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The Real Exchange Rate Volatility and U.S. Exports: An Empirical Investigation

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ABSTRACT

This paper investigates effects of exchange rate volatility on U.S. exports, using disaggregated sectoral data on U.S. exports to its major trading partners. In this paper, we use a generalized ARCH-type model (GARCH) to generate a measure of exchange rate volatility which is then tested in a model of U.S. exports. The analysis uses monthly trade data for the period from January 1990 through December 2007. Testing sectoral trade data allows us to detect whether the direction or magnitude of the impact of volatility differs depending on the types of goods that are traded. The results obtained in this paper suggest that the increase in the volatility of exchange rate exert a negative effect upon export demand in majority of the products: the study finds evidence for significant negative effects in six of ten export products, and significant positive effects in four products.

JEL: F14, F31

KEYWORDS: exchange rate volatility, U.S. Exports, Real exchange rate

INTRODUCTION

The consequences of exchange rate volatility on real exports have long been at the center of debate among researchers. There has been a considerable research concerning the impact of exchange rate volatility on the volume of international trade since the advent of flexible exchange rates in 1973. The interest in this field was incited by two main developments: (a) both the real and nominal exchange rates have undergone periods of substantial volatility since 1973; and (b) during the same period, international trade declined significantly among industrialized countries. Despite the large number of studies conducted, no real consensus has emerged regarding the impact of exchange rate volatility on trade flows.

The empirical literature reveals that the effects of exchange rate volatility on exports are ambiguous. While a large number of studies find that exchange rate volatility 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), Bahmani-Oskooee and Ltaifa (1992), Bini-Smaghi (1991), Perée and Steinheir (1989), and Koray and Lastrapes (1989) find evidence for negative effects. 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. In addition, Aristotelous (2001), Oskooee and Payestch (1993), Bahmani-Oskooee (1991), and Hooper and Kohlhagen (1978) have reported no significant relationship between exchange rate volatility and exports. Majority of these studies have focused on developed countries while developing countries have received little attention.

Exchange rate volatility may have a direct effect on trade through uncertainty and adjustment costs. Further, it may have an indirect effect through its effect on the structure of output and investment and on government policy. While the empirical research on the nexus between exchange rate volatility and volume of trade is inconclusive, a growing body of literature points towards exchange rate volatility causing a decline in trade. If exchange rate volatility tends to deter volume of exports, the volume of trade could be considerably higher in a more stable exchange rate setting. Those who argue that exchange rate volatility promotes exports point out that exchange rate volatility makes exporting more attractive.

In this paper, we investigate the effects of exchange rate volatility on top ten categories of exports by the United States to its top ten trading partners (Canada, China, Mexico , Japan, Germany, the United Kingdom, South Korea, France, Netherlands, and Brazil), during the period from January 1990 to December 2007. Past studies on the impact of exchange rate volatility on the U.S. exports include Byrne, Darby, and MacDonald (2008), Choudhry (2005), Sukar and Hassan (2001), Arize (1995), Belanger, *et al.* (1992), Klein (1990), Lastrapes and Koray (1990), Koray and Lastrapes (1989), and Cushman (1988). The use of the U.S. monthly trade data is by no means unique to this paper as some previous studies have also used similar data. However, the methodology used in this study incorporates many of the recent developments in the literature which may help to uncover the nature of the relationship. For example, the study tests for the stationarity of the financial and macroeconomic time-series data used in the study and uses cointegration technique to establish a long-run relationship among variables and error-corrections models to establish a short-run dynamics of the model. In addition, GARCH models are used to generate the exchange rate volatility variable which is used in the study.

The remainder of the paper is organized as follows: Section 2 provides a brief literature review. In Section 3, the empirical framework of the current study is set out by specifying model. Section 4 discusses the variable definitions and outlines the data sources. Empirical results of unit root tests, cointegration tests, and error-correction model estimates are presented in Section 5. Section 6 presents a summary and a brief conclusion as to the results obtained in this study.

LITERATURE REVIEW

In this section we present a brief overview of some related work. Although there has been considerable research concerning the impact of exchange rate volatility on trade, we only present findings of studies that analyze the effects of exchange rate volatility on U.S. trade flows.

A study conducted by Byrne, Darby, and MacDonald (2008) analyze the impact of exchange rate volatility on the volume of bilateral U.S. trade flows using sectoral data. The study utilizes annual data over the period 1989-2001 for a cross section of 6 countries and 22 industries. The study finds that pooling all industries together provides evidence of a negative effect on trade from exchange rate volatility. Moreover, the effects of exchange rate volatility on trade is negative and significant for differentiated goods but insignificant for homogeneous goods suggesting that sectoral differences do exist in explaining the different impact of volatility on trade.

Choudhry (2005) investigates the influence of exchange rate volatility on real exports of the U.S. 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 exchange rate volatility. The study finds significant and mostly negative effects of the exchange rate volatility on real exports.

Sukar and Hassan (2001) investigate the relationship between the U.S. trade volume and exchange rate volatility using cointegration and error-correction models. The study uses quarterly aggregate data covering the period 1975Q1 – 1993Q2 and a GARCH model was used to measure the exchange rate volatility. The study finds evidence for a significantly negative relationship between U.S. export volume and exchange rate volatility. However, the short-run dynamics of the relationship shows that the effect of exchange rate volatility is insignificant.

Arize (1995) analyzes the effects of real exchange rate volatility on the proportions of bilateral exports of nine categories of goods from the United States to seven major industrial countries. The data are monthly series over the period February 1978 to June 1986. The volatility measure used is the standard deviation of the monthly percentage change in the bilateral exchange rate between the U.S. and the importing country over the period t and t-12. The study finds different effects of exchange rate volatility across 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 major impact on the allocation of resources.

Lastrapes and Koray (1990) investigate the relation between exchange rate volatility, international trade and the macro economy in the context of a VAR model. The model is estimated for U.S. multilateral trade over the floating rate period and includes a moving standard deviation measure of real exchange volatility. The study finds some evidence of a statistically significant relationship between volatility and trade, but the moving average representation of the system suggests that the effects are quantitatively small. The study also finds that exchange rate volatility is influenced by the state of the economy.

A study by Klein (1990) analyze the effects of exchange rate volatility on the proportions of the bilateral exports of nine categories of goods from the United States to seven major industrial countries using fixed effects framework. The data are monthly series over the period February 1978 to June 1986. The study finds mixed evidence on the effects of exchange rate volatility on exports. In six categories the volatility of real exchange rate significantly affects the volume of exports and in five of these categories the effect is positive.

Koray and Lastrapes (1989) investigates the relationship between real exchange rate volatility and bilateral imports from five countries, namely, the United Kingdom, France, Germany, Japan, and Canada, using a vector autoregression (VAR) model. The study uses aggregate monthly data from January 1959 to December 1985. The findings of the study suggest that the effects of volatility on imports is weak, although permanent shocks to volatility do have a negative impact on imports, and those effects are relatively more important over the flexible rate period.

Finally, Cushman (1988) conducted a study to test for real exchange rate volatility effects on U.S. bilateral trade flows using annual data for the period 1974-1983. The study finds evidence for significant negative effects in five of six import flows, and in two of six U.S. export flows with one export flow showing a significant positive effect.

The current study uses the U.S. monthly disaggregated trade data covering the period from January 1990 to December 2007 focusing on the top ten export products to top ten trading partners. The methodology used in this study incorporates many of the recent developments in the literature, namely, cointegration and error-correction models, which may help to uncover the nature of the relationship. In addition, GARCH models are used to generate the exchange rate volatility variable which is used in the study.

MODEL SPECIFICATION

As indicated in the previous section, the main objective of this study is to assess the effects of exchange rate volatility on the disaggregated U.S. sectoral exports to its major trading partners. Previous studies that have investigated the influence of exchange rate volatility on exports have used a measure of exchange rate volatility (or risk) as an explanatory variable in aggregate export demand function.

Drawing on the existing empirical literature in this area, we specify a standard long-run export demand function for commodity i may take the following form (see, for example, Choudhry, 2005, 1993; Klaasses, 2004; Arize, 1998, 1995; Pozo, 1992; Asseery and Peel, 1991; Kenen and Rodrik (1986); and Goutor, 1985):

$$\ln X_{it} = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln P_{it} + \beta_3 \ln V_t + \varepsilon_t \tag{1}$$

where X_{it} is real export volume of commodity i in period t, Y_t is the real foreign income in period t, P_{it} is the relative price of exports of commodity i in period t, V_t is a measure of exchange rate volatility, and ε_t is a white-noise disturbance term.

Economic theory suggests that the real income level of the trading partners of the domestic country would affect the demand for exports positively. Therefore, *a priori*, it is expected that $\beta_1 > 0$. On the other hand, if the relative prices rise (fall), it would cause the domestic goods to become less (more) competitive than foreign goods and, therefore, the demand for exports will fall (rise). Therefore, *a priori*, it is expected that that $\beta_2 < 0$. This variable measures the competitiveness of U.S. exports. The last explanatory variable is a measure of exchange rate volatility. Various measures of real exchange rate volatility 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) deviations from 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. The effect of exchange rate volatility on exports is ambiguous and the international empirical evidence on the influence of volatility on exports is mixed. As Bredin, *et al.* (2003) points out, the effects of exchange rate volatility on exports is also ambiguous from a theoretical point of view. Therefore, β_3 is expected to be either positive or negative.

In order to establish whether there is a long-run equilibrium relationship among the variables in Equation (1), this study uses the cointegration and error-correction models developed by Engle and Granger (1987). Some of the previous studies that used this methodology include Onafowara and Owoye (2008), Choudhry (2005), Bredin, *et al.* (2003), Sukar and Hassan (2001), Fountas and Aristotelous (1999), Arize (1995, 1998), Holly (1995), Lastrapes and Koray (1990), and Koray and Lastrapes (1989). The cointegration approach requires testing the time-series properties of individual variables in Equation (1) for stationarity using unit root tests. If all variables in Equation (1) are integrated of the same order, then the equation is estimated by employing the multivariate cointegration methodology suggested by Johansen (1988) and Johansen and Juselius (1990).

DATA SOURCES AND VARIABLES

Monthly data for the period from January 1990 to December 2007 were used for estimation. The analysis focuses on top ten export products of the U.S. to major markets for U.S. exports, namely, Canada, China, Mexico, Japan, Germany, the United Kingdom, South Korea, France, Netherlands, and Brazil. Monthly data on real export volume and prices were taken from the Global Trade Information Services, *World Trade Atlas Database*. Monthly data on real export volumes and prices were converted into export volume indices and export price indices with year 2000 as the base year. Thus the export volume index and export price index take the value of 100 in the base year. The study focuses on the top ten export commodities defined at the 2-digit Harmonized System (HS) codes level. They are: Machinery (HS 84); Electrical Machinery (HS 85); Passenger Vehicles (HS 87); Aircraft and Spacecraft (HS 88); Optical and Medical Instruments (HS 90); Plastic (HS 39); Mineral Fuel and Oil etc (HS 27); Precious Stones and Metals (HS 71); Organic Chemicals (HS 29); and Pharmaceutical Products (HS 30).

The real foreign income variable is proxied by the trade-weighted average of the industrial production indices (2000=100) of the U.S.'s major export partners. The underlying series were obtained from the International Monetary Fund's *International Financial Statistics database* and from the Organization for Economic Cooperation and Development (OECD)'s online database. The trade-weighted average of the industrial production index of the U.S.'s 10 major export partners was calculated as:

$$Y_t = \sum_{j=1}^{10} EX_{jt}^{w} \times Y_{jt} \tag{2}$$

where Y_t is the real foreign income at time t, EX_{it}^{w} is a weight of U.S. exports (or export share) to the j[th] country at time t, and Y_{jt} is the industrial production index of the j[th] country at time t. The top 10 export partner countries of the U.S. are: Canada, China, Mexico, Japan, Germany, the United Kingdom, South Korea, France, Netherlands, and Brazil.

The relative price ratio for U.S. exports was calculated as the ratio of the export price index of each commodity to the world price level, which is proxied by a trade-weighted average of the consumer price index of the 10 major export partners of the United States. The consumer price indices for the major export trading partners were also obtained from the International Monetary Fund's *International Financial Statistics database*. The trade-weighted average of the consumer price index of the U.S.'s 10 major export partners was calculated as:

$$P_t^{w} = \sum_{j=1}^{10} EX_{jt}^{w} \times P_{jt} \tag{3}$$

where P_t^{w} is the world price level at time t, EX_{it}^{w} is a weight of U.S. exports (or export share) to the j[th] country at time t, and P_{jt} is the consumer price index (2000=100) of the j[th] country at time t. The trade-weighted average of the consumer price index was also converted into a new series with the base year 2000.

Following Sekkat and Varoudakis (2000), the trade-weighted real exchange rate, RER_t, was constructed as,

$$RER_t = \sum_{j=1}^{10} EX_t^{w} \times \left(\frac{ER_{jt} \times P_{jt}}{P_t^{US}} \right) \tag{4}$$

where RER_t is the real exchange rate, ER_{jt} is the bilateral nominal exchange rate (the home currency price of a unit of foreign currency, for example, the number of Japanese Yens per US $) with country j at time t, and EX_{it}^{w} is a weight of U.S. exports (or export share) to the j[th] country at time t, P_{jt} is the consumer price index (2000=100) of the j[th] country at time t, and P_t^{US} is the consumer price index (2000=100) of the U.S. The monthly data on nominal exchange rates were taken from the IMF, *International Financial Statistics database*.

Finally, the series of exchange rate volatility were obtained using the estimated $\mathrm{GARCH}(1,1)$ model. We make use of real as opposed to nominal exchange rates in the measurement. As Choudhry (2005) points out, unlike other measures of exchange rate volatility which 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 $\mathrm{GARCH}(1,1)$ model we estimate is based on an autoregressive model of order 2 ($\mathrm{AR}(2)$) of the first difference of the real exchange rate and it takes the following form:

$$\ln RER_t = \beta_o + \beta_1 \ln RER_{t-1} + \beta_2 \ln RER_{t-2} + e_t, \qquad \text{where} \quad e_t \sim N(0, u_t^2) \tag{5}$$

$$u_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \alpha_2 u_{t-1}^2 \tag{6}$$

The estimated conditional variance (u_t^2) from Equation (7) is used as our measure of exchange rate volatility.

EMPIRICAL RESULTS

We first estimate Equations (5) and (6) for the period January 1990-December 2007, and the results are shown in Table 1. The coefficients of α_0 , α_1, and α_2 are all positive and $\alpha_1 + \alpha_2 = 0.85 < 1$. These results ensure that conditional variance is strictly positive, thus satisfying the necessary conditions of the ARCH model in Equation (6). These findings show that the estimated coefficients of e_{t-1}^2 and u_{t-1}^2 are statistically significant at the 10% and 1% levels, respectively. Therefore, significant ARCH and GARCH effects appear to exist in the data. The predicted value of Equation (6) provides a measure of real exchange rate volatility.

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

$$\ln RER_t = -0.00107 + 0.44051 \ln RER_{t-1} + 0.24243 \ln RER_{t-2}$$
$$(-0.200) \quad (6.411)^* \qquad (3.001)^*$$

$$u_t^2 = 0.00089 + 0.07792\, e_{t-1}^2 + 0.78092\, u_{t-1}^2$$
$$(1.301) \quad (1.850)^{**} \qquad (7.489)^*$$

$\text{Log}\, L = 242.77$ $\qquad$ N = 213

***Note**: This table shows the estimated results of the GARCH (1, 1) model. The predicted value of this model is used as the measure of exchange rate volatility. The figures in parentheses are t-statistics. * and ** indicate the statistical significance at the 1% and 10% level, respectively.*

Before we estimate equation (1), all the variables must be tested for the presence of unit roots. We use the Augmented Dickey-Fuller (ADF) test suggested by Fuller (1976) and Dickey and Fuller (1981) to test for unit roots. The ADF test was performed on the time series of $\ln X$, $\ln Y$, $\ln P$ and $\ln V$, and the test results together with optimal lag lengths are presented in Table 2. The ADF test was conducted on both the level and the first difference of the variables. The results show that all the variables have unit roots. However, the $\ln V$ variable is stationary at levels.

Having tested for unit roots, we then performed the trace test and the maximum eigenvalue test for the presence of cointegrating vectors for each model specification. The results of the cointegration tests are presented in Table 3 while the normalized cointegrating vectors are presented in Table 4. Both the trace test and the maximum eigenvalue test indicate that there is at least one cointegrating vector in each case. All the specifications yielded correct signs for the coefficients. All of the coefficients are statistically significant either at 1% or 5% level of significance. Hence, we interpret these specifications as the long-run export demand relationships for the United States for the period covered in this study. Of the ten products, six of them have negative signs for the exchange rate volatility variable indicating that exchange rate volatility tends to deter exports in the long-run, for these six products.

Table 2: Unit-Root Tests: Augmented Dickey-Fuller (ADF) Test Statistics

	Level				First Difference			
Variable	ADF_1	(k)	ADF_2	(k)	ADF_1	(k)	ADF_2	(k)
Real foreign income	-1.1363	(13)	-2.8479	(13)	-3.1767**	(14)	-3.4415**	(14)
Volatility	-4.3065*	(0)	-4.1955*	(0)	-13.9624*	(0)	-13.9707*	(0)
Exports of Mineral Fuel	-2.3614	(2)	-3.1241	(2)	-18.1346*	(1)	-18.0959*	(1)
Exports of Org. Chemicals	-1.9935	(2)	-2.5246	(1)	-16.0117*	(1)	-15.9730*	(1)
Exports of Pharmaceuticals	-2.1321	(1)	-2.8049	(1)	-13.5611*	(1)	-13.5980*	(1)
Exports of Plastic	-0.9631	(4)	-2.0838	(4)	-11.9828*	(3)	-11.9583*	(3)
Exports of Precious Stones	-1.8590	(2)	-2.1748	(1)	-15.7109*	(1)	-15.7044*	(1)
Exports of Machinery	-2.3497	(12)	-1.1742	(12)	-3.0464**	(11)	-3.6485**	(11)
Exports of Electric. Machinery	-1.0420	(2)	-0.3598	(3)	-19.8627*	(1)	-11.5919*	(2)
Exports of Passenger Vehicles	-1.4999	(14)	-2.1226	(14)	-4.2144*	(13)	-4.1891*	(13)
Exports of Aircraft	-2.5092	(1)	-2.5847	(1)	-20.5778*	(1)	-20.8064*	(1)
Exports of Optical Instruments	-2.0736	(4)	-2.0763	(3)	-11.4371*	(3)	-11.5790*	(3)
Price of Mineral Fuel	-2.0929	(3)	-2.0810	(3)	-14.3813*	(2)	-14.4860*	(2)
Price of Org. Chemicals	-1.2995	(1)	-1.3059	(1)	-13.5280*	(2)	-13.5048*	(2)
Price of Pharmaceuticals	-1.4364	(5)	-2.5653	(5)	-12.3426*	(4)	-12.3129*	(4)
Price of Plastic	-2.3146	(1)	-2.5025	(1)	-15.3488*	(1)	-15.3223*	(1)
Price of Precious Stones	-1.3684	(1)	-1.8529	(1)	-16.2793*	(1)	-9.2976*	(5)
Price of Machinery	-2.1364	(12)	-2.8020	(12)	-4.9147*	(11)	-4.9497*	(11)
Price of Electrical Machinery	-1.7631	(3)	-1.7132	(3)	-13.8375*	(2)	-13.8232*	(2)
Price of Passenger Vehicles	-1.6179	(2)	-2.7900	(1)	-15.5532*	(1)	-15.5683*	(1)
Price of Aircraft	-0.9489	(2)	-1.5181	(2)	-13.9744*	(1)	-14.1004*	(1)
Price of Optical Instruments	-1.0394	(1)	-2.7373	(1)	-13.7852*	(1)	-13.7717*	(1)

*This table shows the results of the Augmented Dickey-Fuller test for unit roots at both level and first difference. The figures in parentheses are optimal lag lengths (k) as determined by Schwarz Information Criterion (SIC). * and ** denote statistical significance at the 1% and 5% levels, respectively.*

ADF_1 tests H_0: $\theta_1 = 0$ in

$$\Delta \ln X_t = \beta_0 + \theta_1 \Delta \ln X_{t-1} + \sum_{j=1}^{m} \beta_j \ln X_{t-j} + \varepsilon_t \quad (8)$$

ADF_2 tests H_0: $\theta_2 = 0$ in

$$\Delta \ln X_t = \alpha_0 + \alpha_1 t + \theta_2 \Delta \ln X_{t-1} + \sum_{j=1}^{m} \alpha_j \ln X_{t-j} + \varepsilon_t \quad (9)$$

The critical values of ADF_1 statistics are -3.46 and -2.87 at 1% and 5% levels of significance, respectively. The critical values of ADF_2 statistics are -4.00 and -3.43 at 1% and 5% levels of significance, respectively.

Table 3: Results from Cointegration Tests for the Series: X, Y, P and V

	Maximum Eigenvalue Test				Trace Test			
Product	$r=0$	$r\le 1$	$r\le 2$	$r\le 3$	$r=0$	$r\le 1$	$r\le 2$	$r\le 3$
Mineral Fuel	30.95*	20.43	9.97	3.24	64.60*	33.64*	13.21	3.24
Org. Chemicals	28.67*	14.94	11.04	2.94	57.61*	28.93	13.99	2.94
Pharmaceuticals	28.14*	19.96	8.51	3.11	59.72*	31.58*	11.61	3.11
Plastic	28.58*	12.65	9.61	3.29	54.14*	25.55	12.90	3.29
Precious Stones	32.45*	12.70	10.04	3.33	65.52*	33.07*	13.37	3.33
Machinery	28.53*	14.15	9.34	3.74	55.78*	27.25	13.09	3.74
Elec. Machinery	28.01*	13.50	8.50	3.18	53.21*	25.20	11.69	3.18
Passeng. Vehicles	35.71*	12.93	10.89	3.36	62.90*	27.19	14.26	3.36
Aircraft	29.82*	9.87	6.11	2.71	48.52*	18.70	8.83	2.71
Optic. Instruments	28.12*	12.91	8.81	3.25	53.10*	24.98	12.06	3.25
Critical value	27.58	21.13	14.26	3.84	47.85	29.79	15.49	3.84

This table summarizes the results of cointegration tests, namely, the Maximum Eigenvalue Test and Trace Test. Critical values for the Maximum Eigenvalue Test and Trace Test are critical values at the 5% level of significance.

The Short-Run Dynamics

The short-run dynamics of the long-run export demand functions can be examined by estimating error-corrections models for each case. For this we follow Hendry's (1987) general-to-specific modeling strategy. The process involves regressing the first-difference of $\ln X$ on the current and lagged values of first-differences of each of the explanatory variables in Equation (1), lagged values of $\ln X$, and one period lagged residuals from Equation (1). According to the Engle and Granger (1987) Representation

Theorem, the presence of cointegration in a system of variables implies that a valid error-correction representation exists. The error-correction model for the cointegrating vector ($\ln X$, $\ln Y$, $\ln P$, $\ln V$) can be written as:

$$\Delta \ln X_t = \alpha_0 + \alpha_1 EC_{t-1} + \sum_{i=1}^{n} \beta_i \Delta \ln X_{t-i} + \sum_{i=0}^{n} \gamma_i \Delta \ln Y_{t-i} + \sum_{i=0}^{n} \delta_i \Delta \ln P_{t-i} + \sum_{i=0}^{n} \eta_i \Delta \ln V_{t-i} + \omega_t \quad (7)$$

where EC_{t-1} is the lagged error-correction term and is the residual from the cointegration regression Equation (1). The error-correction term EC_t represents the error-correction mechanism and α_1 gives the speed of adjustment towards the system's long-run equilibrium. If the variables have a cointegrating vector, then $EC_t \sim I(0)$ represents the deviation from equilibrium in period t. Generally, the error-correction term indicates how the system converges to the long-run equilibrium implied by the cointegrating regressions. The error-correction model enables us to distinguish between the short-run and long-run real exports functions.

Table 4: Normalized Cointegrating Vectors

Product	Constant	Y	P	V
Mineral Fuel	0.0052	2.2334*	-1.2800*	0.0013*
		(0.681)	(0.182)	(0.003)
Organic Chemicals	-0.0965	3.6653*	-0.8493*	-0.0176*
		(0.497)	(0.200)	(0.022)
Pharmaceuticals	-0.0225	3.0408*	-5.8188*	0.0160*
		(0.341)	(0.425)	(0.001)
Plastic	-0.0272	4.4972*	-0.1336*	-0.0029*
		(0.408)	(0.022)	(0.001)
Precious Stones	-1.7780	3.4230*	-2.4242*	-0.3335*
		(0.574)	(0.556)	(0.024)
Machinery	0.0869	3.5193*	-0.6728*	0.0187*
		(0.631)	(0.134)	(0.002)
Electrical Machinery	0.2902	3.2012**	-4.0082*	-0.0592*
		(1.681)	(0.260)	(0.011)
Passenger Vehicles	0.2462	4.4915*	-0.5221*	-0.0462**
		(0.478)	(0.184)	(0.022)
Aircraft	0.0163	3.2748*	-0.7108*	0.0049*
		(0.712)	(0.081)	0.002)
Optical Instruments	-0.0409	3.3541*	-0.0881**	-0.0064**
		(0.819)	(0.041)	(0.003)

*This table summarizes the normalized cointegrating vectors relating the dependent variable and independent variables. Figures in parentheses in normalized cointegrating vectors are standard errors. * and ** denote statistical significance at the 1% and 5% levels, respectively.*

The results of the estimated error-correction models are presented in Table 5. The results presented in Table 5 indicate that in all ten cases the error-correction term has the appropriate (negative) sign and is statistically significant. This result confirms the validity of an equilibrium relationship among the variables in the cointegrating equation and implies that the underlying dynamic structure of the model would have misspecified if the cointegration among the variables were overlooked. The speed of adjustment term (α_1) varies from -0.139 for product HS 85 to -0.938 for product HS 84, indicating that adjustment ranges from about 13.9% for product HS 85 to 93.8% for product HS 84 toward the long-run equilibrium. In general, estimated models for all ten products provide satisfactory results.

The estimated coefficients on exchange rate volatility variable have the expected negative sign in the majority of the cases. Further, it is statistically significant in seven out of ten products. Thus, in general, it appears that the measure of exchange rate volatility has a significant and negative impact on exports of United States at either the 5% or 1% level of significance. For all products, except for machinery (HS 84), electrical machinery (HS 85), passenger vehicles (HS 87), and aircrafts and spacecraft (HS 88), exchange rate volatility has a significantly negative impact on exports.

Table 5: Regression Results for Error-Correction Models

		Variables				
Product	Lag	EC_{t-1}	ΔX	ΔY	ΔP	V
Mineral Fuel	0				-1.569* (-8.93)	
and Oil	1	-0.636* (-4.03)		2.633* (6.56)		-0.232* (-2.18)
	2		0.245* (6.24)			
	3			1.020* (3.40)	-0.273* (-2.35)	
Organic	0		-0.336* (-2.69)			-0.212* (-3.15)
Chemicals	1	-0.549*(-8.11)			-0.710* (-5.37)	
	2		-0.267* (-2.33)	1.987* (6.21)	-0.396* (-2.97)	
	3			0.943* (4.53)		
Pharmaceu.	0				-2.230* (-4.82)	
Products	1	-0.410*(-4.41)		1.072* (4.11)		
	2		-0.928* (-6.62)	0.775* (3.55)	-1.427* (-3.66)	
	3		-0.518* (-4.07)		-0.599* (-2.22)	-0.498** (-1.97)
Plastic	0		-0.877* (-8.76)			
	1	-0.597*(-4.98)		1.535* (3.97)	-0.349* (-2.68)	-0.092* (-2.16)
	2		-0.562* (-3.95)			
	3			0.865* (3.27)	-0.281** (-1.86)	
Precious	0			1.305* (6.32)		
Stones and	1	-0.296*(-7.05)	-0.877* (-8.76)		-0.575* (-4.40)	
Metals	2		-0.562* (-3.95)	0.688* (3.82)		
	3					-0.227 (-1.19)
Machinery	0		-0.226* (-2.59)			
	1	-0.938*(-9.50)	-0.207* (-2.42)		-0.576* (-9.94)	0.029 (1.51)
	2				-0.473* (-7.80)	
	3			1.265* (6.45)		
Electrical	0			1.574* (4.76)		
Machinery	1	-0.139*(-3.23)			-0.344* (-2.65)	
	2		-0.448* (-6.25)		-0.142* (-2.48)	
	3					0.179 (1.33)
Passenger	0		-0.127 (-1.68)			
Vehicles	1	-0.226*(-7.52)		0.917* (6.48)	-0.068** (-1.98)	0.276* (2.06)
	2			0.585* (6.36)		
	3					
Aircraft and	0		-0.262** (1.94)			
Spacecraft	1	-0.296*(-4.77)		1.398* (3.40)		
	2				-0.464* (-4.20)	0.234* (2.37)
	3				-0.192* (-3.01)	
Optical and	0			0.830* (8.62)		
Medical	1	-0.340*(-9.36)			-0.073** (-1.92)	
Instruments	2					-0.092* (-2.46)
	3		-0.412** (-1.89)			

*This table summarizes the results of the error-correction models. The results are used to analyze the short-run dynamics of the model. The figures in parentheses are t-values for the regression coefficients. * and ** denote statistical significance at the 1% and 5% levels, respectively.*

SUMMARY AND CONCLUSIONS

In this paper we have examined the dynamic relationship between exports and exchange rate volatility in United States in the context of a multivariate error-correction model. Estimates of the long-run export demand functions were obtained by employing Johansen and Juselius maximum likelihood cointegration technique to quarterly date for the period 1990-2007.

The cointegration results clearly show that there exists a long-run equilibrium relationship between real exports and real foreign economic activity, real exchange rate, and real exchange rate volatility, in all ten commodities selected. All the specifications yielded correct signs for the coefficients. All of the coefficients are statistically significant either at 1% or 5% level of significance. Of the ten products, six of them have negative signs for the exchange rate volatility variable indicating that exchange rate volatility tends to deter exports in the long-run, for these six products. The error-correction results indicate that exchange rate volatility has a significantly negative impact on exports of United States in six of the ten products.

Although the results of this study tend to suggest that exchange rate volatility has a negative effect for majority of the products analyzes, in order to find strong evidence, we need to analyze more export products. Future research can include longer time period and broader product coverage. Such study can also use analytical tools such as variance decomposition and impulse response models to understand the effects of exchange volatility on exports.

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