Czech	1970	1998	1	Grenada	1977	1998	0	Japan	1971	1971
0	Azerbaijan	1993	1998	4	Denmark	1970	1970	1	Guatemala	1970	1983	1	Japan	1972	1972
0	Belarus	1970	1998	0	Denmark	1971	1998	0	Guatemala	1984	1998	0	Japan	1973	1998
4	Belgium	1970	1998	3	Dominica	1970	1976	0	Guinea	1970	1986	3	Jordan	1970	1971
2	Benin	1970	1998	1	Dominica	1977	1998	1	Guinea	1987	1990	1	Jordan	1972	1974
0	Bolivia	1970	1998	0	Dominican Rep	1970	1998	0	Guinea	1991	1998	*	Jordan	1975	1987
5	Botswana	1970	1976	1	Ecuador	1970	1970	*	Guinea-Bissau	1970	1983	0	Jordan	1988	1995
1	Botswana	1977	1979	0	Ecuador	1971	1973	0	Guinea-Bissau	1984	1997	1	Jordan	1996	1998
0	Botswana	1980	1998	1	Ecuador	1974	1981	2	Guinea-Bissau	1998	1998	*	Kazakstan	1970	1990
0	Brazil	1970	1998	0	Ecuador	1982	1998	3	Guyana	1970	1975	0	Kazakstan	1991	1998
0	Bulgaria	1970	1996	0	Egypt	1970	1991	1	Guyana	1976	1981	3	Kenya	1970	1971
4	Bulgaria	1997	1998	1	Egypt	1992	1998	0	Guyana	1982	1998	1	Kenya	1972	1975
2	Burkina Faso	1970	1998	0	El Salvador	1970	1990	1	Haiti	1970	1984	1	Kenya	1976	1986
1	Burundi	1970	1982	1	El Salvador	1991	1998	0	Haiti	1985	1998	0	Kenya	1987	1998
0	Burundi	1982	1998	0	Eq Guinea	1979	1984	1	Honduras	1970	1984	0	Korea	1970	1974
2	Cameroon	1970	1998	2	Eq Guinea	1985	1998	0	Honduras	1985	1998	1	Korea	1975	1979
0	Canada	1970	1998	0	Estonia	1970	1992	3	Hong Kong	1970	1971	0	Korea	1980	1998
2	Central African R	1970	1998	4	Estonia	1993	1998	0	Hong Kong	1972	1983	1	Kuwait	1970	1974
2	Chad	1970	1998	1	Finland	1970	1972	1	Hong Kong	1984	1998	0	Kuwait	1975	1998
0	Chile	1970	1979	4	Finland	1973	1991	0	Hungary	1970	1998	0	Kyrgyz Rep	1991	1998
1	Chile	1980	1982	0	Finland	1992	1994	0	Iceland	1970	1998	0	Latvia	1991	1994
0	Chile	1983	1998	4	Finland	1995	1998	3	India	1970	1974	1	Latvia	1995	1998
0	China,PR:	1970	1993	1	France	1970	1971	0	India	1975	1991	1	Lebanon	1970	1983
1	China, PR	1993	1998	4	France	1972	1973	1	India	1992	1994	0	Lebanon	1984	1993
0	Colombia	1970	1974	0	France	1974	1986	0	Indonesia	1970	1998	1	Lebanon	1994	1998
1	Colombia	1975	1982	4	France	1987	1998	1	Iran	1970	1976	5	Lesotho	1970	1998
0	Colombia	1983	1984	2	Gabon	1970	1998	0	Iran	1977	1998	1	Liberia	1970	1987
1	Colombia	1985	1993	3	Gambia	1970	1980	3	Iraq	1970	1972	0	Liberia	1988	1998
0	Colombia	1994	1998	0	Gambia	1981	1998	1	Iraq	1973	1981	3	Libya	1970	1971

(continued on next page)

Table A5 (*continued*)

Indicators: 0, no peg; 1, peg to US dollar; 2, peg to French Franc; 3, peg to Pound Sterling; 4, peg to DM; 5, peg to South African Rand; *other or na

Ind.	Country	Start	End	Ind.	Country	Start	End	Ind.	Country	Start	End
0	Libya	1972	1998	0	Netherlands	1971	1983	0	Sri Lanka	1970	1998
1	Lithuania	1995	1998	4	Netherlands	1984	1998	3	St Kitts	1970	1976
4	Luxembourg	1970	1998	3	New Zealand	1970	1971	1	St Kitts	1977	1998
0	Macedonia	1993	1998	1	New Zealand	1972	1972	3	St Lucia	1970	1976
2	Madagascar	1970	1970	0	New Zealand	1973	1998	1	St Lucia	1977	1998
0	Madagascar	1971	1971	1	Nicaragua	1970	1978	1	Suriname	1970	1973
2	Madagascar	1972	1981	0	Nicaragua	1979	1991	0	Suriname	1974	1998
0	Madagascar	1982	1998	1	Nicaragua	1992	1992	5	Swaziland	1970	1998
3	Malawi	1970	1972	0	Nicaragua	1993	1998	1	Sweden	1970	1972
0	Malawi	1973	1994	2	Niger	1970	1998	0	Sweden	1973	1998
1	Malawi	1995	1996	0	Nigeria	1970	1998	1	Switzerland	1970	1972
0	Malawi	1997	1998	1	Norway	1970	1972	0	Switzerland	1973	1998
3	Malaysia	1970	1974	0	Norway	1973	1998	1	Syria	1970	1972
0	Malaysia	1975	1998	0	Pakistan	1970	1971	0	Syria	1973	1998
2	Mali	1970	1998	1	Pakistan	1972	1981	0	Tajikistan	1992	1998
3	Malta	1970	1971	0	Pakistan	1982	1998	3	Tanzania	1970	1970
0	Malta	1972	1998	1	Panama	1970	1998	0	Tanzania	1971	1998
2	Mauritania	1970	1973	1	Paraguay	1970	1980	1	Thailand	1970	1996
0	Mauritania	1974	1998	0	Paraguay	1981	1998	0	Thailand	1997	1998
0	Mauritius	1970	1998	1	Peru	1970	1970	2	Togo	1970	1998
1	Mexico	1970	1975	0	Peru	1971	1999	2	Tunisia	1970	1973
0	Mexico	1976	1977	0	Philippines	1970	1992	0	Tunisia	1974	1998
1	Mexico	1978	1980	1	Philippines	1993	1996	0	Turkey	1970	1998
0	Mexico	1981	1992	0	Philippines	1997	1998	9	Turkmenistan	1970	1992
1	Mexico	1993	1993	0	Poland	1970	1998	0	Turkmenistan	1993	1998
0	Mexico	1994	1998	1	Portugal	1970	1972	0	U.K.	1970	1998
0	Micronesia	1991	1995	0	Portugal	1973	1993	0	U.S.	1970	1998
1	Micronesia	1996	1997	4	Portugal	1994	1998	3	Uganda	1970	1970
0	Micronesia	1998	1998	0	Romania	1970	1998	0	Uganda	1971	1986
0	Moldova	1991	1995	0	Russia	1970	1998	1	Uganda	1987	1988
1	Moldova	1996	1997	1	Saudi Arabia	1970	1998	0	Uganda	1989	1998
0	Moldova	1998	1998	2	Senegal	1970	1998	*	Ukraine	1970	1990
0	Mongolia	1970	1998	3	Singapore	1970	1971	0	Ukraine	1991	1998
2	Morocco	1970	1972	1	Singapore	1972	1972	1	Uruguay	1970	1970
0	Morocco	1973	1998	0	Singapore	1973	1998	0	Uruguay	1971	1998
3	Myanmar	1970	1973	0	Slovak Rep	1993	1998	1	Venezuela	1970	1982
0	Myanmar	1974	1998	0	Slovenia	1991	1998	0	Venezuela	1983	1998
*	Nepal	1970	1977	3	South Africa	1970	1971	3	Zambia	1970	1970
0	Nepal	1978	1993	0	South Africa	1972	1998	0	Zambia	1971	1998
1	Nepal	1994	1994	1	Spain	1970	1973	5	Zimbabwe	1970	1979
0	Nepal	1995	1998	0	Spain	1974	1994	0	Zimbabwe	1980	1999
1	Netherlands	1970	1970	4	Spain	1995	1998				

References

Abrahms, R., 1980. Actual and Potential Trade Flows with Flexible Exchange Rates. Federal Reserve Bank of Kansas City Working Paper No. 80-01.

Alesina, A., Barro, R., 2002. Currency unions. Quarterly Journal of Economics 409–436 (May).

Alesina, A., Barro, R., Tenreyro, S., 2002. Optimal currency areas. In: Gertler, M., Rogoff, K. (Eds.), NBER Macroeconomics Annual.

Anderson, J., 1979. A theoretical foundation for the gravity equation. American Economic Review 69, 106–116.

Anderson, J., van Wincoop, E., 2003. Gravity with gravitas: a solution to the border puzzle. American Economic Review 93, 170–192 (March).

Anderson, J., van Wincoop, E., 2004. Trade costs. Journal of Economic Literature (September).

Bacchetta, P., van Wincoop, E., 2001. Does exchange rate stability increase trade and welfare? American Economic Review 90 (5), 1093–1109.

Barro, R., Tenreyro, S., 2006. Closed and open economy models of business cycles with marked-up and sticky prices. Economic Journal 116 (511), 434–456 (April).

Bergstrand, J., 1985. The gravity equation in international trade: some microeconomic foundations and empirical evidence. Review of Economics and Statistics 69, 474–481.

Broda, C., Romalis, J., 2003. Identifying the relationship between Exchange Rate Volatility and Trade. Mimeo, Federal Reserve Bank of New York, November 2003.

Central Intelligence Agency, World Factbook, 2002. http://www.cia.gov/cia/publications/factbook/.

Côté, A., 1994. Exchange rate volatility and trade: a survey. Bank of Canada Working Paper 94–95.

Davis, D., 1995. Intra-industry trade: a Hecksher-Ohlin-Ricardo approach. Journal of International Economics 39, 201–226.

Deardoff, A., 1998. Determinants of bilateral trade: does gravity work in a neoclassical world? In: Frankel, Jeffrey (Ed.), The Regionalization of the World Economy. University of Chicago Press, Chicago, IL.

De Grauwe, P., Skudelny, F., 2000. The impact of EMU on trade flows. Weltwirtschaftliches Archiv 136, 381–400.

Eaton, J., Kortum, S., 2001. Technology, Geography and Trade. NBER Working Paper No. 6253.

Eichengreen, B., Irwin, D., 1996. The Role of History in Bilateral Trade Flows. NBER Working Paper No. 5565.

Engel, C., Rose, A., 2000. Currency unions and international integration. Journal of Money, Credit and Banking 136, 381–400.

Feenstra, R.C., Lipsey, R.E., Bowen, H.P., 1997. World Trade Flows, 1970–1992, with Production and Tariff Data. NBER Working Paper No. 5910.

Feenstra, R., Markusen, J., Rose, A., 1999. Using the Gravity Equation to Differentiate Among Alternative Theories of Trade. http://www.econ.ucdavis.edu/~feenstra.

Frankel, J., 1997. Regional Trading Blocs in the World Economic System. Institute for International Economics, Washington, DC.

Frankel, J., Rose, A., 2002. An estimate of the effect of currency unions on trade and growth. Quarterly Journal of Economics.

Frankel, J., Wei, S., 1993. Trade Blocs and Currency Blocs. NBER Working Paper No. 4335.

Gray, A., 2001. http://argray.fateback.com/dist/formula.html.

Hallak, J.C., 2006. Product quality and the direction of trade. Journal of International Economics 68 (1), 238–265.

Haveman, J., Hummels, D., 2001. Alternative Hypotheses and the Volume of Trade: The Gravity Equation and the Extent of Specialization. Mimeo, Purdue University.

Helpman, E., Krugman, P., 1985. Market Structure and Foreign Trade. MIT Press, Cambridge, MA.

Helpman, E., Melitz, M., Rubinstein, Y., 2004. Trading Patterns and Trading Volumes. Havard mimeo.

Hooper, P., Kohlhagen, S., 1978. The effect of exchange rate uncertainty on the prices and volume of international trade. Journal of International Economics 8, 483–511.

International Financial Statistics, International Monetary Fund, Haver Analytics, 2003.

Reinhart, C., Rogoff, K., 2004. The modern history of exchange rate arrangements: a reinterpretation. Quarterly Journal of Economics CXIX (1), 1–48 (February).

Rose, A., 2000. One money one market: estimating the effect of common currencies on trade. Economic Policy 15, 7–46.

Rose, A., van Wincoop, E., 2000. National money as a barrier to international trade: the real case for currency union. American Economic Review 386–390.

Santos Silva, J., Tenreyro, S., in press. The log of gravity. Review of Economics and Statistics.

Sekkat, K., 1997. Exchange Rate Variability and EU Trade. Final Report to the Commission of the EU, Brussels.

Staiger, D., Stock, J., 1997. Instrumental variables regression with weak instruments. Econometrica 65, 557–586.

Tenreyro, S., Barro, R., 2002. Economic Effects of Currency Unions. FRB Boston Series, Working Paper No. 02-4 and NBER Working Paper No. 9435.

Thursby, J., Thursby, M., 1987. Bilateral trade flows, the Linder hypothesis, and exchange risk. The Review of Economics and Statistics 69, 488–495.

Varian, H., 1992. Microeconomic Analysis, 3rd ed. W.W. Norton & Company, New York, NY.

Windmeijer, F., Santos Silva, J., 1997. Endogeneity in count data models: an application to demand for health care. Journal of Applied Econometrics 12, 281–294.

The World Bank. World Development Indicators CD-rom, 2002.