JOURNAL OF ECONOMIC DEVELOPMENT
Volume 24, Number 1, June 1999

Real Exchange Rate Volatility and Sri Lanka's Exports to the Developed Countries, 1978-96

Ananda Weliwita, E.M. Ekanayake and Hiroshi Tsujii*

This paper examines the effects of exchange rate volatility on Sri Lanka's exports to six developed countries during the flexible exchange rate regime. Quarterly data for the 1978I-96II period are used for estimation. We experiment with two measures of exchange rate volatility. The Johansen-Juselius multivariate cointegration technique is used to test for the presence of long-run equilibrium relationships between real exports and its determinants. Short-run dynamics underlying the long-run relationships are examined using the error-correction modelling technique. There is strong evidence to suggest that Sri Lanka's exports to the countries under investigation were adversely affected by the increased volatility in bilateral real exchange rates during the sample period.

I. Introduction

Although there exists a voluminous literature no general consensus has emerged yet on the effect of exchange rate volatility on exports. Most of the previous analyses have found evidence that greater exchange rate volatility reduces international trade.[1] But there also exists some evidence to the country.[2] The bulk of the previous studies that have examined the relationship between exchange rate risk and trade have focused on industrialized countries. Only few attempts have been made to examine the issue in the context of developing countries.[3] All these studies, with the exception of Medhora (1990), provide strong evidence that greater uncertainty in exchange rates reduces developing country trade.

The objective of this paper is to examine the effects of exchange rate volatility on Sri Lanka's exports to six developed countries - Canada, France, Italy, Japan, the U.K., and the U.S.A. - during the post 1977 period. The choice of these countries is justified by the fact that Sri Lanka's exports to these countries comprise a significant portion of its total exports

* Visiting Research Fellow, Natural Resource Economics Division, Graduate School of Agriculture, Kyoto University, Kyoto 606-8224, Japan, Senior Research Manager, Enterprise Florida, Inc., Orlando, Florida 32801, USA and Professor, Natural Resource Economics Division, Graduate School of Agriculture, Kyoto University, Kyoto 606-8224, Japan, respectively.
Ananda Weliwita and Hiroshi Tsujii gratefully acknowledge the Japan Society for the Promotion of Science for providing financial support.

1. See Cushman (1983, 1986), Thursby and Thursby (1987), Brada and Mendez (1988), Koray and Lastrapes (1989), Kenen and Rodrick (1989), Peree and Steinherr (1989), Poso (1992), Bahmani-Oskooee and Payesteh (1993), Chowdhury (1993), and Arize (1995).
2. Some examples are Baron (1976), De Grauwe (1988), and Asseery and Peel (1991).
3. Notable examples include Parades (1989), Medhora (1990), Kurmar and Dhawan (1991), Bahmani-Oskooee and Ltaifa (1992), and Grobar (1993).

to the developed countries. In 1991, Sri Lanka's exports to these six countries accounted for over 67 percent of its total exports to the industrialized countries (Direction of Trade Statistics). First quarter of 1978 was chosen as the start of the sample period to coincide with the initiation of significant economic and financial reforms in Sri Lanka. Soon after taking office in 1977, the new government took several steps to liberalize the trade and financial sectors of the economy. Price controls and quantitative restrictions on import trade were abolished. An incentive scheme was introduced to boost foreign direct investment. Restrictions on capital transactions were removed in an attempt to integrate the domestic capital market with the foreign capital market. An export processing zone was established near Colombo to enhance manufactured exports.

However, the most significant event of the economic reform process at the time of its inception was the switch in the exchange rate regime from the fixed exchange rate system to a managed floating system. From 1948 when Sri Lanka achieved its independence from Britain until 1977 the Sri Lankan rupee had been closely linked to sterling. In November 1977 the government consolidated the rupee and brought it under a managed floating system. This was quickly followed by a massive devaluation of the rupee against the U.S. dollar. The rupee was devalued by 85 percent within a single year, from 8.41 rupees per dollar in 1977 to 15.61 rupees per dollar in 1978 (Annual Report, Central Bank of Sri Lanka). Between 1978 and 1996, the rupee was devalued by 272 percent against the U.S. dollar.[4] Although the rupee was continuously devalued against all major currencies throughout the post 1977 period the movements in real exchange rates have not been able to match the depreciations in the nominal exchange rates (Figure 1).[5] High and variable rates of domestic inflation have resulted in real exchange rate appreciations (Figure 2).[6] Although real exchange rates did

4. The usual policy prescription recommended by the world's leading financial institutions such as the World Bank and the IMF to countries that are trying to expand their exports is to devalue their currencies and reduce the import barriers. Yet, little has been said about the importance of mitigating the uncertainty in the real exchange rates. If greater uncertainty in real exchange rates depresses exports, then policy makers in developing countries should pay attention to this when they formulate policies to promote their exports (Grobar (1993)).

5. Figure 1 shows the movements in the real and nominal effective exchange rates for the six countries for the sample period. Trade weighted real and nominal effective exchange rates were calculated following the procedure outlined in Edwards (1989, p.88). Import shares for the six countries for 1990 were used as trade weights. The real effective exchange rate (RER) is defined as

$$RER_t = \frac{\sum_{j=1}^{6} s_j e_{jt} P_{jt}}{P_{SL,t}} \tag{1}$$

where s_j is the import share corresponding to partner j, e_{jt} is the nominal exchange rate defined as rupees per unit of country j's currency, P_{jt} is the CPI of country j, $P_{SL,t}$ is the CPI for Sri Lanka, and t is time. The nominal effective exchange rate (NER) is computed using Equation (1) without P_{jt} and $P_{SL,t}$.

6. After coming to power in 1977 the new government embarked upon three major investment projects: (1) establishing an export processing zone in Colombo to enhance manufactured exports, (2) initiating a massive public housing scheme, and (3) implementing the accelerated Mahaweli development program. The objectives of the Mahaweli development program were mainly threefold (1) to provide employment, (2) to make the country self-sufficient in rice, and (3) to generate hydroelectricity. The implementation of the Mahaweli development program was accelerated from thirty to six years. This required a large sum of money most of which came in forms of foreign aid and loans. Huge injection of foreign funds within a relatively short period of time bid up the prices of domestic

depreciate during the 1980s against all major currencies they did so with frequent, short periods of appreciations. A combination of high domestic inflation and often erratic depreciations and appreciations in real exchange rates create high volatility in real exchange rates which could significantly affect the volume of trade.

The present paper adds to the relatively small stock of evidence on the effect of exchange rate volatility on developing country trade. It, however, differs from previous developing country analyses in several ways. First, almost all previous developing country analyses have failed to recognize the fact that exports and its determinants are potential nonstationary variables. The failure to take into account the nonstationarity of macroeconomic time series results in what is called "spurious regressions." In this paper, particular attention is paid to the issue of nonstationarity of the time series used. Second, unlike previous developing country analyses, the present study allows for the possibility of the existence of a lagged relationship between the volume of exports and its determinants. We first test whether there existed a long-run equilibrium relationship between the volume of exports and its determinants. We then examine the short-run dynamics associated with the long-run equilibrium relationship by estimating the error-correction model. Third, we use two different measures as proxies for exchange rate volatility. Our first measure is a moving sample standard deviation of the growth rate of the real exchange rate. This measure captures the temporary variation in the absolute magnitude of the changes in real exchange rates (Chowdhury (1993)). The second measure models the uncertainty in the real exchange rate as an autoregressive conditional heteroscedastic (ARCH) process. The ARCH model or modifications of it has been commonly used for dealing with nonconstant volatilities in real exchange rates (e.g., Arize (1995), Asseery and Peel (1991), Poso (1992)).

II. Model Specification

The long-run equilibrium relationship between Sri Lanka's real exports to a country under investigation, the real activity of the importing country, the bilateral real exchange rate between the importing country and Sri Lanka, and a measure of the real exchange rate volatility is specified as (in natural logs)

$$\ln REXP_t = \delta_0 + \delta_1 \ln RGDP_t + \delta_2 \ln RER_t + \delta_3 \mu_{j,t} + \varepsilon_t, \tag{2}$$

where $REXP$ is Sri Lanka's real exports to the importing country, $RGDP$ is the real GDP of the importing country, RER is the bilateral real exchange rate between Sri Lanka and the importing country, μ_j is the measure of the real exchange rate volatility, ε is the economic error term, and t is time.[7] Equation (2) can be derived as a long-run solution of the supply

resources resulting in high inflation during the 1978-84 period (For a detailed discussion on this and related issues see Dunham and Kelegama (1997)).

7. See Gotur (1985), Asseery and Peel (1991), Chowdhury (1993), or Poso (1992) for more details on this specification.

and demand functions for exports (Chowdhury (1993)). Since higher real income in the importing country leads to higher imports we expect $\delta_1 > 0$. RER is defined as

$$RER_t = \frac{ER_t * CPI_t^{importer}}{CPI_t^{Sri\ Lanka}}, \tag{3}$$

where ER is the nominal exchange rate measured as the number of rupees per unit of foreign currency, and CPI is the consumer price index. Since the depreciation of the rupee (i.e., increase in RER) increases Sri Lanka's exports we expect $\delta_2 > 0$. As cited earlier, existing theoretical and empirical evidence on the effect of real exchange rate volatility on exports is ambiguous. Majority of the previous empirical studies support the common hypothesis that the exchange rate volatility reduces exports because greater uncertainty in real exchange rate imposes an additional cost on risk averse firms that would respond by preferring domestic trade to international trade (Asseery and Peel (1991)). If this hypothesis holds true, then, we must expect $\delta_3 < 0$. However, there also exists some studies that have argued that the impact of the exchange rate volatility could actually be favorable to the international trade (Franke (1988), Giovannini (1988), and Sercu and Vanhulle (1992)). According to these studies, trade can be considered as an option held by firms. Then it can be argued that the value of this option will increase with the rise in the exchange rate volatility (see Asseery and Peel (1991) for more on this). If this hypothesis hold true then we must expect $\delta_3 > 0$. This ambiguity has compelled the researches to resolve the issue on empirical grounds.

We experimented with two different measures for the real exchange rate volatility. Our first measure (μ_1) is the moving sample standard deviation of the growth rate of the real exchange rate volatility. It is defined as

$$\mu_1 = [\frac{1}{m} \sum_{i=1}^{m} (\ln RER_{t+i-1} - \ln RER_{t+i-2})^2]^{0.5}, \tag{4}$$

where m (4 or 8) is the order of the moving average.[8] The measure is capable of capturing the temporal variation in the absolute magnitude of real exchange rate changes, and hence exchange rate volatility over time (Koray and Lastrapes (1989)).

Our second measure models the real exchange volatility as an ARCH process. The ARCH process has been widely used for modeling the exchange rate volatility because of its ability to capture the so called "volatility clustering" phenomenon - the tendency that large changes in real exchange rate follow large changes while small changes tend to follow small changes, thus, leading to periods of persistently high or low volatility (Poso (1992)). The ARCH process is a better approach to modeling the changes in real exchange rates than the commonly used method of standard deviations of the changes in real exchange rates. The ARCH process assumes that errors have zero means and are serially uncorrelated but have nonconstant variances that

8. The same measure or modification of it has been used by Cushman (1983), Kenen and Rodrik (1986), Koray and Lastrapes (1989), Lastrapes and Koray (1990), and Chowdhury (1993).

are conditional upon the past changes in real exchange rates. Modeling the ARCH (p, q) process begins with estimating the following AR (p) process:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \ldots + \alpha_p y_{t-p} + \varepsilon_t, \tag{5}$$

where y_t is the log difference of the real exchange rate from period t to $t-1$, $\alpha_p(L) = \sum_{j=1}^{p} \alpha_j L^j$ is the polynomial autoregressive lag operator, and ε_t is the econometric error term. Note that

$$y_t \sim N[\alpha_p(L)y_t, \mu_2], \tag{6}$$

with

$$\mu_2 = \beta_0 + \sum_{j=1}^{q} \beta_j \varepsilon_{t-j}^2, \tag{7}$$

where ε_t is assumed to be generated by a white noise process defined by $E(\varepsilon_t) = 0$ for all t, $E(\varepsilon_t \varepsilon_s) = 0$ for $t \neq s$, and $E(\varepsilon_t^2) = \sigma^2$ for all t. The ARCH process allows the conditional variance of $\varepsilon_t = var(\varepsilon_t \mid y_{t-1}) = E(\varepsilon_t^2 \mid y_{t-1}) = \mu_2$ to vary as a linear function of the past squared residuals. Thus, the absence of ARCH effects implies accepting the null hypothesis that the conditional variance μ_2 is constant over time. In other words, we test $H_0: \beta_1 = \beta_2 = \ldots \beta_q = 0$ in Equation (7) against the alternative $H_1: \beta_1 \neq \beta_2 \neq \ldots \beta_q \neq 0$. To test for the H_0, we first obtain the residuals ε_t, from estimating Equation (5) by OLS. Next, we obtain estimates of $\beta_0, \beta_1, \ldots, \beta_q$ by estimating Equation (7) by OLS. The H_0 is tested using the Lagrange multiplier (LM) test statistic computed as $R^2.N$, where R^2 is the coefficient of determination and N is the sample size. The LM test statistic is distributed as χ^2 with degrees of freedom equal to q. If an ARCH process is detected, then predicted values for μ_2 in Equation (7) are used as the ARCH measure of the exchange rate volatility in Equation (2). The optimal lag lengths p and q in Equations (5) and (7) can be determined using the Akaike final prediction criterion.

III. Data

Quarterly data for the 1978I-96II period were used for estimation. The analysis focuses on Sri Lanka's exports to six major trading partners - Canada, France, Italy, Japan, the U.K., and the U.S.A. Nominal data on Sri Lanka's exports to these countries, denominated in rupees, were deflated by the CPI (1990=100) for Sri Lanka to express the series in real terms. Export data are available in *Direction of Trade Statistics*. The nominal exchange rate is defined as the number of rupees per unit of foreign currency. Data on nominal GDP for the six countries were deflated by the corresponding CPI(1990=100) for each country. Data on nominal exchange rates, GDP, and CPI were taken from *International Financial Statistics*. All the variables, with the exception of real exchange rates, were seasonally adjusted. Following the suggestion by Lee and Siklos (1991) real rather than nominal data were seasonally adjusted. Except for μ_1 and μ_2, all the other variables were expressed as indexes with 1990=100.

IV. Estimation Procedure and Empirical Results

The ARCH estimation results are reported in Table 1. At the top of the table are the results of several diagnostic tests on the distributional properties of the changes in bilateral real exchange rates. These results reveal that changes in real exchange rates for all the countries, except Japan, deviate from the nominal distribution. The Kurtosis statistics for the five countries are greater than that for the standard normal distribution, indicating that changes in the real exchange rates exhibit fat tails (leptokurtic). Deviation from the normality of the changes in real exchange rates for the five countries are further supported by the significance of the Jarque-Bera test statistics. The Jarque-Bera test statistic indicates the possibility that the variance of the changes in the real exchange rates does not remain constant over time. Therefore, the changes in real exchange rates for Canada, France, Italy, the U.K., and the U.S.A were modeled as ARCH processes. The results are presented at the bottom half of Table 1. For each of the five counties, the optimum lag length for both the AR process and the ARCH process was found to be one. Only for Italy and the U.K., the estimates of the constant term (β_0) and the autocorrelation term (β_1) in Equation (7) are significantly positive, indicating that only for these two countries the predicted values for μ_2 in (7) are positive and stationary. Thus, the volatility was modeled as ARCH processes for Italy and the U.K. For the other measure of volatility (μ_1), the optimal lag length was found to be four. Akaike final prediction criterion was used to find out the optimal lag length.

Table 1 Diagnostic Test Statistics on Distributional Properties of Changes in Real Exchange Rates (logs) and ARCH (p, q) Estimates, 1978I-96II

	Canada	France	Italy	U.K.	U.S.A.	Japan
			Diagnostic Test Statistics			
Skewness	0.75	-0.97	0.26	-0.10	0.24	0.02
Kurtosis	3.12	3.01	3.06	3.72	3.72	1.69
Jarque-Bera Test for Normality	7.12	7.74	3.55	8.73	2.39	5.27
Sample Size	71	71	71	71	71	71
			ARCH (p, q) Estimates			
α_0	-0.002 (-0.49)	-0.00 (-0.05)	0.001 (0.16)	0.001 (0.11)	0.001 (0.05)	-
α_1	0.107 (0.89)	0.172 (1.44)	0.125 (1.05)	-0.046 (-0.38)	-0.07 (-0.65)	-

Table 1 (Continued)

	Canada	France	Italy	U.K.	U.S.A.	Japan
ARCH (p, q) Estimates						
β_0	0.001** (4.03)	0.002** (4.59)	0.002** (3.32)	0.002** (2.35)	0.001** (3.54)	-
β_1	-0.039 (-0.32)	0.048 (0.4)	0.233** (1.99)	0.437** (4.04)	-0.039 (-0.33)	-
Log Likelihood	324.30	294.88	274.43	239.01	334.63	-
Lagrange Multiplier	0.11	0.16	3.88*	13.61**	0.11	-

Notes: Figures in parentheses are t-ratios. ** and * indicate the statistical significance at the 99 and 95 percent level, respectively.

We are now ready to estimate Equation (2) - two specifications each for Italy and the U.K. with μ_1 and μ_2 and one specification each for Canada, France, Japan, and the U.S.A. with μ_1. Yet, since the variables in Equation (2) are generated through time series processes there exists a possibility that they are not stationary. If the variable are nonstationary, then standard regression techniques such as the OLS are not appropriate to obtain the coefficients in Equation (2) due to the "spurious regression" phenomenon. Therefore, we must test whether the variables in Equation (2) are nonstationary or in particular whether they have unit roots. To test for the presence of unit roots, the Augmented Dickey-Fuller (ADF) test and the Phillip-Perron tests were performed on $\ln REXP$, $\ln RGDP$, $\ln RER$, μ_1, and μ_2. The ADF test results and the Phillips-Perron test results are presented in Table 2 and 3, respectively. The ADF test was performed on the level as well as the first-difference of each variable. Moreover, the ADF test was conducted separately with and without a time trend in the ADF equation. For Canada, France, the U.K., and the U.S.A., $\ln REXP$, $\ln RGDP$, $\ln RER$, and μ_1 were found to have unit roots. Whereas μ_1 for Italy and Japan and μ_2 for Italy and the U.K. were found to be stationary.

Table 2 Augmented Dickey-Fuller Test Statistics

Variable		Canada	France	Italy	Japan	U.K.	U.S.A.
Level							
$\ln RER$	ADF_1	-1.52	-1.51	-1.44	-0.79	-2.08	-2.34
	ADF_2	-1.28	-1.87	-1.58	-3.05	-2.04	-2.14
$\ln REXP$	ADF_1	-1.20	-0.68	-1.11	-1.19	-0.54	-1.14
	ADF_2	-1.85	-2.11	-1.55	-2.73	-2.03	-3.01
$\ln RGDP$	ADF_1	-0.95	-0.41	-1.08	-0.65	-0.43	-0.97
	ADF_2	-2.81	-2.45	-1.66	-1.43	-1.41	-3.21
μ_1	ADF_1	-2.74	-3.05	-4.28**	-4.68**	-2.51	-2.46
	ADF_2	-2.85	-2.95	-4.52**	-4.58**	-2.48	-1.54
μ_2	ADF_1	-	-	-8.68**	-	-7.97**	-
	ADF_2	-	-	-8.62**	-	-7.92**	-

Table 2 (Continued)

Variable		Canada	France	Italy	Japan	U.K.	U.S.A.
First Difference							
$\ln RER$	ADF_1	-6.14**	-5.32**	-5.81**	-5.89**	-5.75**	-6.70**
	ADF_2	-6.30**	-5.37**	-5.77**	-6.01**	-5.72**	-6.82**
$\ln REXP$	ADF_1	-6.32**	-8.55**	-7.57**	-7.56**	-7.62**	-10.69**
	ADF_2	-6.29**	-8.51**	-5.97**	-7.61**	-6.70**	-8.01**
$\ln RGDP$	ADF_1	-9.34**	-5.61**	-5.50**	-4.97**	-2.98**	-4.23**
	ADF_2	-8.87**	-5.60**	-5.47**	-4.77**	-7.84**	-4.35**
μ_1	ADF_1	-5.34**	-7.82**	-	-	-6.19**	-5.55**
	ADF_2	-6.98**	-7.90**	-	-	-6.14**	-6.61**

Notes:

$$ADF_1 \text{ tests } H_0: \beta = 0 \text{ in } \Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{j=1}^{m} \gamma \Delta Y_{t-j} + \varepsilon_t \tag{8}$$

$$ADF_2 \text{ tests } H_0: \beta = 0 \text{ in } \Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{j=1}^{m} \gamma \Delta Y_{t-j} + \rho t + \varepsilon_t \tag{9}$$

1. ** and * indicate statistical significance at the 99 and 95 percent level, respectively.
2. The critical values for the ADF test are from MacKinnon (1991). The optimal lag length (m) in the ADF equations were chosen based on the Akakike's final prediction criterion.

Table 3 Phillips-Perron Test Statistics

Variable	$Z(\tilde{\alpha})$	$Z(t_{\tilde{\alpha}})$	$Z(\Phi_3)$	$Z(\Phi_2)$	$Z(\alpha^*)$	$Z(t_{\alpha^*})$	$Z(\Phi_1)$
Canada							
$\ln RER$	-4.03	-1.18	0.99	0.68	-4.43	-1.38	1.01
$\ln REXP$	-3.19	-2.20	2.51	3.06	-1.91	-1.22	2.93
$\ln RGDP$	-9.06	-2.18	2.09	1.08	-1.92	-1.23	2.01
μ_1	-2.18	-2.10	2.51	2.31	-2.29	-1.61	2.56
France							
$\ln RER$	-5.04	-1.63	1.58	1.06	-3.01	-1.35	0.94
$\ln REXP$	-1.68	-3.32	2.56	3.91	-2.05	-1.31	1.14
$\ln RGDP$	-1.69	-2.39	2.94	2.39	-0.55	-0.39	2.29
μ_1	-2.63	-2.68	2.90	2.61	-2.75	-2.73	1.98
Italy							
$\ln RER$	-1.55	-1.42	1.07	0.73	-3.69	-1.38	0.98
$\ln REXP$	-2.94	-2.64	3.75	2.52	-2.66	-2.32	2.67
$\ln RGDP$	-3.87	-1.76	1.88	3.45	-1.21	-1.23	2.72
μ_1	-24.2**	-3.64**	6.86**	4.59**	-21.7**	-3.58*	6.48**
μ_2	-55.3**	-6.61**	21.8**	14.5**	-52.4**	-6.38**	20.3**
Japan							
$\ln RER$	-2.11	-2.25	2.97	2.21	-1.47	-0.64	0.53
$\ln REXP$	-2.97	-2.72	1.39	2.64	-2.01	-2.35	2.81
$\ln RGDP$	-0.77	-0.30	0.65	1.93	-0.50	-1.15	2.11
μ_1	-21.5*	-3.44*	6.04**	4.03**	-21.6**	-3.49*	6.13**

Table 3 (Continued)

Variable	$Z(\bar{\alpha})$	$Z(t_{\bar{\alpha}})$	$Z(\Phi_3)$	$Z(\Phi_2)$	$Z(\alpha^*)$	$Z(t_{\alpha^*})$	$Z(\Phi_1)$
U.K.							
$\ln RER$	-2.99	-2.15	2.42	1.64	-2.72	-2.21	2.47
$\ln REXP$	-1.31	-2.87	2.81	3.30	-2.71	-1.38	1.06
$\ln RGDP$	-2.77	-2.37	2.73	2.65	-2.25	-1.13	1.89
μ_1	-3.18	-2.59	2.51	2.34	-1.21	-2.61	3.42
μ_2	-38.7**	-5.07**	12.8**	8.59**	-38.8**	-5.11**	13.1**
U.S.A.							
$\ln RER$	-1.54	-2.26	2.86	1.93	-3.44	-2.35	2.81
$\ln REXP$	-3.14	-2.73	1.39	2.37	-1.59	-0.92	2.85
$\ln RGDP$	-2.58	-2.48	2.97	2.14	-0.50	-0.57	2.94
μ_1	-2.46	-3.39	3.83	3.03	-2.31	-2.39	2.79

Notes:

1. Testing for the presence of a unit root with the Phillips-Perron tests (Phillips (1987) and Phillips and Perron (1988)) involves estimating the following equations by the OLS:

$$Y_t = \mu^* + \alpha^* Y_{t-1} + \varepsilon_t^*, \text{ and} \tag{10}$$

$$Y_t = \bar{\mu} + \bar{\beta}\,(t - 0.5T) + \bar{\alpha} Y_{t-1} + \bar{\varepsilon}_t, \tag{11}$$

where ε_t^* and $\bar{\varepsilon}_t$ are error terms and T is the sample size. Using the regression results of (10) and (11), we compute the following test statistics:

$Z(\alpha^*)$ $\quad H_0: \alpha^* = 1$ in (10). (1)

$Z(t_{\alpha^*})$ $\quad H_0: \alpha^* = 1$ in (10). (2)

$Z(\Phi_1)$ $\quad H_0: \mu^* = 0$ and $\alpha^* = 1$ in (10). (3)

$Z(\bar{\alpha})$ $\quad H_0: \bar{\alpha} = 1$ in (11). (4)

$Z(t_{\bar{\alpha}})$ $\quad H_0: \bar{\alpha} = 1$ in (11). (5)

$Z(\Phi_3)$ $\quad H_0: \bar{\beta} = 0$ and $\bar{\alpha} = 1$ in (11). (6)

$Z(\Phi_2)$ $\quad H_0: \bar{\mu} = \bar{\beta} = 0$ and $\bar{\alpha} = 1$ in (11). (7)

The critical values from Fuller (1976) and Dickey and Fuller (1981) can be used in testing. ** and * indicate statistical significance at the 99 and 95 percent level, respectively.

After determining the order of integration of the variables, we tested Equation (2) for the presence of any cointegrated relationships using the Johansen and Juselius multivariate cointegration technique (see Appendix). But before Equations (2) can be estimated, we must determine the optimal lag length k in Equation (12) for each model specification. Following the procedure adopted in Haffer and Jansen (1991), we first estimated each equation as an unrestricted model with k arbitrarily set equal to 12. This unrestricted model was then tested against a restricted model with $k = 11$ by an LR test statistic distributed as χ^2 with degrees of freedom equal to 16 for the specifications that have four variables and with the degrees of freedom equal to 9 for the specifications that have three variables. The test was conducted sequentially by further reducing k by one at a time from both the unrestricted and the restricted model. The procedure was repeated until the restriction could be rejected at the 95 percent significance level. The value of k in the unrestricted model, when the restriction is rejected, is taken as the optimal lag length for the model. The optimal lag lengths for various model specifications are presented in Table 4.

Table 4 Optimal Lag Lengths for Various Model Specifications

Country	Model Specification	Unrestricted Model	Restricted Model	LM Test Statistic
Canada	$\ln RER$, $\ln RGDP$, μ_1	$k=10$	$k=9$	87.82**
France	$\ln RER$, $\ln RGDP$, μ_1	$k=11$	$k=10$	38.81**
Italy	$\ln RER$, $\ln RGDP$	$k=10$	$k=9$	33.72**
Japan	$\ln RER$, $\ln RGDP$	$k=10$	$k=9$	18.16**
U.K.	$\ln RER$, $\ln RGDP$, μ_1	$k=10$	$k=9$	58.05**
U.K.	$\ln RER$, $\ln RGDP$	$k=9$	$k=8$	20.71**
U.S.A.	$\ln RER$, $\ln RGDP$, μ_1	$k=10$	$k=9$	27.12**

Notes:
1. In all regression equations $\ln REXP$ was the "dependent" variable.
2. k is the lag length in Equation (12) for various specifications of Equation (2).
3. The LM test statistic is distributed as χ^2 with degrees of freedom equal to 16 for Canada, France, the U.K., (with μ_1), and the U.S.A. and with degrees of freedom equal to 9 for Italy, Japan, and the U.K.
4. ** denotes rejection of the restriction at the 99 percent level.

Next, we performed the trace test and the maximum eigenvalue test for the presence of cointegrating vectors. The results are presented in Table 5. The null hypothesis for the trace test is that there are at most r cointegrating vectors (see Appendix). Model specifications for Canada, France, the U.K., and the U.S.A. that have μ_1 as the measure of the exchange rate volatility indicate that there are at most three cointegrating vectors in each specification. The two specifications for Italy, one with μ_1 and the other with μ_2, and the specification for the U.K. with μ_2 have at most two cointegrating vectors each. The null hypothesis in each case is rejected at the 95 percent significance level. The null hypothesis for the maximum eigen value test, which is more powerful than the trace test, is that there are $r-1$ cointegrating vectors. This null is tested against the alternative that there are only r cointegrating vectors. The results of each specification for the maximum eigen value test are identical to those of the trace test. The result of both tests confirm that variables included in each specification have long-run equilibrium relationships with $\ln REXP$. The exact correlation between the variables of these relationship are presented at the bottom of Table 5. The coefficients for the cointegrating vectors have been normalized on $\ln REXP$. All the explanatory variables in all model specifications carry the expected algebraic signs. The coefficients can be interpreted as long-run elasticities with respect to real exports. The results reveal that a positive long-run relationship had existed between the income of the importing country and Sri Lanka's exports to that country. The positive coefficients obtained for $\ln RER$ indicate that depreciation of the rupee has resulted in increase in Sri Lankan exports to the countries under investigation. However, there had existed a negative correlation between real exports and our first measure of exchange rate volatility.

Table 5 Cointegration Tests and Vectors Normalized on $\ln REXP$

Trace Test								
H_0	Canada	France	Italy (μ_1)	Italy (μ_2)	Japan	U.K. (μ_1)	U.K. (μ_2)	U.S.A.
$r=0$	160.6**	139.9**	48.9**	49.6**	41.7**	108.3**	49.6**	114.3**
$r\leq 1$	69.9**	67.8**	21.0**	15.8*	16.4*	55.9**	17.2*	60.9**
$r\leq 2$	17.3*	29.6**	1.6	0.3	2.6	24.6**	1.56	26.2**
$r\leq 3$	0.7	1.3	-	-	-	0.2	-	0.1
Maximum Eigenvalue Test								
H_0								
$r=0$	90.7**	72.1**	27.9**	33.7**	35.3**	52.3**	32.4**	53.4**
$r=1$	52.6**	36.2**	19.4**	15.5*	13.7*	31.3**	15.6*	34.7**
$r=2$	16.6*	28.3**	1.6	0.3	2.6	24.4**	1.5	26.1**
$r=3$	0.7	1.3	-	-	-	0.2	-	0.1
Cointegrated Vectors Normalized on $\ln REXP$								
Variable								
Constant	-10.26	-25.50	8.09	4.87	-4.91	2.42	-5.59	-7.48
$\ln RGDP$	0.47 (1.38)	6.34** (54.7)	2.10** (2.43)	2.21** (4.33)	1.96** (6.31)	0.24** (9.11)	4.91** (3.39)	4.42** (38.5)
$\ln RER$	3.12** (5.42)	0.46** (3.92)	3.01** (2.18)	2.39** (3.29)	0.12** (2.77)	0.47** (5.17)	2.72** (2.06)	1.78** (6.94)
μ_1	-92.9** (-5.22)	-31.1** (-6.29)	-	-	-	-4.31** (-2.63)	-	-2.67 (-0.81)

Notes:
1. Critical values for the Trace test and the Maximum Eigenvalue are from Table 1, Osterwald-Lenum (1992).
2. Figures in parentheses are t-ratios. ** and * indicate statistical significance at the 99 and 95 percent level, respectively.

Let us now examine the short-run dynamics underlying the long-run relationships by estimating error-correction models. Error-correction models are estimated following Hendry's general-to-specific modeling approach (Gilbert (1986)). For Canada, France, the U.K. (with μ_1), and the U.S.A., the first difference of $\ln REXP$ is regressed on its own lagged values, lagged values of the first differences of $\ln RGDP$, $\ln RER$, μ_1, and one period lagged residuals obtained from the corresponding cointegration equation. For Italy, two error correction models are estimated: (1) the first difference of $\ln REXP$ is regressed on its own lagged values, lagged values of the first differences of $\ln RGDP$, $\ln RER$, one period lagged residuals from the cointegrating equation, and μ_1 in levels, and (2) the first difference of $\ln REXP$ is regressed on its own lagged values, lagged values of the first differences of the $\ln RGDP$, $\ln RER$, one period lagged residuals from the cointegrating equation, and μ_2 in levels. The error correction model for Japan involves regressing the first difference of $\ln REXP$ on its own lagged values, lagged values of the first differences of $\ln RGDP$, $\ln RER$, one period lagged residuals from the cointegration equation, and μ_1 in levels. Finally, the U.K. with μ_2, we regressed the first difference of $\ln REXP$ on its own lagged values, lagged values of the first differences of $\ln RGDP$, $\ln RER$, one period lagged residuals from the cointegrating equation, and μ_2 in levels. All the variables in each model specification were thus confirmed to be stationary. Initially, we estimated each model with four lags for each variable. We then eliminated the nonsignificant terms from each model to obtain a more simplified model. If and when the elimination of a lagged dependent variable (first differenced) introduced serial correlation, it was later put back into the model even though its coefficient was not statistically significant at the conventional level.

Parameter estimates and results of several diagnostic tests are reported in Table 6. At the conventional significance level, the tests do not reject the null hypothesis of no serial correlation, no ARCH effects, no functional misspecification, homo- scedasticity, and normality of residuals. The coefficients for the error correction term (EC_{t-1}) for each model specification was found to be statistically significant and have the expected negative sign. The significance of the error correction term is a clear indication that overlooking the cointegratedness of the variables could lead to a serious misspecification in the dynamic relationship. The significance of the error correction term also indicates that a causality exists in the direction from the explanatory variables toward real exports. The magnitude of the error correction term indicates the speed at which adjustment toward the equilibrium takes place. The coefficient estimates for the error correction term various from the largest of 0.43 for France to the smallest of 0.02 for the U.K.

V. Concluding Remarks

In this study, we have examined the effects of exchange rate volatility on Sri Lanka's exports to six developed countries during the flexible exchange rate regime. Applying the multivariate cointegration technique and the error correction modelling procedure to quarterly data for the 1978I-96II period, we have found evidence to suggest that real exchange rate

Table 6 Error-correction Models (Dependent Variable = $\Delta \ln REXP_t$)

Variable	Canada	France	Italy (with μ_1)	Italy (with μ_2)	Japan	U.K. (with μ_1)	U.K. (with μ_2)	U.S.A.
Constant	0.021 (0.54)	0.054* (1.75)	-2.190** (-2.49)	-2.506*** (-3.04)	0.198*** (2.35)	0.130 (0.70)	-0.008 (-0.24)	-2.086 (-1.41)
EC_{t-1}	-0.051* (-1.68)	-0.428*** (-4.74)	-0.091*** (-2.66)	-0.127*** (-3.18)	-0.164*** (-2.74)	-0.040* (-1.68)	-0.021*** (-2.81)	-0.130* (-1.74)
$\Delta \ln REXP_{t-1}$	0.857*** (6.75)	0.210* (1.83)	0.539*** (5.46)	0.543*** (5.57)	0.495*** (4.89)	0.390*** (3.35)	0.607*** (5.14)	0.338** (3.24)
$\Delta \ln REXP_{t-2}$	0.514*** (3.52)	-0.184* (-1.71)					0.291** (2.18)	
$\Delta \ln REXP_{t-3}$	-0.312*** (-2.73)						-0.196 (-1.64)	0.219** (2.37)
$\Delta \ln REXP_{t-4}$		0.187* (1.93)						0.322*** (3.37)
$\Delta \ln RGDP_t$		-3.547** (-2.19)				2.694* (1.79)	2.419* (1.66)	
$\Delta \ln RGDP_{t-1}$	3.185* (1.81)				1.620 (1.18)	1.254 (1.14)		
$\Delta \ln RGDP_{t-2}$		5.693*** (3.44)						
$\Delta \ln RGDP_{t-3}$	3.229* (1.84)							3.356** (2.04)
$\Delta \ln RGDP_{t-4}$			-1.553 (-1.19)	1.681 (1.28)	-2.110 (-1.58)	1.622 (1.21)	1.399 (1.11)	-2.381 (-1.47)
$\Delta \ln RER_t$							-0.414 (-1.30)	
$\Delta \ln RER_{t-2}$	1.357 (1.30)	-1.90*** (-3.18)	-1.376 (-1.38)	1.179** (2.18)	0.925* (1.79)			0.646 (1.11)
$\Delta \ln RER_{t-3}$						0.943*** (2.82)	1.186*** (3.68)	
$\Delta \ln RER_{t-4}$		1.162* (1.87)		-0.549 (-1.04)		0.494* (1.84)		
$\mu_{1(t-2)}$			-6.124** (-2.02)		-6.131** (-1.98)			
$\Delta \mu_{1t}$		-7.748* (-1.67)				-2.914* (-1.74)		
$\Delta \mu_{1(t-2)}$		7.514 (1.57)						
$\Delta \mu_{1(t-3)}$	15.398* (1.90)	-11.166** (-2.22)						7.857** (1.99)
$\Delta \mu_{1(t-4)}$								-8.888** (-2.27)
$\mu_{2(t-1)}$				-34.601* (-1.74)			-10.042* (-1.83)	

Table 6 (Continued)

Variable	Canada	France	Italy (with μ_1)	Italy (with μ_2)	Japan	U.K. (with μ_1)	U.K. (with μ_2)	U.S.A.
Adj. R^2	0.62	0.54	0.43	0.46	0.44	0.37	0.46	0.70
Q(10)	5.10	9.68	8.90	9.30	6.50	11.51	13.84	3.80
Jarque-Bera	0.44	0.48	1.59	0.59	0.39	1.45	1.43	1.05
AR(4)	0.65	0.28	1.47	1.80	0.88	1.38	0.01	1.16
HET[k]	1.54[19]	0.52[22]	1.44[10]	1.49[12]	1.75[12]	1.21[16]	1.08[18]	0.52[18]
ARCH(4)	1.26	0.32	1.08	0.25	1.43	0.15	0.08	0.16
RESET	1.02	0.54	1.20	0.58	0.97	1.26	0.04	0.04

Notes:
1. ***, **, and * denote statistical significance at the 99%, 95% and 90% level, respectively.
2. Figures in parentheses are t-statistics. Ljung-Box Q(10) tests for serial autocorrelation; Jarque-Bera tests for normality of residuals; AR(4) tests for the fourth order autocorrelation; HET[k] is the White's heteroscedasticity test where k is the degrees of freedom; ARCH(4) tests for the forth order ARCH residuals; and RESET $\chi^2(1)$ is the Ramsey's test for functional misspecification of degree one.

volatility adversely affected Sri Lanka's exports to the countries under investigation during the sample period. This finding further adds to the preponderance of evidence of previous developing country analyses that greater exchange rate volatility reduces developing country exports. When formulating policies to promote Sri Lanka's exports, policy planners need to pay careful attention to the issue of the effect of exchange rate volatility on exports. Lowering the level and the variability of domestic inflation will alleviate the uncertainty in the real exchange rates. The effects of devaluation, a mechanism commonly used to boost exports, can further be enhanced by implementing macroeconomic policies that dampen the real exchange rate volatility. The presence of forward markets in currencies that enables the exporters to hedge against the risks in international trade will certainly help them cope with adverse effects of exchange rate volatility on exports.

Appendix

Johansen and Juselius multivariate cointegration procedure (Johansen (1988), Johansen and Juselius (1990)) begins with the following vector autoregressive (VAR) model:

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \ \ldots \ + \Pi_k X_{t-k} + \varepsilon_t, \quad (t = 1, \ldots, T) \tag{12}$$

where X_t is a column vector of m endogenous variable. The stochastic terms $\varepsilon_1, \ldots, \varepsilon_T$ are drawn from an m-dimensional *identically and independently* normally distributed covariance matrix Λ. Since most economic time series are nonstationary, VAR models such as (12) are generally estimated in their first-difference forms. Equation (12) can be rewritten in first difference form as

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ \ldots \ + \Gamma_{k-1} \Delta X_{t-k+1} - \Pi X_{t-k} + \varepsilon_t \quad (t = 1, \ldots, T) \tag{13}$$

where

$$\Gamma_i = -(I + \Pi_1 + \Pi_2 + \ \ldots \ + \Pi_i) \quad (i = 1, \ldots, k-1), \tag{14}$$

and

$$\Pi = I - \Pi_1 - \ \ldots \ - \Pi_k. \tag{15}$$

Equation (13) differs from a standard first-difference version of a VAR model only by the presence of ΠX_{t-k} term in it. It is this term that contains information about the long-run equilibrium relationship between the variables in X_t. If the rank of Π matrix r is $0 < r < m$, then there are two matrices α and β each with dimension $m \times r$ such that $\alpha\beta' = \Pi$. r represents the number of cointegrating relationships among the variables in X_t. The matrix β contains the elements of r cointegrating vectors and has the property that the elements of $\beta' X_t$ are stationary. α is the matrix of error correction parameters that measure the speed of adjustments in ΔX_t. Information contains in β matrix can be used to construct two log likelihood ratio test statistics-trace test and maximum eigenvalue test.

References

Arize, A. (1995), "The Effects of Exchange Rate Volatility on U.S. Exports: An Empirical Investigation," *Southern Economic Journal*, Vol. 62, No. 2, 34-43.

Asseery, A., and D.A. Peel (1991), "The Effects of Exchange Rate Volatility on Exports," *Economic Letters*, Vol. 37, No. 2, 173-177.

Bahmani-Oskooee, M., and N. Ltaifa (1992), "Effects of Exchange Rate Risks on Exports: Cross Country Analysis," *World Development*, Vol. 20, No. 8, 1173-1181.

Bahmani-Oskooee, M., and S. Payesteh (1993), "Does Exchange Rate Volatility Deter Trade Volume in LDCs," *Journal of Economic Development*, Vol. 18, No. 2, 189-205.

Baron, D.P. (1976), "Fluctuating Exchange Rates and the Pricing of Exports," *Economic Enquiry*, Vol. 14, No. 3, 425-438.

Brada, J.C., and J.A. Mendez (1988), "Exchange Rate Risk, Exchange Rate Regime and the Volume of International Trade," *Kyklos*, Vol. 41, No. 2, 263-280.

Central Bank of Sri Lanka, *Annual Report*, Colombo, Sri Lanka, various issues.

Chowdhury, A.R. (1993), "Does Exchange Rate Volatility Depress Trade Flows? Evidence from Error-Correction Models," *Review of Economics and Statistics*, Vol. 75, No. 4, 700-706.

Cushman, D.O. (1983), "The Effects of Real Exchange Rate Risk on International Trade," *Journal of International Economics*, Vol. 15, No. 1, 45-63.

_____ (1986), "Has Exchange Rate Risk Depressed International Trade? The Impact of Third Country Exchange Risk," *Journal of International Money and Finance*, Vol. 5, No. 3, 361-379.

De Grauwe, P. (1988), "Exchange Rate Variability and the Slow-down in Growth of International Trade," *IMF Staff Papers*, Vol. 35, No. 2, 63-84.

Dickey, D., and W. Fuller (1981), "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica*, Vol. 49, No. 4, 1057-1072.

Direction of Trade Statistics Yearbook, *International Monetary Fund*, Washington, D.C., various issues.

Dunham, D., and S. Kelegama (1997), "Stabilization and Adjustment: A Second Look at the Sri Lankan Experience, 1977-93," *The Developing Economies*, Vol. 35, No. 2, 166-184.

Edwards, S. (1989), *Real Exchange Rates Devaluation and Adjustment*, MIT Press, Cambridge.

Franke, G. (1991), "Exchange Rate Volatility and International Trade," *Journal of International Money and Finance*, Vol. 10, No. 2, 292-305.

Fuller, W.A. (1976), *Introduction to Statistical Time Series*, Wiley, New York.

Gilbert, C.L. (1986), "Professor Hendry's Econometric Methodology," *Oxford Bulletin of Economics and Statistics*, Vol. 48, No. 1, 283-225.

Giovannini, A. (1988), "Exchange Rates and Traded Goods Prices," *Journal of International Economics*, Vol. 24, No. 1, 45-68.

Grobar, L.M. (1993), "The Effect of Real Exchange Rate Uncertainty on LDC Manufactured Exports," *Journal of Development Economics*, Vol. 41, No. 2, 367-376.

Haffer, R.W., and D.W. Jansen (1991), "The Demand for Money in the United States: Evidence from Cointegration Tests," *Journal of Money, Credit, and Banking*, Vol. 23, No. 2, 155-168.

International Financial Statistics, *International Monetary Fund*, Washington, D.C., various issues.

Johansen, S. (1988), "Statistical Analyses of Cointegrated Vectors," *Journal of Economic Dynamics and Control*, Vol. 12, No. 2, 231-254.

Johansen, S., and K. Juselius (1990), "Maximum Likelihood Estimation and Inference on Cointegration with Application to the Demand for Money," *Oxford Bulletin of Economics and Statistics*, Vol. 52, No. 2, 169-210.

Kenen, P.B., and D. Rodrik (1986), "Measuring and Analyzing the Effects of Short-term Volatility in Real Exchange Rates," *Review of Economics and Statistics*, Vol. 68, No. 2, 311-315.

Koray, F., and W.D. Lastrapes (1989), "Real Exchange Rate Volatility and the U.S. Bilateral Trade: A VAR Approach," *Review of Economics and Statistics*, Vol. 71, No. 4, 708-712.

Kumar, R., and R. Dhawan (1991), "Exchange Rate Volatility and Pakistan's Exports to the Developed World, 1974-85," *World Development*, Vol. 19, No. 9, 1225-1240.

Lastrapes, W.D., and F. Koray (1990), "Exchange Rate Volatility and U.S. Multilateral Trade Flows," *Journal of Macroeconomics*, Vol. 12, No. 3, 341-362.

Lee, H.S., and P.L. Siklos (1991), "Unit Roots and Seasonal Unit Roots in Macroeconomic Time Series: Canadian Evidence," *Economic Letters*, Vol. 35, No. 3, 273-277.

MacKinnon, J. (1991), "Critical Values for Cointegration Tests," in *Long-Run Economic Relationships: Readings in Cointegration*, eds. by Engle, R.F., and C.W.J. Granger, Oxford University Press, Oxford, Ch. 13.

Medhora, R. (1990), "The Effect of Exchange Rate Variability on Trade: The Case of the West African Monetary Union's Imports," *World Development*, Vol. 18, No. 2, 313-324.

Phillips, P.C.B. (1987), "Time Series Regression with Unit Roots," *Econometrica*, Vol. 55, No. 2, 277-301.

Phillips, P.C.B., and P. Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biometrika*, Vol. 75, No. 1, 335-346.

Osterwald-Lenum, M. (1992), "A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics," *Oxford Bulletin of Economics and Statistics*, Vol. 54, No. 3, 461-471.

Paredes, C. (1989), "Exchange Rate Regimes, the Real Exchange Rates and Export Performance in Latin America," *Brookings Discussion Papers in International Economics* 77, The Brookings Institution, Washington, D.C.

Peree, E., and A. Steinheir (1989), "Exchange Rate Uncertainty and Foreign Trade," *European Economic Review*, Vol. 33, No. 6, 1241-1264.

Poso, S. (1992), "Conditional Exchange Rate Volatility and Volume of International Trade: Evidence from the Early 1900s," *Review of Economics and Statistics*, Vol. 74, No. 2, 325-329.

Sercu, P., and C. Vanhulle (1992), "Exchange Rate Volatility, Exposure, and the Value of Exporting Firms," *Journal of Banking and Finance*, Vol. 16, No. 1, 155-182.

Thursby, M.C., and J.G. Thursby (1987), "Bilateral Trade Flows, the Linder Hypothesis, an Exchange Risk," *Review of Economic and Statistics*, Vol. 69, No. 3, 488-495.