

Exchange-Rate Volatility and Trade Once Again: A Semiparametric Approach

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Abstract:

We use a gravity model to analyze the impact of exchange-rate volatility on the volume of bilateral international trade. Semiparametric regression methods are applied to pooled data for over 200 countries. Our results indicate that volatility affects trade negatively although at very high level of volatility the effect diminishes and eventually becomes statistically indistinguishable from zero. Countries apparently find avenues to mitigate the detrimental impact of exchange rate uncertainty when volatility attains very high levels. These results help reconcile the contradictory findings often found in the literature on the impact of exchange-rate uncertainty on trade volume.

Keywords: volatility, international trade, semiparametric regression

JEL Classification: F4, C14

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1. Introduction:

Despite the completion of a great number of studies on the impact of exchange-rate volatility on the volume of international trade, there is still little consensus on how uncertainty in currency values affects trade flows. Theoretical and empirical studies can be cited to support a host of conclusions; that exchange-rate volatility depresses trade, that it induces increases in the level of international trade, or that it has no impact on trade flows. Researches have tried to reconcile these differences by slicing the data in a myriad of ways. In what follows we give an overview of these attempts and then offer our own solution to the reconciliation of the numerous results on the impact of exchange-rate volatility on trade.

Our approach is to use a gravity equation and apply semiparametric regression technique. Using a pooled sample for over 200 countries we find that exchange-rate volatility affects trade negatively with the negative impact strengthening with the level of volatility. However, at a very high level of volatility the negative effect weakens and gradually adjusts to zero. What may explain this behavior? Countries may respond to higher levels of volatility by reducing their volume of trade but after a certain point the countries find avenues to mitigate the harmful impact of exchange-rate uncertainty. For example countries might informally dollarize when exchange-rate volatility attains “unbearably” high levels, thereby insulating the country from the harmful impacts of very high volatility. Section 2 provides background and a literature review, section 3 explains the methodology used and section 4 describes the data. Results are analyzed in section 5 while section 6 discusses the implications and limitations of our findings.

2. Background and Literature Review

While most inquiries into the effects of exchange-rate volatility on trade conclude that uncertainty reduces trade, there are enough exceptions to raise doubts with respect to the universality of this conclusion. The lack of consensus exists with respect to both theoretical and empirical studies. While theoretical models were derived early on showing that increases in currency volatility will induce risk-averse traders to reduce the level of international trade that takes place (e.g. Hooper and Kohlhagen, 1978), later models demonstrated the possibility of the converse. Firms might reorganize production and ultimately increase their share of international trade in response to increases in exchange risk (e.g. De Grauwe, 1988). Lack of consensus on the impact of exchange-rate volatility also arises with respect to the numerous empirical studies that have been conducted. While many studies link exchange-rate volatility to decreases in the level of trading (e.g. Kenen and Rodrik, 1986; Dell’Ariccia, 1999), others fail to find conclusive evidence that volatility negatively impacts on trade flows (e.g. Hooper and Kolhagen, 1978; Tenreyro, 2004) and a few concur with the theoretical models attributing increased trade to increases in volatility in exchange rates (e.g. Baum, et al, 2004).

Several avenues have been pursued in an attempt to reconcile the differing conclusions about exchange-rate uncertainty on trade. One approach has been to disaggregate trade by type of good traded. Differentiated products are found to be much more susceptible to exchange-rate volatility relative to less differentiated products or commodities (Broda and Romalis, 2004). Other attempts have been made by considering the development status of trading partners, or the region in which trade is taking place. Sauer and Bohara (2001) find that while developing countries’ exports fall with

exchange-rate volatility, the exports of developed countries' are not affected. They also find regional variations in the effect of exchange risk, with Africa and Latin America displaying high susceptibility and Asia no susceptibility to exchange-rate risk. But these disaggregations have not led to a consistent generalization aside from concluding that whether exchange-rate volatility's impact is negative or not "depends" on specific circumstances. As such these disaggregations have not succeeded in bringing us any closer to a comprehensive understanding of the impact of exchange-rate volatility on trade.

Alternative approaches to obtaining consistent results revolve around correcting for econometric problems and experimenting with alternative specifications. Export supply and import demand functions (e.g. Cushman, 1983) have given way to the gravity model (e.g. Rose, 2000). Studies have also tended to move from focusing on a relatively small number of countries (e.g. Thursby and Thursby, 1987 with a sample of 17 countries) to studies consisting of very large samples (e.g. Rose, 2000 and Sauer and Bohara, 2001 with 186 and 91 countries respectively). Pozo (1992) examined historical data from the early 1900s and Dell'Ariccia (1999) experimented with different specifications for the volatility variable. In addition to using both nominal and real exchange rates, he constructed proxies for exchange-rate instability using the standard deviation of returns, the sum of squares of the forward errors, and the range of the nominal spot exchange rate. Baum, Caglayan and Ozkan (2004) introduce dynamics to the relationship between volatility and trade by applying various lag structures to volatility.

Our paper offers an alternative approach to the empirical literature on the impact of exchange-rate volatility on trade by using a semiparametric model of trade flows. This model allows for a general nonlinear (nonparametric) relationship between volatility and trade, avoiding the need to superimpose the linearity restriction on the underlying relationship between exchange-rate volatility and trade. Hence our approach is free from any bias due to misspecification of the functional form in the aforementioned relationship. The results indicate that increase in the level of volatility depresses trade. However, after a point the negative impact weakens. At the highest levels of volatility we find no significant effect of volatility on trade. We offer explanations for why this non-linear impact is observed and for why the impact fades to zero as volatility rises. The non-linear nature of the impact of exchange risk on trade that we uncover provides an explanation for some of the contradictory findings present in the literature.

3. Methodology

The overall plan for tracking how volatility impacts trade is to use a gravity model of international trade. Gravity models have been very successful at explaining trade volume and as discussed earlier have been increasing in popularity when testing for the impact of exchange risk on said flows. The gravity model specifies that the log of the value of real bilateral trade at time t between countries i and j (T_{ijt}) can be expressed as:

$$\ln(T_{ijt}) = \alpha_1 + \alpha_2 \ln(GDP_i * GDP_j)_t + \alpha_3 \ln((GDP_i/Pop_i)(GDP_j/Pop_j))_t + \alpha_4 \ln(D_{ij}) + \varepsilon_{ijt} \quad (1)$$

Pop_i and Pop_j are populations in i and j and D_{ij} is the distance between i and j . The product of real GDP and real GDP per capita are presumed to positively impact trade volume.

As has been common in the literature, this equation has been augmented with a series of dummy variables that are thought to further explain variations in the level of trade.

$$\ln(T_{ijt}) = \alpha_1 + \alpha_2 \ln(GDP_i * GDP_j)_t + \alpha_3 \ln((GDP_i/Pop_i)(GDP_j/Pop_j))_t + \alpha_4 \ln(D_{ij}) + \alpha_5 Border_{ij} + \alpha_6 ComLang_{ij} + \alpha_7 Regional_{ij} + \alpha_8 Colony_{ij} + \alpha_9 CUStrict_{ij} + \varepsilon_{ijt} \quad (2)$$

Countries sharing borders ($Border_{ij} = 1$) or languages ($ComLang_{ij} = 1$) are expected to trade more with one another. Countries in the some trade integration arrangement ($Regional_{ij} = 1$) and countries who are either currently in a colonial relationship or in the past maintained a colonial relationship ($Colony_{ij} = 1$) are also expected to engage in more trade. Trade is expected to be enhanced when the trading partners share a single currency ($CUStrict_{ij}=1$), and trade is expected to be disrupted and diminished when either partner experiences a currency crisis ($Crisis=1$).²

To test for the impact of exchange rate uncertainty, the gravity equation is augmented once more with a continuous variable that proxies for uncertainty in the exchange rate and is denoted as σ_{ijt} .

² In this paper we consider four different currency crisis episodes. The Asian currency crisis is presumed to have taken place during 1997 and 1998. All trade flows including an Asian country are assigned a crisis dummy value of 1 in 1997 and in 1998. We assign a crisis dummy variable value of 1 to any trading pair that includes a Latin American nation during 1981 through 1986 and again in 1994 through 1998 to capture the 2 currency crises believed to have impacted the Latin American nations and their trading partners. Finally, we assigned a dummy variable value of 1 for all trade taking place from 1971 through 1974 to account for the breakdown of the Bretton Woods system.

$$\begin{aligned}
\ln(T_{ijt}) = & \alpha_1 + \alpha_2 \ln(GDP_i * GDP_j)_t + \alpha_3 \ln((GDP_i/Pop_i)(GDP_j/Pop_j))_t + \alpha_4 \ln(D_{ij}) \\
& + \alpha_5 Border_{ij} + \alpha_6 ComLang_{ij} + \alpha_7 Regional_{ij} + \alpha_8 Colony_{ij} + \alpha_9 CUStrict_{ij} + \alpha_{10} Crisis_{ijt} \\
& + \alpha_{11} \sigma_{ijt} + \varepsilon_{ijt}
\end{aligned} \tag{3}$$

Unlike the dummy variables we do not have a prior expectation on the sign of the coefficient α_{11} . There has been much discussion in the literature on the methodology that should be employed to measure the latent exchange rate uncertainty variable (e.g. Pozo, 1992; Dell’Arricia, 1999). Following Rose (2000), we take a simple approach, computing the standard deviation of monthly real exchange rate returns over the preceding year to construct the volatility of the exchange-rate (σ_{ijt}) which essentially is the exchange-rate volatility in the period before t. One may be concerned with the potential issue of endogeneity between exchange-rate volatility and trade volume. Using disaggregated data on bilateral trade for different types of products, Broda and Romalis (2004) find the evidence of endogeneity by reporting a substantial impact of trade on exchange-rate volatility. Rose (2000) addresses this issue by using some instruments to account for the possible issue of endogeneity, and has shown that allowing for the endogeneity of exchange-rate volatility does not change the results at all (as long as volatility itself is measured with a one period lag). Our volatility and trade variables are as in Rose (2000). We also use a very similar dataset. Therefore, we follow the same trail by simply using a one period lagged volatility variable in our ‘true’ model.

The novelty in our estimation is to use semiparametric methods to explain the effect of volatility on trade volume. Simple Ramsey’s RESET test (incorporating fitted

terms up to the power of three) rejects linearity.³ A more rigorous kernel based test for functional form misspecification as provided by Li et al (2002) rejects linearity in exchange-rate volatility and trade relationship as well. The computed J statistic of the test turns out to be 1.33 with a bootstrapped p value of 0.07.⁴ A recent paper has also suggested that the relationship between volatility in the exchange rate and trade is nonlinear in nature. Using specific bilateral trade flows for the Group of Seven, Herwartz (2003) finds that the relationship between volatility and trade is nonlinear and uses a semiparametric approach. It is a well known fact that misspecification of the functional relationship can lead to biased estimation and hypothesis testing. It is in this regard, that nonparametric regression, which does not impose functional form restrictions, has been increasingly popular in econometrics. However, a pure nonparametric approach has several costs (sometimes double-edged) associated with it. The computational problem on the one hand and the problem of dimensionality on the other are of major concerns. A fully nonparametric regression technique that incorporates both continuous and categorical data has been discussed in the classic paper by Racine and Li (2004). However, the well known computational challenge of any fully nonparametric technique is also discussed in the same paper as well as in the literature. We face serious computational challenge especially given the size of the sample and the number of regressors involved. But we do not want to lose information by reducing the sample size. Thus we resort to a simple, more conventional and easily computable partially linear framework. In our partially linear model (semiparametric approach) the main variable of

³ The plots provided at the end of the paper clearly show that the underlying relationship between volatility and trade is nonlinear.

interest is assumed to affect the dependent variable in a general nonlinear fashion (unknown functional form is allowed for this component of the regression) while the other control covariates are assumed to affect the dependent variable in a linear way. This will not only take care of any possible functional-form misspecification in our main variable of interest; but will also shed some lights on how volatility affects trade at various levels of volatility. In addition, the model will provide information on the extent to which the underlying relationship between these two variables is linear.

One might be concerned with the possible remaining bias in the estimated semiparametric coefficient of the exchange-rate volatility variable (our main variable of interest) due to the linearity assumptions in the other variables, which could be misspecified as well. But note that, the correlation coefficients between exchange-rate volatility and the other regressors are very low in our sample. For example, the correlation coefficient between the volatility and the crisis variable is 0.05 and between volatility and per capita GDP product is -0.08. For the other regressors the correlation is even lower. Therefore, any possible misspecification due to linearity assumptions for the other regressors should not have a serious impact on the coefficient of volatility variable.

While Herwartz also uses a semiparametric approach to explore how exchange-rate volatility impacts trade, our approach and his differ in a variety of ways. Most importantly, he uses mainly time series data, while we use pooled data with large n (number of cross sectional observations) and small T (time dimension). In this respect, our approach is similar to Rose (2000) who also considers a pooled sample with large n and small T . Herwartz estimates export supply and import demand equations separately

⁴ For this test we have taken a random sub sample of 2400 observations from our sample. The number of wild bootstrap replications is 400. The null is OLS model whereas the alternative is our partially linear

while in our approach we employ the gravity model. Herwartz (2003) concentrates on the growth of trade among the Group of Seven while we use trade flows from over 200 countries. He constructs exchange-rate volatility by using a GARCH (1,1) model while we use the standard deviation of exchange rate movement over the previous year.

In terms of the technical estimation, Herwartz first assumes that the true model governing trade flows is linear. Herwartz wipes out the effects of control variables from trade and volatility by using a partitioned regression technique and then looks at the pure effect of volatility on trade in a bivariate regression. At this final stage, he considers the effect of volatility on trade in a general nonlinear fashion.⁵ While Herwartz's approach is well suited to dealing with high frequency time series data (as he is faced with issues such as cointegration and the need for error correction), his approach is at a disadvantage in capturing the true nonlinear relationship between volatility and trade. Our intent in the paper is to focus on the true nonlinear relationship using a very large pooled data with a fixed time period (small yearly observations) and the number of cross sections going to infinity.

The details of our approach is first to assume that our true model is a pooled partially linear semiparametric model.⁶ We allow our primary variable of interest, (exchange-rate volatility) to affect trade volume in a general nonlinear fashion

model. See Li et al (2002) for details.

⁵ Herwartz's final nonparametric equation looks at the bivariate relationship between trade and volatility where the two variables are obtained from the linear projections as described in his paper. In that sense it is a semiparametric approach.

⁶ To our knowledge, fixed effect unbalanced panel regression results are not yet developed for the nonparametric/semiparametric framework. As mentioned earlier, our objective is to use as much information as possible. Hence we use unbalanced panel. Otherwise, the loss of observations will be quite substantial for our sample. Also our main focus is to investigate how trade responds to volatility at different levels of volatility without superimposing any functional form restrictions on the underlying relationship. Hence we have used Li and Stengos (1996) type pooled semiparametric regression. Li and Stengos (1996)

(nonparametrically, so that there is no pre-assigned functional form) whereas the other control covariates are assumed to affect the dependent variable in a linear fashion. The partially linear model that we have used can be written as

$$Y_{ijt} = X_{ijt}\beta + g(Z_{ijt}) + \varepsilon_{ijt} \quad (4)$$

Where Y_{ijt} denotes the dependent variable ($\ln(T_{ijt})$), Z_{ijt} denotes our main variable of interest, (σ_{ijt}) , X_{ijt} captures all other control variables (as listed in (3)), and $g(\cdot)$ denotes the unknown (nonparametric) functional form. The basic estimation method (as described below) is similar to that in Li and Stengos (1996) which is similar to the one in Robinson (1988) and the approach is summarized in Pagan and Ullah (1999).

From (4) we get:

$$Y_{ijt} - E(Y_{ijt}|Z_{ijt}) = [X_{ijt} - E(X_{ijt}|Z_{ijt})]\beta + [g(Z_{ijt}) - E(g(Z_{ijt})|Z_{ijt})] + [\varepsilon_{ijt} - E(\varepsilon_{ijt}|Z_{ijt})] \quad (5)$$

Let \hat{m}_{ijt}^1 and \hat{m}_{ijt}^2 denote the kernel based estimators of $E(Y_{ijt}|Z_{ijt})$ and $E(X_{ijt}|Z_{ijt})$ respectively and $E(\varepsilon_{ijt}|Z_{ijt}) = 0$.

Rewriting (5) in matrix form we can present the typical semiparametric estimator of β as

$$\hat{\beta} = [(X - \hat{m}^2)'(X - \hat{m}^2)]^{-1} [(X - \hat{m}^2)'(Y - \hat{m}^1)]$$

Where Y is an $nT \times 1$ vector of Y_{ijt} , Z is an $nT \times 1$ vector of Z_{ijt} , X is an $nT \times K$ matrix capturing the control variables (K being the number of controls) and \hat{m}^1 and \hat{m}^2 are the vector and matrix generated from \hat{m}_{ijt}^1 and \hat{m}_{ijt}^2 respectively.

approach incorporates predetermined and strictly exogenous regressors. It also allows for lagged dependent variables although our set of regressors does not include any lagged dependent variable.

After obtaining $\hat{\beta}$, we can then rewrite (4) as

$$(Y_{ijt} - X_{ijt} \hat{\beta}) = Y_{ijt}^* = g(Z_{ijt}) + \varepsilon_{ijt} \quad (6)$$

For the final stage estimation of this nonlinear part we apply Nadaraya-Watson kernel regression estimation.⁷ Following the usual practice, $\frac{\partial g}{\partial Z}$ can be interpreted as the point wise partial effect of exchange-rate volatility on trade volume. Our final stage of estimation is similar to the final stage estimation in Herwartz (2003) in the sense that they also use kernel weighted regression method to estimate the effect of volatility on export/import. However, their estimation strategy differs from ours at the pre-final stage.⁸ Overall, Herwartz's approach can tease out variations in the response across countries as countries may respond differently to exchange-rate risk. In our case, we derive an overall conclusion backed by the results from a large number of countries. As such we are able to better generalize about the impact of exchange risk on trade.

4. Data

The data set used in this estimation is very large. We began with the data compiled and used by Rose (2004) to study the impact of WTO membership on trade stability. While many follow-ups to Rose's (2000) widely cited study of the currency union effect have been undertaken using Rose's currency union database, it only contains

⁷ See Robinson, 1988, Pagan and Ullah, 1999 and Li and Wooldridge, 2000, Fan and Yao (2003) and Racine and Ullah (forthcoming) for more details on semiparametric and nonparametric regressions, their asymptotic properties as well as some applications. We have used standard Gaussian kernel, exact binning and optimal as well as cross validated bandwidths. Our conclusion is robust to the choice of bandwidths.

⁸ Note that if we start with a partially linear model as in (4), instead of a linear model, we can not first eliminate the effects of control variables X from Y and from Z by using a linear projection method (as in Herwartz, 2003) because $[g(Z_{ijt}) - E(g(Z_{ijt})|X_{ijt})]$ will not be the same as $[Z_{ijt} - E(Z_{ijt}|X_{ijt})]$ and $g(Z_{ijt})$ itself is unknown. Hence, a Li and Stengos or a Robinson type approach is called for.

5-year intervals of data. We wished to use annual data. We supplemented the WTO database with annual observations for real exchange-rate volatility. The volatility of the exchange rate is constructed by first constructing monthly real exchange rate returns. These returns are computed as the log differences in the month to month exchange rate. Twelve monthly returns are then used to compute a standard deviation for the year. These standard deviations are then matched to the appropriate yearly observation so that the volume of trade between two countries is presumed to be influenced by the previous year's real exchange-rate volatility. International Financial Statistics data on bilateral exchange rates with their appropriate CPIs are used to construct the real exchange rates used in the computation.

The original Rose data set includes observations, when available, from 1948 to 2000. Monthly exchange rate data were available in an easily accessible format only since 1957, hence our database does not contain observations earlier than 1957. There are a total of 214 countries in our sample and we use yearly data. Since all countries do not trade with one another and since there are some missing observations our sample consists of a total of 121501 observations.⁹

5. Results

The results of a simple pooled OLS parametric regression for the gravity equation specified in (3) is presented in the middle column of Table 2 while the semiparametric results are presented in the final column. These results are, broadly speaking, in line with results from Rose (2000). The forces of attraction -- the product of real GDPs and of

GDP per capita -- increase trade, as do the various dummy variables specifying the existence of common borders, current or former colonial ties, trade integration agreements, and common language. In contrast and as expected, the log of distance reduces trade flows while the common currency variable promotes trade. The estimated value of the coefficient on the common currency variable is similar to Rose's value of 1.25 implying that countries with common currencies trade about 3 times more than do countries that do not share common currencies ($\exp(1.1) = 2.99$). The coefficient of the crisis variable turns out to be negative and significant, as expected.

Of particular interest to us is the coefficient associated with the exchange-rate volatility variable. As in any typical semiparametric regression, we obtain point wise partial effects of volatility on trade (the conditional first derivatives or $\partial g(Z_{ijt}) / \partial Z_{ijt}$). The median of these point wise partial effects are reported in Table 2.¹⁰ This median value of (-0.87) indicates that on an average real exchange-rate volatility depresses the volume of trade, thereby concurring with the segment of the empirical and theoretical literature that concludes that uncertainty in the exchange rate will depress the amount of trade taking place. However, more comprehensive is the plot of these partial effects, i.e., the plot of the conditional first derivatives (measured on the vertical axis) against volatility (measured on the horizontal axis) as shown in Figure 1 for the entire range of observations on volatility. While this allows us to observe how the partial effects vary with the level of volatility, it is important to recall that not all levels of volatility are

⁹ Note that our data set is a pooled one with large cross sections. The time dimension varies from about 10 to 40 annual observations per cross section. Thus the nonstationarity issues are not of major concern for us because our data set, although pooled, contains large n . See Phillips and Moon (1999).

¹⁰ We have used Gauss and Nonparametric software *NPREG* at various stages of our computations. For more information on NPREG software, see, <http://faculty.maxwell.syr.edu/jracine/np.html>

equally represented. In fact most of the values of volatility (97.4%) are between 0 and 0.05 and are thus clustered in the first section of the graph¹¹.

To better understand how trade, in practice, is impacted by exchange-rate volatility we “blow up” the initial segment which contains 97.4% of total observations and display it in Figure 2. Interestingly, we find that when volatility assumes values from 0 to 0.025 the plotted values appear almost as a horizontal line (though slightly downward sloping). As volatility increases trade seems to be depressed at a fairly constant rate. However, this rate is not really constant. A distinction between the partial effects for nonparametric vs. parametric (constant partial effect, hence horizontal) regressions is shown in Figure 5 (for the range of volatility up to 0.015) which depicts a steadily downward sloping partial effects for the nonparametric model as opposed to the parametric model. However, at higher volatility (above 0.025 and up to about 0.05), the relationship becomes noticeably nonlinear. The partial effects drop sharply implying that volatility’s detrimental impacts become noticeably greater. Hence we can conclude that exchange-rate volatility does depress trade and the depressing impact increases with the level of volatility. Furthermore, at very high levels of volatility the “penalty” increases at an increasing rate.

In Figure 3 we plot how volatility impacts trade when volatility assumes even greater values, specifically values between 0.05 and 0.07. This range contains about one-

¹¹ It is noteworthy that we observe a sharp and large hump (for volatility level around 0.025-0.07). This hump does not disappear even if we use larger bandwidths. However, the other relatively smaller humps appearing to the right (beyond this volatility level) partly gets smoothed out when we use larger bandwidths. The coefficients associated with this large hump are always highly significant. Thus the hump appearing in the volatility range nearly about 0.025-0.07 is an economic phenomenon that deserves some discussion. We therefore, focus on this in Figures 2 and 3.

half of one percent of total observations.¹² Here we observe a curious phenomenon. The partial effect diminishes. As volatility grows the detrimental impact on trade weakens. Greater exchange-rate uncertainty no longer elicits an even greater penalty on trade volume. Instead the detrimental impact weakens (though it is still negative.) What might explain such? We argue that after some point, as the level of exchange-rate uncertainty grows, countries learn to adapt to volatility, lessening its harmful impacts. Countries employ hedging strategies that might otherwise be too expensive to employ when volatility is relatively low. But when volatility surpasses a point (and our data seem to indicate that point to be approximately a level of volatility of 0.05) it becomes cost-effective to employ these strategies. Eventually (when volatility reaches 0.07) trade is no longer depressed by exchange-rate volatility. When volatility is this high countries have fully adjusted to the volatility employing one means or another to mitigate its effect on trade.

In Figure 4 we show that at the highest range of volatility (0.07 and above) the partial effect becomes noisy around the value zero. This noisy range contains about 2% percent of the observations. It is difficult to know exactly what is taking place in this “noisy tail region”¹³ but it is noteworthy that almost all the insignificant coefficients fall in this range.

Overall these plots seem to be suggesting that for the most part exchange-rate volatility depresses trade and that the negative impact grows with the level of volatility. However, after a point countries seem to get a handle on the volatility and in one way or

¹² Pakistan falls consistently in this range for the year 1973. This is basically the year after Bangladesh gained its independence from Pakistan (the official date of independence was December 16th 1971). So it is natural to observe some unusual exchange rate and trading behavior for Pakistan economy which just experienced a considerable partitioning during that time.

another learn to diminish its impact. Figure 3 shows the weakening impact and suggests that by the time exchange-rate volatility reaches 0.07 countries have learned to totally mitigate volatility's negative impact on trade. How Might This Happen? Take for example the case of trade between say the U.S. and the Dominican Republic (DR). Suppose that exchange-rate volatility between the peso and the dollar becomes very large. This will result in diminished trade. But over time with increasing levels and persistence of volatility traders may protect themselves by informally dollarizing, defining all of their transactions and assets in dollars, creating a mini "dollar economy." Official levels of exchange-rate volatility will be recorded as high given our tracking of the peso/dollar exchange rate, when in fact these traders are not affected to a great extent by the peso/dollar exchange rate due to their operations in a "dollar" economy. This is one manner by which traders may be mitigating the harmful impacts of exchange-rate volatility and may explain what we are observing in the highest volatility ranges which constitute about 3% of total observations.

An examination of observations in the region of volatility running from 0.0488 and 0.07 (where countries impact of volatility is weakening with greater volatility) is supportive of this supposition. While a large cross-section of countries is represented, ten countries show up repeatedly (with each consisting from 2.5 to 6 percent of total observations). These are Argentina, Bolivia, Chile, Costa Rica, Ethiopia, Guatemala, Pakistan, Nigeria, Sri Lanka, and Uruguay. We examined inflation series for these countries in relation to the other countries in their respective geographic region. In the case of the Latin American nations, all of these countries have experienced inflation rates well in excess of the average for the region over extended periods of time. The incidence

¹³ This may simply be the noisy tail behavior.

of informal (and formal) dollarization for many of these countries is well known (e.g. Argentina, Uruguay, and Bolivia). The Asian nations represented in this group have also experienced relatively high inflation rates (in relation to neighboring nations) over various periods in time. Nigeria has experiences periods of run-away inflation, and Ethiopia's inflation series is noteworthy in its variability, from high inflation to deflation. As such, for each of these nations, domestic money, as a unit of account, has suffered. Over time, countries that suffer from declines in the usefulness of money tend to develop alternative methods to effectuate and to define transactions including informal dollarization. It is conceivable that this region of observations is picking up some of that adjustment to high and variable inflation which accompanies exchange-rate volatility.

The question then arises, how do our results compare with Herwartz (2003)? He finds that the impact of exchange-rate volatility on trade (growth) is non-linear and as such our findings coincide. However, Herwartz does not find that trade is as consistently negatively impacted as we find. The seven countries that he examines appear in some cases to experience positive growth in trade on account of increased uncertainty, while other countries experience the converse. His results appear to be country-specific. Our larger sample, on the other hand, seems to point to an overall negative impact of volatility on trade volume.

6. Discussions and Limitations:

To our knowledge, this is the first attempt to explore the relationship between exchange-rate volatility and trade using a very large sample in a semiparametric framework. A fully linear parametric model is a special case of a partially linear model, i.e., our semiparametric model is a more generic one. Unless one estimates a more

general model it is not possible to assess to what extent a linear model is an appropriate one. Overall and on average, the parametric and the semiparametric models give very similar conclusions as far as the sign and significance of the (average values) coefficients are concerned. However, our partially linear model gives us some additional economic information on how volatility affects trade at various levels of volatility and this information has an intuitive appeal.¹⁴

Overall our results can be interpreted as a reconciliation of the alternative findings on the impact of exchange-rate volatility on trade volume. We find that by and large exchange-rate volatility depresses trade, which is in accord with what has been found in the bulk of the empirical literature. We also find that the negative impact of volatility on trade strengthens as the level of uncertainty increases. Greater uncertainty increases the costs of trade (and hedging) and in accordance the volume of trade is further reduced. That is, there is nonlinearity in the way that volatility impacts trade. Most interesting however, is our finding that at very high levels of exchange-rate volatility trade volumes are unaffected. The impact of uncertainty on trade volume fades as volatility grows. This provides us with an explanation for the less common, yet bothersome occasional result in the empirical literature suggesting no impact of volatility on trade. We find that at very high levels of volatility countries adjust or somehow eliminate the harmful impact of volatility on trade. Informal dollarization is suggested as one avenue that traders may be using to mitigate high levels of volatility.

¹⁴In particular, the behavior of the data around the hump could never be revealed in a linear framework where we just obtain a single coefficient.

References

- Baum, Christopher F., Mustafa Caglayan and Neslihan Ozkan, "Nonlinear Effects of Exchange-Rate Volatility on the Volume of Bilateral Exports," *Journal of Applied Econometrics*, 19, 2004, pp. 1-23.
- Broda, Christian and John Romalis, "Identifying the Relationship between Trade and Exchange Rate Volatility," FRBNY working paper, February 2004.
- Clark, Peter, Natalia Tamirisa, and Shang-Jin Wei, "Exchange Rate Volatility and Trade Flows- Some New Evidence," IMF Working Paper, May 2004.
- Cushman, David O., "The Effects of Real Exchange Rate Risk on International Trade," *Journal of International Economics*, 15, 1983, pp. 45-63.
- De Grauwe, Paul, 1988, "Exchange Rate Variability and the Slowdown in Growth of International Trade," IMF Staff Papers, 35, pp. 63-84.1988
- Dell'Ariccia, Giovanni, "Exchange Rate Fluctuations and Trade Flows: Evidence from the European Union," IMF Staff Papers, Vol. 46, No. 3 (September/December 1999) pp. 315-334).
- Fan J. and Gijbels I., *Local Polynomial Modelling and its Applications*, 1996, Chapman and Hall.
- Fan J. and Yao Q., *Nonlinear Time Series*, 2003, Springer Series in Statistics.
- Herwartz, H., "On the (Nonlinear) Relationship between Exchange Rate Uncertainty and Trade – An Investigation of US Trade Figures in the Group of Seven," *Review of World Economics*, 2003,139, 4, pp. 650- 682.
- Hooper, Peter and Steven Kohlhagen, "The Effect of Exchange Rate Uncertainty on the Prices and Volume of International Trade," *Journal of International Economics*, 1978, Vol. 8, 99. pp. 483-511.
- Kniesner, T. and Q. Li, "Nonlinearity in Dynamic Adjustment: Semiparametric Estimation of Panel Labor Supply", *Empirical Economics*, 2002, 27, pp. 131-148.
- Kenen Peter B. and Dani Rodrik, "Measuring and Analyzing the Effects of Short-Term Volatility in Real Exchange Rates," *Review of Economics and Statistics*, Vol. 68, No. 2, May 1986, pp. 311-315.
- Li, Q. and T. Stengos, "Semiparametric Estimation of Partially Linear Panel Data Models", *Journal of Econometrics*, 1996, 71, pp. 389-397.

Li, Q. and J. Wooldridge, "Estimating Semiparametric Econometrics Models by Local Linear Method: With an Application to Cross-Country Growth", *Annals of Economics and Finance*, 2000, 1, pp. 337-357.

Li, Q., C.J. Huang, D. Li and T. Fu, "Semiparametric Smooth Coefficient Models", *Journal of Business and Economic Statistics*, 2002, 20, 3, pp. 412-422.

Nitsch, Volker, "Honey, I Shrunk the Currency Union Effect on Trade," *The World Economy*, xxxxx 2002.

Pagan, A. and A.Ullah, *Nonparametric Econometrics*, 1999, Cambridge University Press.

Phillips P.C.B. and H.R. Moon, "Linear Regression Limit Theory for Nonstationary Panel Data", *Econometrica*, 1999, 67, 5, pp.1057-1111.

Pozo, Susan, "Conditional Exchange Rate Volatility and the Volume of International Trade: Evidence from the Early 1900s," *Review of Economics and Statistics*, 1992, 74, pp. 325-9.

Racine, J.S. and Q. Li (2004), "Nonparametric Estimation of Regression Functions with both Categorical and Continuous Data", *Journal of Econometrics*, 119, 99-130.

Racine, J.S. and A. Ullah (forthcoming), "Nonparametric Econometrics", *Palgrave Handbook of Econometrics*, Vol. 1, Theoretical Econometrics.

Robinson, P. M., "Root-N-Consistent Semiparametric Regression", *Econometrica*, 1988, 56, pp. 931-954.

Rose, Andrew K., "One Money, One Market: The Effect of Common Currencies on Trade." *Economic Policy*, April 2000, p. 9-45.

Rose, Andrew K., "Does the WTO Make Trade More Stable?" University of California, Berkeley working paper, January 13, 2004.

Sauer, Christine and Alok K. Bohara, "Exchange Rate Volatitliy and Exports: Regional Differences between Developing and Industrialized Countries," *Review of International Economics*, Vol. 9, No. 1, 2001, pp. 133-52.

Tenreyro, Silvana, "On the Trade Impact of Nominal Exchange Rate Volatility," Federal Reserve Bank of Boston working paper, April 2004.

Thursby, Jerry G. and Marie C. Thursby, "Bilateral Trade Flows, The Linder Hypothesis and Exchange Risk," *Review of Economics and Statistics*, xxxx 1987m pp. 488-495.

Table 1: Descriptive Statistics

Variables	Minimum	Mean	Maximum	Standard Deviation
LTrade	-2.922218	10.35365	20.88974	3.300390
Volatility	1.08E-06	0.006386	0.953461	0.031778
Border	0	0.027275	1	0.162886
Colony	0	0.119011	1	0.323803
Crisis	0	0.272368	1	0.445180
Custrict	0	0.011300	1	0.105701
LDistance	3.684131	8.167526	9.421514	0.811257
LGDP	22.36991	35.44595	44.80403	2.595156
LGDPPC	11.42344	17.04276	21.00741	1.414036
ComLang	0	0.211109	1	0.408098
Regional	0	0.018592	1	0.135081

Note: *LTrade* denotes log of the value of real bilateral trade, *Volatility* denotes exchange-rate volatility. *Border* is a dummy variable (=1, if the trading partners are sharing a common border), *Colony* is a dummy variable (=1, if the trading partners are in a colonial relationship or had such relationship in the past), *Crisis* denotes a dummy variable (=1, if either partner is experiencing a currency crisis), *Custrict* is a dummy variable (=1, if the trading partners are sharing a single currency). *LDistance* denotes log of distance between two trading partners, *LGDP* is the product of real GDPs of the trading partners and *LGDPPC* is the product of real per capita GDPs of the two countries. *ComLang* is a dummy variable (=1, if the countries are sharing a language) and *Regional* is a dummy variable (=1, if the countries are engaged in some trade integration arrangement).

Table 2: Parametric and Semiparametric Results

Variables	Parametric Coefficients	Semiparametric Coefficients
Constant	-21.42292 (<0.0000)	-21.11680 (<0.0000)
Volatility	-1.759797 (<0.0000)	-0.873055 (<0.0000)
Border	0.465245 (<0.0000)	0.472295 (<0.0000)
Colony	0.847734 (<0.0000)	0.843751 (<0.0000)
Crisis	-0.136141 (<0.0000)	-0.149814 (<0.0000)
Custrict	1.096692 (<0.0000)	1.053165 (<0.0000)
LDistance	-1.115850 (<0.0000)	-1.115877 (<0.0000)
LGDP	0.882682 (<0.0000)	0.884052 (<0.0000)
LGDPCC	0.554013 (<0.0000)	0.543616 (<0.0000)
ComLang	0.340807 (<0.0000)	0.340966 (<0.0000)
Regional	0.606424 (<0.0000)	0.591568 (<0.0000)

Note: Dependent variable is the log of real bilateral trade. *P-values* are in the parentheses. Total number of observations is 121501. Note, for the nonparametric part, medians of the nonparametric point-wise estimates are reported. For details about nonparametric conditional first derivatives (partial effects of volatility on logarithm of trade volume) and their significance, refer to the graphs. For variable descriptions, refer to Table 1.

Figure 1: Partial Effects of Volatility on Trade

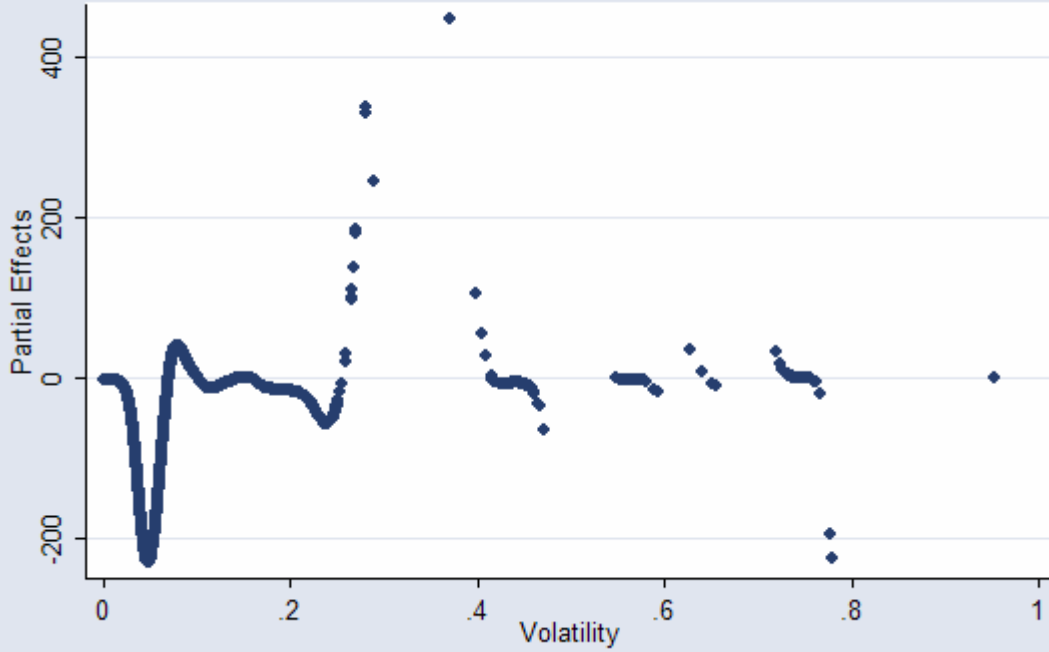


Figure 2: Partial Effects of Volatility on Trade
For volatility from 0 to 0.0488 (97.4% of observations)

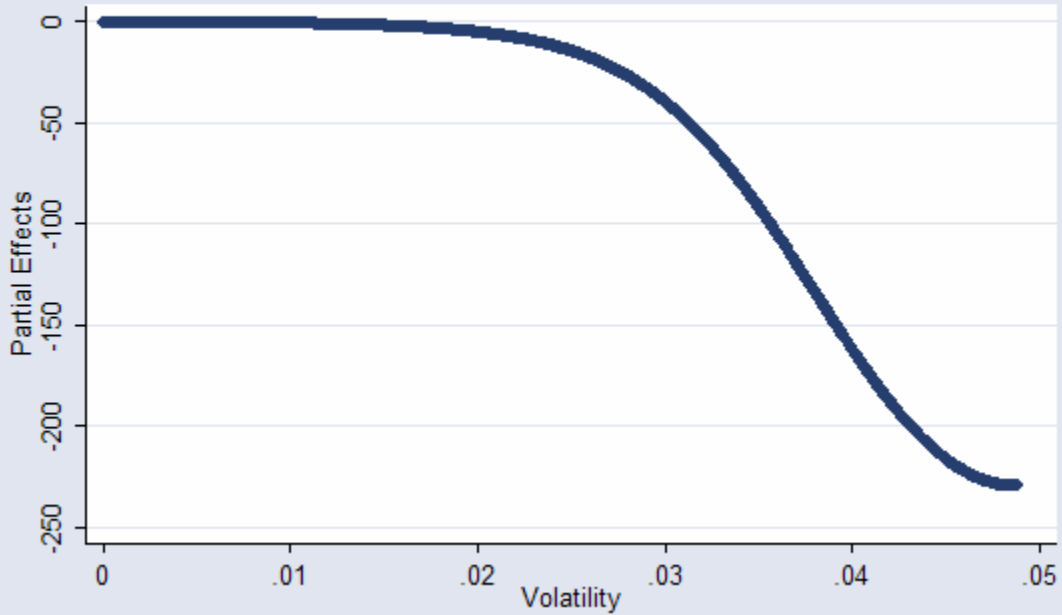


Figure 3: Partial Effects of Volatility on Trade
For volatility from 0.0488 to 0.07 (0.6% of observations)

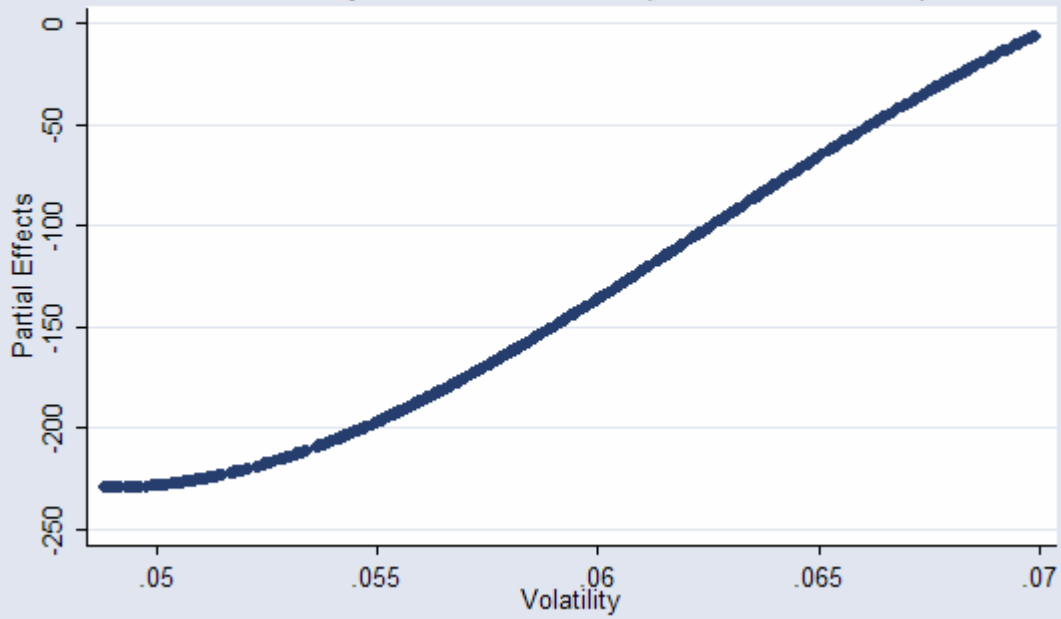


Figure 4: Partial Effects of Volatility on Trade
For volatility greater than 0.07 (2% of observations)

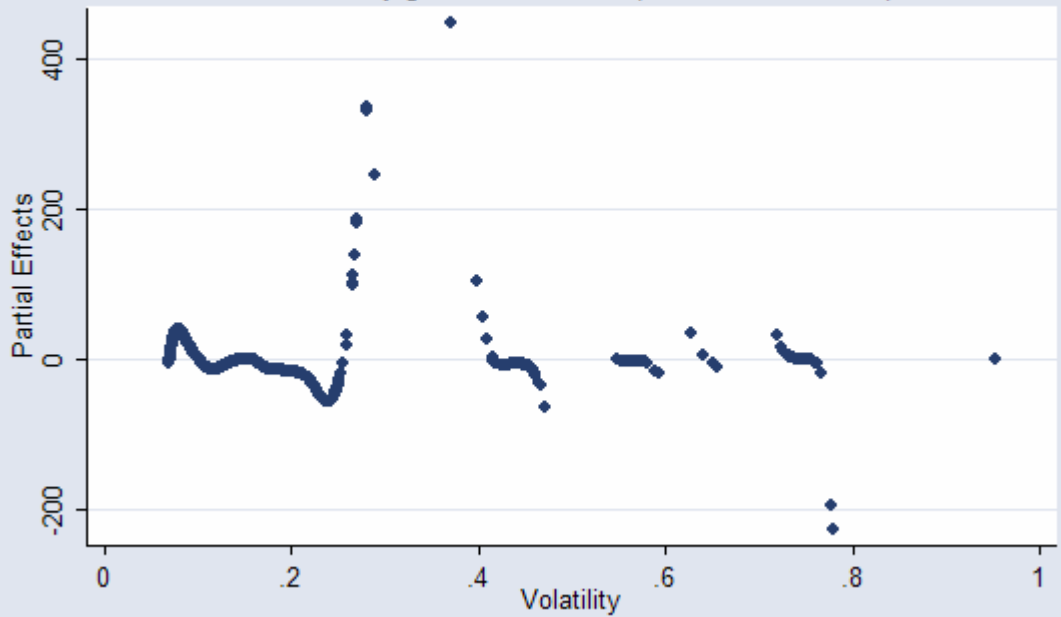


Figure 5: Parametric and Nonparametric Partial Effects

For volatility from 0 to 0.015 (93% of observations)

