

THE IMPACT OF DOLLAR-RAND VOLATILITY ON U.S. EXPORTS TO SOUTH AFRICA

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ABSTRACT

This study investigates the effects of exchange rate volatility on the top ten categories of exports by the United States to South Africa over a 20-year period from January 1990 to December 2009. The paper uses several measures of volatility to generate a measure of exchange rate volatility, which is then tested in a model of U.S. exports to South Africa. We employ sectoral trade data at the 2-digit HS level to evaluate these effects on the top ten individual commodities traded. Utilizing bounds testing cointegration, we estimate the short- and long-run impact of exchange-rate volatility on the US exports to South Africa. Our results suggest that while the effects of exchange rate volatility on exports is mixed in the short-run, in the long-run, exchange rate volatility exerts a negative effect on the U.S. exports to South Africa.

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KEYWORDS: exchange rates, volatility, exports, ARDL bounds testing, South Africa.

INTRODUCTION

The breakdown of the Bretton Woods system and the adoption of the flexible exchange rate regime in 1973 has led to a proliferation of research on the impact of exchange rate volatility (ERV) on real exports. The interest in this research was prompted by three main developments: (a) both the real and nominal exchange rates have undergone periods of substantial volatility since 1973; (b) during the same period, international trade declined significantly among industrialized countries; and (c) macroeconomic instability in terms of output, inflation, interest rates, and employment began to surface.

Despite the sizeable number of studies conducted, no real consensus about the impact of exchange rate volatility on exports has emerged. While a large number of studies find that ERV tends to reduce the level of trade, others find either weak or insignificant or positive relationships. For example, Onafowara and Owoye (2008), Byrne, Darby, and MacDonald (2008), Choudhry (2005), Bahmanee-Oskooee (2002), Arize, *et al.* (2000), Arize (1995), Chowdhury (1993), Pozo (1992), and Bahmani-Oskooee and Ltaifa (1992), find evidence for negative effects. According to these scholars, ERV may affect exports directly through uncertainty and adjustment costs for risk-averse exporting investors. Further, it may have an indirect effect through its impact on the structure of output, investment and government policy. On the other hand, Doyle (2001), Chou (2000), McKenzie and Brooks (1997), Qian and Varangis (1994), Kroner and Lastrapes (1993), and Asseery and Peel (1991) find evidence for a positive effect for volatility on export volumes of some developed countries because exchange rate volatility makes exporting more attractive to risk-tolerant exporting firms. However, other scholars such as Aristotelous (2001), Bahmani-Oskooee and Payestch (1993), Bahmani-Oskooee (1991), and Hooper and Kohlhagen (1978) have reported no significant relationship between ERV and exports.

Reasons for contradictory results by different studies may be due to a variety of factors, among them: different methods used to measure ERV; the use of different price deflators; the differential use of sample data, for example, the use of aggregate export data versus sectoral export data; different time-frame periods; ignoring import dependency on intermediate and capital goods of the receiving country, as is the

case with many developing countries; and the absence of complex econometric methods for studying these variations. As a result scholars stopped investigating the ERV-export nexus by the late 1990's. However, with better access to sectoral data and the development of more sophisticated econometric models, recent studies have begun evaluating the ERV-export connection from a sectoral perspective. The rationale behind this is that different trade sectors would be impacted differentially by ERV, and therefore may be more revealing than aggregate studies.

This study focuses on sectoral export trade from the United States to South Africa, a developing country, using three different measures of volatility that may help to uncover the nature and sensitivity of the relationship between ERV and sectoral exports. We use the bounds testing approach to cointegration to establish a long-run relationship among the explanatory variables. We also employ error-corrections models (ECM) to establish the short-run dynamics of the relationship. In addition, we use the generalized autoregressive conditional heteroskedasticity (GARCH) model to generate one of the three measures of ERV. Using this approach we investigate the effects of exchange rate volatility on the top ten categories of exports by the U.S. to South Africa over a period of 20 years using monthly data from January 1990 to December 2009. Although South Africa accounts only for a very small share of U.S. total trade, it is the largest African trading partner of the United States. On the other hand, the United States is the third largest market for South African exports.

To this end we provide a brief review of the literature in the next section. Thereafter, we lay the empirical framework of our study by specifying our model. In the section following that we discuss variable definitions and outline our data sources. Empirical results from the bounds testing approach to cointegration, and error-correction model estimates are presented in the penultimate section. The final section presents a summary and conclusion of the results obtained in this study.

LITERATURE REVIEW

In this section we present a brief overview of studies that examine the ERV-trade nexus on U.S. trade flows using sectoral data. We begin by discussing the most recent and sophisticated studies, employing cointegration techniques using GARCH and ECM models, to older, less complex studies.

Bahmani-Oskooee and Hegerty (2009) investigate the effects of exchange rate fluctuations on trade flows between the U.S. and Mexico using disaggregated, industry-level annual export and import data for 102 industries from 1962 to 2004. They analyze both the short- and long-term effects of volatility in the peso/dollar real exchange rate on Mexican-United States trade. They conclude that in the short-term increased volatility negatively affects trade flows in most industries. Long-term effects however, are significant for only one-third of the industries studied, and of this, only two-thirds are negative. They speculate that increased Mexican integration and liberalization of economic policies allow for greater adjustments in the long-term so that volatility is less of a problem in the long-term than in the short-term.

Byrne, Darby, and MacDonald (2008) analyze the impact of ERV on the volume of bilateral U.S. trade flows using homogenized and differentiated sectoral annual data over the period 1989-2001 for a cross-section of 6 EU countries and 22 industries. Their study finds that clustering all industries together provides evidence of a negative effect on trade from ERV, which confirms findings of other studies using aggregate data. However, when investigating sectoral trade differences, the effects of ERV on trade is negative and significant for differentiated goods and insignificant for homogeneous goods, confirming recent studies that sectoral differences are in fact crucial to explaining the differential impact of volatility on trade. They suggest that a greater degree of disaggregation at the industry level may provide more worthwhile results, which is what we do in this study.

Bahmani-Oskooee and Kovyryalova (2008) investigate the effect of exchange rate fluctuations on trade flows between the U.S. and the United Kingdom using disaggregated annual export and import data for 177 commodities industries from 1971 to 2003. They analyze both the short- and long-term effects of real ERV on trade between the U.S. and the UK. Their results reveal that the volatility of the real dollar–pound rate has a short-term significant effect on imports of 109 industries and on exports of 99 industries. In most cases, such effects are unfavorable. In the long run, however, the number of significant cases is somewhat reduced: only 62 import and 86 export industries are significantly and adversely affected by ERV. The industries affected involve both durable and non-durable goods, and include small as well as large industries, supporting findings by aggregate studies.

In another study, Bahmani-Oskooee and Mitra (2008), investigate the effects of ERV on trade flows between the U.S. and India, an emerging economy. Using annual data from 40 industries from 1962–2004, their results demonstrate that ERV has more short-run than long-run effects. In the short-run, 17 industries were affected on the import side and 15 on the export side. The industries affected show India's increasing ability to produce import substitutable goods. However, in the long run, only a few industries are affected because the increasing dependence on trade between India and the US cause industries to respond inelastically to ERV.

Using both the nominal and the real exchange rate between the United States dollar and the currencies of Canada and Japan, Choudhury (2005) investigates the influence of exchange rate volatility on U.S. real exports to Canada and Japan using aggregate monthly data ranging from January 1974 to December 1998. The study uses conditional variance from the GARCH (1, 1) model as a measure of exchange rate volatility, and finds significant and mostly negative effects of ERV on real exports.

As in the above studies, Sukar and Hassan (2001) investigate the relationship between U.S. trade volume and ERV using cointegration and error-correction models. Their study uses quarterly aggregate data covering the period 1975Q1 – 1993Q2 and a GARCH model to measure the exchange rate volatility. Paralleling other studies, the authors find evidence for a significantly negative relationship between U.S. export volume and ERV. However, unlike other findings, they reveal that the short-run dynamics of the ERV-trade relationship is insignificant. They argue that this result may be due to the existence of avenues for hedging against exchange risks so as to neutralize the negative impact of ERV. Other scholars argue that this short-run insignificant relationship may be because of the investigators' use of aggregate data, which ignores sectoral differences. For example, while one sector may exhibit a negative relationship, another may exhibit an equal but opposite effect so that they offset each other.

Arize (1995), using monthly series from February 1978 to June 1986 analyzes the effects of real ERV on the proportions of bilateral exports of nine categories of goods from the U.S. to seven major industrial countries. The volatility measure employed is the standard deviation of the monthly percentage change in the bilateral exchange rate between the U.S. and the importing country from t to $t-12$. The study reveals differential effects of ERV across different categories of exports. The study also concludes that exchange rate uncertainty has a negative effect on U.S. real exports, and that it may have a major impact on the allocation of resources to different industries depending on trade elasticities.

Lastrapes and Koray (1990) analyze the interrelationships among exchange rate volatility, international trade, and macroeconomic variables using the vector autoregression (VAR) model. The model estimates U.S. multilateral trade from 1973 to 1990 and includes a moving standard deviation measure of real ERV. While the results reveal some evidence of a statistically significant relationship between volatility and trade, the moving average representation of the model implies a rather small quantitative effect. The study concludes that ERV is influenced by the state of the economy, a factor ignored in a variety of other studies.

Klein (1990) is one of the first few scholars to analyze the effects of ERV on the proportion of disaggregated bilateral exports of nine categories of goods from the U.S. to seven major industrial countries using fixed effects framework. Using monthly series data from February 1978 to June 1986, the study reveals that in six categories of exports ERV significantly affects the volume of exports and in five of these categories the effect is positive, suggesting that real ERV may in fact increase exports by risk-taking firms.

Koray and Lastrapes (1989) examine the relationship between real ERV and bilateral imports from five countries, namely, the UK, France, Germany, Japan, and Canada, employing a VAR model. The study uses aggregate monthly data over a 17-year period from January 1959 to December 1985, and tests for different effects during both the fixed and the flexible exchange rate regimes. Results suggest that while the effects of volatility on imports is weak, permanent shocks to volatility experience a negative impact on imports. However, those effects are relatively more important during the flexible-rate than the fixed-rate period.

Finally, Cushman (1988) tests for real exchange rate volatility on U.S. bilateral trade flows using annual data from 1974-1983 to study the effects of the floating exchange rate regime on ERV. The study finds evidence for significant negative effects in only two of six U.S. export flows with one export flow showing a significant positive effect, confirming other studies of a weak risk-averse effect of ERV on exporting firms.

One major problem with most of the studies above is that the sample period includes the period prior to the end of the fixed exchange regime, so results may include the lag effects of fixed exchange rates on trade before 1973 lingering on during the transition period after the implementation of the floating exchange rate regime. The current study corrects for this potential bias by using U.S. monthly-disaggregated trade data covering a 20-year period from January 1990 to December 2009. We focus on the top ten export products in U.S.-South Africa trade to better understand how each industry is affected by ERV. The methodology used in this study incorporates many of the recent developments in the literature, namely, bounds testing approach to cointegration and error-correction models, which may uncover the nature and sensitivity of the ERV-trade nexus. In addition, GARCH models are used to generate the ERV variable used in the study.

MODEL SPECIFICATION

The objective of this study is to assess the effects of exchange rate volatility on the disaggregated U.S. sectoral exports to South Africa. Drawing on the existing empirical literature in this area, we specify that a standard long-run export demand function for commodity i may take the following form (see, for example, Ozturk and Kalyonku, 2009; Choudhry, 2005; Arize, 1998, 1996, 1995; and Asseery and Peel, 1991):

$$\ln X_{it} = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln P_{it} + \beta_3 \ln RER_t + \beta_4 \ln ERV_t + \varepsilon_t \quad (1)$$

Where X_{it} is real export volume of commodity i in period t , Y_t is the real income of South Africa in period t , P_{it} is the relative price of exports of commodity i in period t , RER_t is the real exchange rate between the U.S. dollar and the South African rand, ERV_t is a measure of exchange rate volatility, and ε_t is a white-noise disturbance term.

Economic theory posits that the real income level of the domestic country's trading partners would have a positive effect on the demand for its exports. Therefore, *a priori*, we would expect that $\beta_1 > 0$. On the

other hand, if the relative price of exports rise (fall), domestic goods become less (more) competitive than foreign goods, causing the demand for exports to fall (rise). Therefore, *a priori*, one would expect that β_2 , which measures the competitiveness of U.S. exports relative to South African domestic production, is negative. Similarly, if a real depreciation of the U.S. dollar, reflected by a decrease in the RER, is to increase export earnings of industry *i*, we would expect an estimate of β_3 to be negative. Of course, this will at the same time imply that the South African import demand for commodity *i* is elastic. If, however, the South African import demand for commodity *i* were inelastic, we would expect β_3 to be positive. The last explanatory variable is a measure of exchange rate volatility. Various measures of real ERV have been proposed in the literature. Some of these measures include (1) the averages of absolute changes, (2) the standard deviations of the series, (3) the deviations from the trend, (4) the squared residuals from the ARIMA or ARCH or GARCH processes, and (5) the moving sample standard deviation of the growth rate of the real exchange rate. Since the effects of ERV on exports have been found to be empirically and theoretically ambiguous (Bredin, *et al.* 2003), β_4 could be either positive or negative.

Equation (1) shows the long-run relationships among the dependent and independent variables in our model. Given the recent advances in time-series analysis, in estimating the long-run model outlined by equation (1), it is now a common practice to distinguish the short-run effects from the long-run effects. For this purpose, equation (1) should be specified in an error-correction modeling (ECM) format. This method had been used in many recent studies including Bahmani-Oskooee and Hegerty (2009), Bahmani-Oskooee and Wang (2008, 2009), Bahmani-Oskooee and Mitra (2008), Bahmani-Oskooee and Kovyryalova (2008), and Bahmani-Oskooee and Ardalani (2006). According to Bahmani-Oskooee and Wang (2008), such an approach is warranted given that the measure of exchange rate volatility is a stationary variable (see, for example, De Vita and Abbot, 2004; Bahmani-Oskooee & Payesteh, 1993; and Doyle, 2001), whereas the other variables in equation (1) are non-stationary. Therefore, following Pesaran, Shin, and Smith (2001) and their method of bounds testing or the Autoregressive Distributed Lag (ARDL) approach to cointegration analysis, we rewrite equation (1) as an error-correction model in equation (2) below.

$$\Delta \ln X_t = \alpha_0 + \sum_{i=1}^n \beta_i \Delta \ln X_{t-i} + \sum_{i=0}^n \gamma_i \Delta \ln Y_{t-i} + \sum_{i=0}^n \delta_i \Delta \ln P_{t-i} + \sum_{i=0}^n \eta_i \Delta \ln RER_{t-i} + \sum_{i=0}^n \varphi_i \Delta \ln ERV_{t-i} + \lambda_0 \ln X_{t-1} + \lambda_1 \ln Y_{t-1} + \lambda_2 \ln P_{t-1} + \lambda_3 \ln RER_{t-1} + \lambda_4 \ln ERV_{t-1} + \omega_t \tag{2}$$

Where Δ is the difference operator and the other variables are as defined earlier. Pesaran, Shin, and Smith's (2001) bounds testing approach to cointegration is based on two procedural steps. The first step involves using an F-test or Wald test to test for joint significance of the no cointegration hypothesis $H_0 : \lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 0$ against an alternative hypothesis of cointegration, $H_1 : \lambda_0 \neq 0, \lambda_1 \neq 0, \lambda_2 \neq 0, \lambda_3 \neq 0, \lambda_4 \neq 0$. This test is performed using equation (2). The advantage of this approach is that there is no need to test for unit roots, as is commonly done in cointegration analysis. Pesaran, Shin, and Smith (2001) provide two sets of critical values for a given significance level with and without time trend. One assumes that the variables are stationary at the levels or I(0), and the other assumes that the variables are stationary at the first difference or I(1). If the computed F-values exceed the upper critical bounds value, then H_0 is rejected signaling cointegration among the independent variables. If the computed F-value is below the critical bounds values, we fail to reject H_0 . Finally, if the computed F-statistic falls within the boundary, the result is inconclusive. After establishing cointegration, the second step involves estimation of the long-term elasticities and the error-correction model.

DATA SOURCES AND VARIABLES

Our export data time series spans a 20-year period from January 1990 through December 2009, leading to 240 monthly observations. Monthly data on real export volume and prices are taken from the Global Trade Information Services, *World Trade Atlas Database*. Monthly data on real export volumes and prices have been converted into export volume indices and export price indices with 2005 serving as the base (=100). The study focuses on the top ten export commodities defined at the 2-digit Harmonized System (HS) codes level, and selected based on their average export value between 1990 and 2009. They are: Machinery (HS 84); Passenger Vehicles (HS 87); Aircraft and Spacecraft (HS 88); Electrical Machinery (HS 85); Optical and Medical Instruments (HS 90); Organic Chemicals (HS 29); Mineral Fuel and Oil (HS 27); Cereals (HS 10); Plastic (HS 39); and Miscellaneous Chemical Products (HS 38).

The real income variable for South Africa is proxied by the industrial production index (2005=100) of South Africa. The underlying series is obtained from the International Monetary Fund's *International Financial Statistics database* and from the Organization for Economic Cooperation and Development's online database.

The relative price ratio for U.S. exports is calculated as the ratio of the export price index of each commodity to the price level, proxied by the consumer price index (2005=100) of South Africa. The export price index for each of the export products is computed using the unit prices taken from the Global Trade Information Services, *World Trade Atlas Database*, while the consumer price index is also obtained from the International Monetary Fund's *International Financial Statistics database*.

Following Bahmani-Oskooee and Wang (2008, 2009), and Sekkat and Varoudakis (2000), the real exchange rate, RER_t , is constructed as:

$$RER_t = \left(\frac{ER_t \times P_t^{US}}{P_t^{SA}} \right) \quad (3)$$

where RER_t is the real exchange rate, ER_t is the bilateral nominal exchange rate between the United States and South Africa defined as number of rand per U.S. dollar at time t, P_t^{SA} is the consumer price index (2005=100) of South Africa at time t, and P_t^{US} is the consumer price index (2005=100) of the U.S. at time t. The monthly data on nominal exchange rates are taken from the IMF, *International Financial Statistics database*.

Finally, we use three alternative measures of exchange rate volatility in this study so we may test the sensitivity of our results. It should be noted at this juncture that there is no unique way to measure real exchange rate volatility. The first ERV measure is obtained using the estimated GARCH (1,1) model, which has also been used in recent studies by, among others, Chowdhury and Wheeler (2008), Choudhury (2005), and Gheong, Mehari, and Williams (2005). We make use of real as opposed to nominal exchange rates in our measurement. As Choudhury (2005) points out, unlike other measures of ERV that can potentially ignore information on the stochastic processes by which exchange rates are generated, ARCH-type models capture the time-varying conditional variance as a parameter generated from a time-series model of the conditional mean and variance of the growth rate, and thus are very useful in describing volatility clustering.

The GARCH (1,1) model we estimate is based on an autoregressive model of order 2 (AR(2)) of the first difference of the real exchange rate and it takes the following form:

$$\ln RER_t = \beta_0 + \beta_1 \ln RER_{t-1} + \beta_2 \ln RER_{t-2} + e_t, \quad \text{where } e_t \sim N(0, u_t^2) \quad (4)$$

$$u_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \alpha_2 u_{t-1}^2 \quad (5)$$

The estimated conditional variance (u_t^2) from Equation (4) is used as our measure of ERV.

Our second measure of volatility is constructed following Bredin, Fountas, and Murphy (2003), Weliwita, Ekanayake, and Tsujii (1999), Chowdhury (1993), Lastrapes and Koray (1990), and Koray and Lastrapes (1989). Following these authors the real exchange rate volatility measure is constructed as:

$$VOL_t = \left[\frac{1}{m} \sum_{i=1}^m (\ln RER_{t+i-1} - \ln RER_{t+i-2})^2 \right]^{1/2} \quad (6)$$

where VOL_t is the volatility of real exchange rate, RER_t is the real exchange rate and $m = 4$ is the order of the moving average. According to Koray and Lastrapes (1989), this measure can capture general movements in real exchange rate volatility and exchange rate risk over time.

We also experimented with a third measure of volatility. This alternative measure of exchange rate volatility is defined as the time-varying twelve-month coefficient of variation of the real exchange rate given by:

$$CV_{t+m} = \frac{\left[\frac{1}{m} \sum_{i=1}^m (RER_{t+i-1} - \overline{RER})^2 \right]^{1/2}}{\overline{RER}} \quad (7)$$

where \overline{RER} is the mean of the bilateral real exchange rate between months t and $t+m-1$.

EMPIRICAL RESULTS

Applying the ARDL approach to cointegration to monthly data from January 1990 to December 2009, we assess the exports of the U.S. to South Africa for the top ten export products. First, we estimate equation (2). Following Bahmani-Oskooee and Mitra (2008) we impose a maximum of four lags on each first differenced variable and employ Akaike's Information Criterion (AIC) to select the optimum lag length. Choosing a combination of lags that minimizes the AIC, we then test whether the variables for each industry are cointegrated. These results are shown in Table 1.

Table 1 reveals that seven of the ten industries (HS84, HS87, HS88, HS90, HS29, HS10, HS39) encompass an F-statistic above the upper bound of 3.79, implying that these industries' five variables are cointegrated. This result is consistent across industries for all three volatility measures. The other three industries (HS27, HS38, HS85) reveal an F-statistic below the lower bound of 2.62, indicating no cointegration among variables. Therefore, only those seven industries that exhibit cointegrating relationships among variables are used to analyze the effects of ERV on exports.

We first estimate Equations (4) and (5) for this period, and the results are shown in Table 2. The coefficients of α_0 , α_1 , and α_2 are all positive and $\alpha_1 + \alpha_2 = 0.94 < 1$. These results ensure that conditional variance is strictly positive, thus satisfying the necessary conditions of the ARCH model in Equation (5). Our findings also demonstrate that the estimated coefficients of e_{t-1}^2 and u_{t-1}^2 are statistically

significant at the 1% level, implying that significant ARCH and GARCH effects exist in the data. The predicted value of Equation (5) provides our first measure of real exchange rate volatility.

Table 1: Cointegration Test Results of Top Ten Export Commodities from the U.S. to South Africa

Industry	Volatility Measure	F	ECM	Cointegrated?
HS 84: Machinery	1	3.83**	-0.247 (5.22)	Yes
	2	4.47**	-0.338 (2.74)	Yes
	3	3.80**	-0.054 (2.25)	Yes
HS 87: Passenger Vehicles	1	6.28**	-0.412 (2.85)	Yes
	2	5.65**	-0.428 (3.19)	Yes
	3	6.13**	-0.421 (3.08)	Yes
HS 88: Aircraft and Spacecraft	1	8.54**	-0.325 (4.51)	Yes
	2	5.90**	-0.184 (1.66)	Yes
	3	7.81**	-0.249 (4.05)	Yes
HS 85: Electrical Machinery	1	2.77	-0.178 (1.97)	No
	2	2.03	-0.183 (2.08)	No
	3	2.61	-0.136 (1.59)	No
HS 90: Optical and Medical Instruments	1	9.07**	-0.563 (3.71)	Yes
	2	9.11**	-0.570 (3.79)	Yes
	3	7.67**	-0.573 (3.75)	Yes
HS 29: Organic Chemicals	1	9.05**	-0.709 (4.02)	Yes
	2	9.29**	-0.725 (4.17)	Yes
	3	8.21**	-0.776 (4.22)	Yes
HS 27: Mineral Fuel and Oil etc.	1	1.48	-0.844 (5.33)	No
	2	1.38	-0.923 (5.93)	No
	3	1.54	-0.844 (5.01)	No
HS 10: Cereals	1	4.42**	-0.512 (2.18)	Yes
	2	6.56**	-0.629 (2.87)	Yes
	3	5.05**	-0.560 (2.43)	Yes
HS 39: Plastic	1	6.59**	-0.308 (5.22)	Yes
	2	9.56**	-0.349 (2.06)	Yes
	3	7.01**	-0.527 (1.62)	Yes
HS 38: Miscellaneous Chemical Products	1	1.31	-0.464 (3.22)	No
	2	1.93	-0.411 (2.89)	No
	3	1.34	-0.483 (3.37)	No

Note: This table summarizes the results of the bounds testing approach to cointegration. The figures in parentheses are absolute value of the t-statistic. ECM represents the error-correction term. Volatility measures 1, 2, and 3 are defined earlier in equations (4) and (5), (6), and (7), respectively. The upper bound critical value for the F-statistic with unrestricted intercept and no trend at the 5% level of significance is 3.79. The lower bound critical value is 2.62. These values are taken from Pesaran, Shin, and Smith (2001, Table CI(iii) Case III, p. 300). ** indicates the significance at the 5 percent level.

Table 2: Estimation of Real Exchange Rate Variance as a GARCH (1, 1) Process

$$\ln RER_t = 0.00730 + 0.17667 \ln RER_{t-1} + 0.06874 \ln RER_{t-2}$$

(2.94) (2.09)* (0.84)

$$u_t^2 = 0.00013 + 0.25977 e_{t-1}^2 + 0.68601 u_{t-1}^2$$

(2.69)** (3.45)** (7.31)**

Log L = 453.19 *N* = 237

Note: This table shows the results of the first measure of volatility as defined by Equations (4) and (5). The figures in parentheses are t-statistics. * and ** indicate the statistical significance at the 5% and 1% level, respectively.

The estimated coefficients for the seven cointegrated industries are presented in Table 3. Following the studies by Bahmani-Oskooee and Hegerty (2009), Bahmani-Oskooee and Wang (2008, 2009), Bahmani-Oskooee and Mitra (2008), Bahmani-Oskooee and Kovyryalova (2008), and Bahmani-Oskooee and Ardalani (2006), we report only the short-run volatility coefficients and all the long-run coefficients.

Short-Run Effects of Exchange Rate Volatility: The short-run estimated coefficients on ERV presented on the left panel in Table 3 reveal a mixture of negative and positive signs regardless of the volatility

measure employed. There is also a significance variation of the exchange rate volatility on exports among industries in the short-run. The first industry, machinery, has a negative and statistically significant coefficient regardless of the volatility measure. The reason for this may be because of South Africa's ability to import machinery from other trading partners. Passenger vehicles industry has a negative but statistically insignificant impact in the short-run in all three cases.

The next two industries, aircraft and spacecraft, and medical and optical instruments, have positive signs under all three measures of volatility. Each of the coefficients is also statistically significant in all cases. The organic chemicals industry has a positive and statistically significant coefficient under the first and third measure of volatility but has a negative and insignificant effect under the second measure. The last two industries, cereals and plastic, have mixed results. In general, the impact of ERV on exports for these seven industries is mixed in the short-run. The U.S. dominates these industries globally, and South Africa is import dependent on these products, so even though exchange rates have increased in volatility since the 1990's, demand for these goods have continued. That cereals and plastics render mixed results may be due to South Africa's strong domestic production in these industries.

Long-Run Effects of Exchange Rate Volatility: The long-run coefficient estimates are shown in the right panel of Table 3. As economic theory postulates, the real income variable renders a positive sign in all cases, regardless of the volatility measure. This coefficient is statistically significant in the majority of industries including HS84, HS87, HS88, HS90, HS29, HS10, and HS39; the coefficient for cereals (HS 10) is insignificant under volatility measures (1) and (3), while the coefficients for plastic (HS 39) and cereals are insignificant under volatility measure (2). The relative price variable displays the expected negative sign and is statistically significant at the 1% level in 19 of the 21 cases, and at the 5% level for machinery (HS 85) under volatility measures (2) and (3). This result is similar to those of Bahmani-Oskooee and Mitra (2008), Bahmani-Oskooee and Kovryalova (2008), and Bahmani-Oskooee and Ardalani (2006).

The real exchange rate coefficient has a negative sign in all cases and is statistically significant in the majority of cases, except for machinery and passenger vehicles. Finally, the estimated coefficients on ERV show a mixture of negative signs for machinery, passenger vehicles, optical and medical instruments, organic chemicals, and plastic industries and positive signs for aircraft and spacecraft, and cereal, regardless of the volatility measure used. Under volatility measure (1), five of the seven coefficients are negative and only three coefficients are statistically significant. Under volatility measures (2) and (3), five of the seven coefficients are negative and four coefficients are statistically significant at either the 5% or 1% levels. Thus, ERV has a negative effect in five of the seven industries presented in Table 3. They include machinery, passenger vehicles, optical and medical instruments, organic chemicals, and plastic. Our findings are somewhat similar to those of Bahmani-Oskooee and Hegerty (2009) and Bahmani-Oskooee and Wang (2008, 2009). In general, in the long-run, ERV appears to have a negative effect on the U.S. exports to South Africa.

SUMMARY AND CONCLUSIONS

In this paper we have examined the dynamic relationship between exports and exchange rate volatility in United States' exports to South Africa in the context of a multivariate error-correction model. Estimates of the long-run export demand functions were obtained by employing the bounds testing approach to cointegration using monthly data for the period January 1990 - December 2009.

The cointegration results clearly show that there exists a long-run equilibrium relationship between real exports and real foreign economic activity, relative prices, real exchange rate, and real exchange rate volatility, in seven of the ten commodities selected. All the specifications yielded expected signs for the coefficients. All our coefficients are statistically significant either at the 1% or 5% levels. Of the seven

products analyzed in detail, five of them, namely, machinery, passenger vehicles, optical and medical instruments, organic chemicals, and plastic, have negative signs for the ERV variable indicating that ERV tends to deter exports of these products in the long-run.

Table 3: Short-Run and Long-Run Coefficient Estimates

Panel A: Volatility Measure 1: ARCH Volatility Measure as Defined in Equations (4) and (5)									
Industry	Short-Run Coefficient Estimates				Constant	Long-Run Coefficient Estimates			
	$\Delta \ln V_{1t}$	$\Delta \ln V_{1t-1}$	$\Delta \ln V_{1t-2}$	$\Delta \ln V_{1t-3}$		$\ln Y_t$	$\ln P_t$	$\ln RER_t$	$\ln V_{1t}$
Machinery			-0.086*		-19.506	5.901**	-1.288**	-1.307*	-0.168
			(2.21)			(3.90)	(3.43)	(2.73)	(1.31)
Passenger Vehicles				-0.071	-41.366	9.837**	-1.288**	-1.307*	-0.101
				(1.29)		(5.33)	(3.43)	(2.73)	(1.62)
Aircraft & Spacecraft			0.238*		40.332	7.103*	-0.752**	-1.307*	0.234
			(2.11)			(2.18)	(4.20)	(2.73)	(1.52)
Optical & Med. Inst.	0.068*	0.099**			1.562	1.001*	-1.533**	-0.818**	-0.076*
	(2.09)	(3.21)				(2.31)	(9.78)	(5.46)	(1.96)
Organic Chemicals				0.101**	-0.538	1.098*	-0.953**	-0.043	-0.133**
				(2.93)		(2.21)	(4.25)	(1.26)	(2.90)
Cereals			-0.469*		-15.156	6.621	-1.821**	-1.390**	0.759*
			(2.17)			(1.29)	(9.23)	(3.01)	(2.31)
Plastic				-0.055*	-6.687	2.728**	-0.961**	-0.587*	-0.038
				(2.11)		(3.88)	(3.01)	(2.14)	(1.53)

Panel B: Volatility Measure 2: Volatility Measure as Defined in Equation (6)									
Industry	Short-Run Coefficient Estimates				Constant	Long-Run Coefficient Estimates			
	$\Delta \ln V_{1t}$	$\Delta \ln V_{1t-1}$	$\Delta \ln V_{1t-2}$	$\Delta \ln V_{1t-3}$		$\ln Y_t$	$\ln P_t$	$\ln RER_t$	$\ln V_{1t}$
Machinery	-0.039*		-0.020*		-20.148	7.958**	-1.148*	-0.300	-1.832*
	(2.54)		(2.58)			(3.06)	(2.29)	(1.56)	(7.95)
Passenger Vehicles			-0.022		-44.811	9.581**	-2.788**	-0.388	-0.038
			(1.27)			(5.07)	(9.43)	(0.93)	(1.62)
Aircraft & Spacecraft			0.064*		30.844	7.771*	-0.721**	-0.941*	0.060
			(2.04)			(2.02)	(4.55)	(2.29)	(1.28)
Optical & Med. Inst.		0.038*	0.046**		1.645	1.543*	-2.165**	-0.717**	-0.298**
		(2.23)	(2.81)			(1.97)	(9.47)	(4.59)	(3.35)
Organic Chemicals		-0.117			-2.462	1.195*	-0.482**	-0.411**	-0.374**
		(1.58)				(2.02)	(2.99)	(2.96)	(5.45)
Cereals		-0.112			-8.859	6.732	-3.575**	-1.624*	0.442
		(1.61)				(1.43)	(9.38)	(2.23)	(1.21)
Plastic		0.054*	0.035	0.030*	-6.019	5.393	-1.149**	-2.943**	-0.137**
		(2.58)	(1.85)	(2.10)		(0.97)	(5.22)	(2.52)	(6.46)

Panel C: Volatility Measure 3: Volatility Measure as Defined in Equation (7)									
Industry	Short-Run Coefficient Estimates				Constant	Long-Run Coefficient Estimates			
	$\Delta \ln V_{1t}$	$\Delta \ln V_{1t-1}$	$\Delta \ln V_{1t-2}$	$\Delta \ln V_{1t-3}$		$\ln Y_t$	$\ln P_t$	$\ln RER_t$	$\ln V_{1t}$
Machinery	-0.038*		-0.020		-23.043	7.958**	-1.477*	-0.583	-1.858**
	(2.54)		(1.73)			(3.06)	(2.29)	(1.25)	(6.48)
Passenger Vehicles		-0.086			-39.438	9.581**	-2.788**	-0.338	-0.038
		(1.45)				(5.07)	(9.43)	(0.94)	(1.18)
Aircraft & Spacecraft	0.255*		0.301*		41.708	7.710*	-0.721**	-0.941*	0.060
	(2.08)		(2.44)			(2.02)	(4.55)	(1.80)	(1.27)
Optical & Med. Inst.		0.111**			-0.124	1.543*	-2.165**	-0.717**	-0.298**
		(3.39)				(1.97)	(9.47)	(4.59)	(3.35)
Organic Chemicals	0.302**				1.090	0.631*	-0.482**	-0.411**	-0.374**
	(2.78)					(2.08)	(2.99)	(2.97)	(5.45)
Cereals		0.528			-19.835	6.732	-3.375**	-1.624*	0.442
		(1.91)				(1.42)	(9.38)	(2.23)	(1.21)
Plastic				0.067	18.177	5.398*	-1.149**	-2.943**	-0.137**
				(1.86)		(2.01)	(5.22)	(2.52)	(4.59)

Note: This table summarizes the results obtained using the ARDL model defined in Equation (2). The figures in parentheses are absolute value of t-statistic. ** and * indicate the statistical significance at the 1% and 5% levels, respectively.

The short-run dynamics also indicate that, in general, the impact of ERV on exports in these seven industries is mixed in the short-run. These results point out to the decreasing competitiveness of U.S. exports in the global economy despite the depreciating value of the dollar over time. It underscores the

degree to which a developing country such as South Africa has succeeded in finding alternative markets in Europe and especially in Asia in the last decade.

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