IMPACT OF EXCHANGE RATE VOLATILITY ON CANADIAN EXPORTS TO THE UNITED STATES

by

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APPROVAL

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Title of Project   *Impact Of Exchange Rate Volatility On Canadian Exports To The United States*

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ABSTRACT

This paper examines the impact of exchange rate volatility on Canadian exports to the United States using quarterly data from 1971 to 2000. Two measures of real exchange rate volatility are employed to verify the robustness of the results. Test procedure that allows for structural break is utilized to examine the stationarity property of the export series. Results from cointegration tests do not support the presence of a long-run relationship between export volume, foreign income, relative price, and real exchange rate volatility. Estimates from ARDL models show that exchange rate volatility has adverse effects on exports in the short-run.

DEDICATION

To my family

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. Introduction

The high degree of exchange rate volatility since the breakdown of the Bretton-Woods agreement has led policy makers and economists to examine the impact of such movements on the volume of trade.[1] However, the studies on exchange rate volatility and trade flows have yielded mixed results.

The theoretical work of Ethier (1973) and Brodsky (1984) suggests that exchange rate volatility may reduce trade flows. This argument considers traders as risk-averse agents bearing undiversified exchange risk. If perfect hedging is impossible or costly, risk-adjusted expected profits from trade would fall as exchange rate risk increases. On the other hand, Franke (1991), Giovannini (1988), and Sercu and Vanhulle (1992) propose that exchange rate volatility positively affects international trade. The potential for increased volatility to promote trade is linked to imperfection in the goods market. Violations of the law of one price create arbitrage opportunities for international trade. The increase in exchange rate volatility increases the potential price differences and creates more scope for profitable commodity arbitrage through international trade. De Grauwe (1988) derives a model in which the effect of an increase in exchange rate risk depends on the degree of risk aversion. If traders exhibit only a slight degree of risk aversion, exports will fall as the higher exchange rate risk reduces the expected marginal utility of export revenues. However, if traders are extremely risk averse, they may export more to avoid the possibility of a drastic decline in revenues as exchange rate risk increases.

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[1] See Cote (1994) and McKenzie (1999) for a review of the literature on exchange rate volatility and trade flows

The empirical evidence is also mixed. Chowdhury (1993), Arize et al. (2000), and De Grauwe and Skudelny (2000) provide evidence that exchange rate volatility negatively affects trade volumes. On the other hand, studies by Koray and Lastrapes (1989), Klein (1990), Asseery and Peel (1991), Kroner and Lastrapes (1993), and McKenzie and Brooks (1997) have found cases where an increase in exchange rate volatility may have both positive and negative effects on trade volumes. There is a number of studies, such as a recent study by Aristotelous (2001), which conclude that exchange rate volatility plays no significant role in explaining trade volumes. Overall, the empirical literature has reaffirmed the ambiguous link between exchange rate volatility and trade indicated by the theoretical literature on the subject.

The objective of this paper is to investigate the relationship between Canadian exports to the United States and exchange rate volatility. Unlike most other studies, two measures of exchange rate volatility are employed to verify the robustness of the results. As show by Nelson and Plosser (1982), a number of macroeconomic variables are clearly non-stationary; therefore, unit root tests are performed to examine the stationarity of the individual series. Cointegration tests are performed to detect the presence of a long-run relationship between exports and its various determinants. Furthermore, the short-run effect of exchange rate volatility on exports is considered.

The rest of the paper is organized as follows: Section II looks at the specification of the export function, Section III describes the data and the two measures of exchange rate volatility. Tests of stationarity and structural breaks are given in Section IV, tests of cointegration are presented in Section V, Section VI

2

explores the short-run dynamics by means of ARDL models, and the conclusions are contained in section VII.

II. Model Specification

There are two primary determinants of exports (Dornbusch, (1998) and Hooper and Marquez, (1993)). First is the foreign income variable which measures the economic activity and purchasing power of the trading partner country. Second is the relative price variable which measures competitiveness. A recent study by Forbes (2001) has further shown that income effects and competitive effects are among the most important determinants explaining trade fluctuations between countries. In addition, sharp movements in the foreign exchange markets in the last decade (Bird and Rajan, 2001) call for the inclusion of exchange rate volatility as another explanatory variable in the export function. Incorporating all of the determinant factors, we can derive the following export function:

$$x_t = \beta_0 + \beta_1 y_t + \beta_2 p_t + \beta_3 V_t + e_t, \tag{1}$$

where:

x_t - the natural logarithm of Canada's export volume (Figure 1),

y_t - the natural logarithm of US real GDP (Figure 2),

p_t - relative price, the natural logarithm of the ratio of the domestic export price in US dollar to the US GDP deflator (Figure 3), and

V_t - volatility of the real exchange rate (Figure 4).

According to our theoretical priors, the volume of export to a foreign country ought to increase (decrease) as the real income of the foreign economy rises (falls); hence, we expect β_1 to be positive. A rise (fall) in the relative price of will cause

3

domestic goods to become less (more) competitive than foreign goods; therefore, exports will fall (rise). Thus, we expect β_2 to be negative. As discussed previously, the impact of exchange rate volatility on exports is ambiguous. Consequently, β_3 could either be positive or negative.

III. Data and Volatility Measures

Quarterly data from 1971 to 2000 are employed in this study. The data are obtained from International Monetary Fund's International Financial Statistics and Statistics Canada's socio-economic database.

i) Export Volume

For exports, earlier studies suggest that volume or quantity is a more appropriate measurement than value.[2] To obtain the export volume, we divide the value series by a measure of price.

$$X_t = \frac{XVAL_t}{XP_t} \tag{2}$$

X_t is the volume of Canada's export the US, $XVAL_t$ is the value of exports to the US, and XP_t is Canada's export price.

ii) Foreign Income

Quarterly US GDP at 1996 prices is used to measure foreign income.

iii) Relative Price

The relative price variable measures the competitiveness of Canadian exports in the US market.

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[2] For instance, Learner and Stern (1970), suggest that trade volume is a more appropriate measure than value.

$$P_t = \frac{XP_t}{P_t^{US}}$$

(3)

P_t is the price of Canadian exports relative to the price of US goods, XP_t is Canada's export price in US dollar, and P_t^{US} is the US GDP deflator.

iv) Volatility

Two important issues arise in calculating exchange rate volatility. First is the use of nominal versus real exchange rate. Second is the method employed to calculate volatility.

IMF (1984) suggests that we should consider the time horizon of economic decisions when measuring exchange rate volatility. Over the short term time horizon, fluctuations in the nominal exchange rate would have a significant effect on traders' decision because all costs and prices are relatively rigid and therefore known. Over the medium term time horizon and beyond, the real exchange rate would have a significant effect on traders' decisions because the effects of uncertainty on a firm's revenue and costs that arise from fluctuations in the nominal exchange rate are likely to be offset in large part by movements in costs and prices. However, after comparing results from nominal and real exchange rate volatility fitted by an ARCH model, McKenzie and Brooks (1997) concluded that it would be irrelevant whether the volatility index is estimated from real or nominal exchange rates as the volatility is sourced solely from the nominal exchange rate. For this study, the real exchange rate is utilized. The real exchange rate is computed by multiplying the nominal exchange rate by the relative prices:

5

$$RER_t = NER_t \times \frac{PPI_t}{PPI_t^{US}},\qquad(4)$$

where PPI_t is the domestic producer price index and PPI_t^{US} is the US producer price

index. An increase in RER_t (real exchange rate) or NER_t (nominal exchange rate)

implies an appreciation of the Canadian dollar against the US dollar.

Various methods have been used to measure exchange rate volatility. These

include absolute percentage change of the exchange rate, the moving average

standard deviation of the growth rate of exchange rate, the residuals from an ARIMA

model, and measures generated by (G)ARCH-type model. While most studies only

provide a single measure of exchange rate volatility, two measures are employed in

this paper to ensure robustness.

Following Chowdhury (1993) and Lastrapes and Koray (1990), the moving

standard deviation (MASD) of the growth rate of real exchange rate is used as the

first measure of exchange rate volatility.

$$V_t = \left[\left(1/m \right) \sum_{i=1}^{m} (\ln RER_{t+i-1} - \ln RER_{t+i-2})^2 \right]^{\frac{1}{2}},\qquad(5)$$

where m is the order of the moving average. The order of moving average is set

equal to 4.[3] This measurement has an advantage of capturing higher frequency

movements of the exchange rate.

For the second measure of exchange rate volatility, different types of ARCH

models are estimated. Previous papers in the area which have used ARCH based

measures of volatility include Pozo (1992), Kroner and Lastrapes (1993), and

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[3] The main results are robust to alternative specifications of the order of the moving average (m = 6 and m = 8).

McKenzie and Brooks (1997). ARCH models allow us to capture time varying conditional variance, and thus are very useful in describing volatility clustering. Given that volatility of exchange rate is generally characterized as the clustering of shocks to conditional variance, it is appropriate to use ARCH based measures as proxy for exchange rate volatility. The estimated GARCH(1,1) model is based on a first order autoregressive process, which takes the following form:

$$\ln RER_t = a_0 + a_1 \ln RER_{t-1} + e_t, \qquad \text{where } e_t \sim N(0, h_t) \qquad (6a)$$

$$h_t = \omega + \alpha e_{t-1}^2 + \beta h_{t-1} + u_t. \qquad (6b)$$

The conditional variance equation (Eq. 6b) is a function of three terms: i) the mean, ω, ii) news about volatility from the previous period measured as the lag of the squared residual from the mean equation (Eq. 6a), e_{t-1}^2 (the ARCH term), and iii) last period's forecast error variance, h_{t-1} (the GARCH term). The GARCH(1,1) model is chosen among a number of different of ARCH models because the α and β parameters are: i) statistically significant, ii) positive, and iii) sum to less than unity. The square root of the predicted value from Eq. (6b), $\sqrt{\hat{h}_t}$, serves as the second measure of exchange rate volatility.

IV. Stationarity and Structural Break

Prior to testing for cointegration, it is essential to identify the order of integration of each variable in Eq. (1). The order of integration is determined by applying the ADF unit root test to each series. The Schwarz criterion is used to determine the lag order for the tests. Inclusion of exogenous variables in the tests is determined by the inspection of each series. The results are summarized in Table 2.

7

According to the test results, the two volatility measures are stationary and the remaining variables are integrated of order one.

Since this study is based on data observed over the period during which the NAFTA was enacted, we are concerned with the potential impacts of structural breaks on the unit root test result of the export series. Inspection of the export series graph reaffirms our concern (Figure 1). Perron (1989, 1990), Christiano (1992), Banerjee et al. (1992), Zivot and Andrews (1992) have shown that the existence of structural change biases the standard ADF tests toward non-rejection of the null of a unit root. Consequently, it might be incorrect to conclude that the export series is nonstationary on the basis of the result from the standard ADF test. Perron (1990) developed a procedure for testing the hypothesis that a series has a unit root with an exogenous break. Zivot and Andrews (1992) criticized the assumption of an exogenous break and developed a testing procedure that allows an estimated break in the trend function under the alternative hypothesis. It seems appropriate to treat the structural breaks as endogenous and test the order of integration for the export series using the ZA procedure. The ZA test employed in this paper is represented by the following augmented regression:

$$x_t = \mu_1 + \beta t + \gamma DT_t^* + \lambda x_{t-1} + \sum_{j=1}^{k} c_j \Delta x_{t-j} + e_t, \qquad (7)$$

where the dummy variable $DT_t^* = t - T_B$ if $t > T_B$ and is 0 otherwise. T_B refers to a possible break point. The dummy variable allows for a change in the slope of the trend function. The sequential ADF test procedure estimates a regression equation for every possible break point within the sample and calculates the t-statistics for the

estimated coefficient on x_{t-1}. The null of nonstationarity is rejected if λ is significantly different from one. The selected break point for the export series is the T_B for which the t-statistic for the null is minimized. The procedure suggested by Perron (1989) is adopted for selecting the lag order k. Start with an upper bound k_{max} for k. If the last lag is significant, set $k = k_{max}$; otherwise, reduce k by 1 until the last lag becomes significant. k_{max} is set to 8 for the export series. The result of the ZA test is presented in Table 3. The T_B which minimizes the t-statistics is at 1991Q1. By incorporating one trend break in the model, the unit-root hypothesis is rejected by the ZA test. The result suggests that the export series is trend stationary if the trend function incorporates a break.

V. Long-Run Relationship

Since the variables in Eq. (1) are integrated of different orders, Johansen's cointegration testing procedure cannot be employed to test for the existence of a long-run relationship. As such, an alternative approach suggested by Pesaran, Shin and Smith (2001) is applied. This approach tests the existence of a long-run relationship for the variables in Eq. (1) by estimating the following autoregressive distributed lag (ARDL) error-correction model:

$$\Delta x_t = c_0 + c_1 DU + \sum_{i=1}^{n} b_{1i}\Delta x_{t-i} + \sum_{i=0}^{n} b_{2i}\Delta y_{t-i} + \sum_{i=0}^{n} b_{3i}\Delta p_{t-i} + \sum_{i=0}^{n} b_{4i}\Delta V_{t-i}$$

$$+ b_5 x_{t-1} + b_6 y_{t-1} + b_7 p_{t-1} + b_8 V_{t-1} + e_t, \qquad (8)$$

where $DU = 1$ if $t > T_B$ and is 0 otherwise and the remaining variables are as defined earlier. T_B corresponds to the break which minimizes the t-statistics of the ZA unit-root test performed earlier. Eq. (8) will be estimated based on ordinary least squared

9

(OLS) method. The test is based on the Wald or F-statistic. The asymptotic distribution of the F-statistic is not standard under the null hypothesis of no cointegration relationship, regardless of whether the variables are I(0) or I(1). A joint significance test, where the null and alternative hypotheses are: $H_0 : b_5 = ... = b_8 = 0$ and $H_1 : b_5 \neq ... \neq b_8 \neq 0$, is performed. For some significance level α, if the F-statistic falls outside the critical bound values, a conclusive inference can be made without considering the order of integration of the variables. Specifically, if the F-statistic is higher than the upper bound critical value, then the null hypothesis of no cointegration can be rejected. On the other hand, if the F-statistic lies below the lower bound critical value, the null cannot be rejected. The results of the tests are presented in Table 4. The null of no cointegration cannot be rejected; thus, the results do not suggest the presence of a long-run relationship among the variables in Eq. (1).

VI. Short-Run Dynamics

Before we proceed to examine the short-run dynamics, we are going to estimate an equation which takes the exact form of Eq. (1), without concerning ourselves with econometric correctness. The purpose of this exercise is to test whether the contemporaneous relation portrayed by Eq. (1) exists. The results are given in Table 5. The reported coefficients for foreign income and relative price are significant and their signs are consistent with theory, while the coefficient estimates on both measures of exchange rate volatility are positive. The estimated coefficient on the MASD volatility measure is insignificant while the corresponding GARCH coefficient is significant. As one would expect, these equations are statistically

10

unsound, rendering the results dubious. The equations suffer from serial correlation, heteroskedasticity, functional form misspecification, and parameter instability.

Next we proceed to estimate the following ARDL model of the export function:

$$\tilde{x}_t = \alpha_1 \tilde{x}_{t-1} + \sum_{i=1}^{n} \alpha_{2i} \Delta y_{t-i} + \sum_{i=1}^{n} \alpha_{3i} \Delta p_{t-i} + \sum_{i=1}^{n} \alpha_{4i} V_{t-i} + e_t \qquad (9)$$

All the symbols retain their prior meanings and $\tilde{x}_t$ (Figure 5) is generated by detrending x_t. More specifically, $\tilde{x}_t$ is the residual from the following regression:

$$x_t = c + \delta_1 t + \delta_2 DT_t^* + e_t \qquad (10)$$

where $DT_t^* = t - T_B$ if $t > T_B$ and is 0 otherwise and the other variables are defined earlier. T_B corresponds to the break which minimizes the t-statistics of the ZA unit-root test performed earlier. Since y_t and p_t are integrated of order one, they enter Eq. (9) in first difference. The volatility measures are stationary and each measure enters Eq. (9) in level. The lag order which minimizes the Schwarz criterion is chosen.

The regression results are summarized in Table 6. Overall, the findings are not sensitive to the measure of volatility employed. The empirical results suggest that the statistical fit of each model to the data is satisfactory, as indicated by the values of adjusted R^2, which is 0.77. A number of diagnostic tests is performed to ensure the statistical validity of the equations. First the Breusch Godfrey test for serial correlation detected the presence of serially correlated errors. Given these results, Newey-West HAC standard errors are employed. Secondly, White's test for heteroskedasticity suggests that the residuals from each estimated equation are

11

homoskedastic. In addition, Ramsey's RESET test did not detect the presence of functional form misspecification. Lastly, the CUSUM test did not find evidence in favour of parameter instability (Figure 6).

Regardless of which exchange rate volatility is employed, coefficients on foreign income are statistically significant and the signs are consistent with theory. The estimates range from 1.0019 to 1.2151, which means that a 1% increase in foreign income will lead to a 1.0019% to 1.2151% increase in next quarter's exports. The coefficients on the relative price variable have the expected signs but they are insignificant. The most interesting and important finding however, concerns the impact of exchange-rate volatility on exports. In particular, the volatility coefficients have negative signs, which suggest that exchange rate volatility has adverse effects on exports. The coefficient on the MASD volatility measure is significant at the 10% level of significance while its GARCH counterpart is significant at the 5% level of significance. The estimates imply that a change in the MASD volatility measure from 0 to its mean value of 0.01497 will lead to a 0.6139% decrease in next quarter's exports. Likewise, a change in the GARCH volatility measure from 0 to its mean value of 0.01543 will cause exports to decrease by 0.9744% in the upcoming quarter.

These findings suggest that exchange rate volatility have adverse effects on the allocation of resources as market participants attempt to adjust to the effects of exchange rate risk. Previous studies have found that the development of markets for various hedging instrument is indispensable to alleviate the adverse consequence of the rise in volatilities. However, our results for Canada have shown that hedging facilities may be a necessary, but certainly not a sufficient condition for alleviating

such adverse consequences. Given Canada's trade flows are heavily concentrated with the United States, the findings suggest that it may be beneficial to fix our currency to that of the US.

VII. Conclusion

This study investigates the impact of exchange rate volatility on Canadian exports to the United States over the quarterly period from 1971 to 2000. Exchange rate volatility is measured by the moving average standard deviation of the real exchange rate and the conditional standard deviation of the real exchange rate from a GARCH model. The analysis began with tests of stationarity of the individual series. Given the study is based on data observed over the period during which the NAFTA was enacted, test procedure allowing for structural break was employed to examine the stationarity of the export series. Cointegration tests fail to detect the presence of a long-run relationship between exports and the explanatory variables in Eq. (1). Estimates from ARDL models show that exchange rate volatility has adverse short-run effects on exports. Each estimated model fulfills the conditions of homoskedasticity, absence of functional form misspecification, and parameter stability. Since the equations suffer from serial correlation, Newey-West HAC consistent standard errors are employed. The results suggest that the availability of hedging instruments do not alleviate the adverse consequences of exchange rate volatility. The findings also suggest that fixing the Canadian dollar to the US dollar can be beneficial to trade, assuming that real exchange rate volatility is sourced primarily from movements in nominal exchange rate.

Table 1. ARCH Model Summary: Quarterly US/Canada Real Exchange Rate Data

$$h_t = \omega + \alpha e_{t-1}^2 + \beta h_{t-1} + u_t$$

The GARCH volatility measure has been generated based on observations from 1957:1 to 2000:4.

	α (t-stat)	β (t-stat)	$\Sigma(\alpha + \beta)$
GARCH(1,1)	0.142 (2.03)	0.848 (12.20)	0.98

Table 2. ADF Unit-Root Test

Series		ADF statistic	Test Type	Lag	Critical Values 5%	10%	Result
x_t	Level	-1.5444	Intercept, Trend	0	-3.4478	-3.1488	I(1)
	Δ	-11.9432*	Intercept	0	-2.8859	-2.5796	
y_t	Level	-2.8717	Intercept, Trend	1	-3.4481	-3.1489	I(1)
	Δ	-7.5661*	Intercept	0	-2.8859	-2.5796	
p_t	Level	-2.3918	Intercept, Trend	1	-3.4475	-3.1486	I(1)
	Δ	-8.7141*		0	-1.9426	-1.6171	
V_t^{MASD}	Level	-3.5056*	Intercept	4	-2.8865	-2.5799	I(0)
V_t^{GARCH}	Level	-3.1735*	Intercept	0	-2.8857	-2.5795	I(0)

* Significant at the 5% level

Table 3. ZA Unit-Root Test for One Break of the Export Series

Series	t-statistic	Break	Lag	Critical Values* 1%	5%
x_t	-5.1873**	1991:1	7	-4.93	-4.42

* From Table 3A in Zivot and Andrews (1992)
** Significant at the 1% level

Table 4. Results from Bounds Test

Measure of volatility	Lag*	F-statistic	5% Critical Values** Lower	Upper	$H_0 : b_5 = ... = b_8 = 0$
V^{MASD}	1	2.96	3.23	4.25	Fail to reject at 5%
V^{GARCH}	1	2.89	3.23	4.25	Fail to reject at 5%

* Lag order is selected based on Schwarz Criterion.
** From Pesaran, et al. (2001), Table C1.iii, $k = 3$. The critical values were derived assuming the absence of dummy. However, the asymptotic theory and critical values are not affected by the inclusion of dummy variables unless the fraction of periods in

which the dummy variables are non-zero does not tend to zero with the sample size T (Pesaran, et al. (2001), P. 307). In this case, the fraction of observations where DU is non-zero is 33%.

Table 5. Basic Model

i) Measure of volatility: V^{MASD}

$$x_t = 1.7063y_t - 0.8110p_t + 0.9935V^{MASD} - 9.0566$$

SE*   (0.02631)**(0.05668)** (1.3224)

ii) Measure of volatility: V^{GARCH}

$$x_t = 1.6962y_t - 0.8353p_t + 4.1244V^{GARCH} - 9.0163$$

SE*   (0.02687)**(0.05763)**(2.4464)***

* Newey-West HAC Standard Errors & Covariance (lag truncation = 4)
** Significant at the 5% level
*** Significant at the 10% level

Table 6. ARDL Results

i) Measure of volatility: V^{MASD}

$$\tilde{x}_t = 0.8521\tilde{x}_{t-1} + 1.0019\Delta y_{t-1} - 0.1104\Delta p_{t-1} - 0.4101V_{t-1}^{MASD}$$

SE*   (0.03926)** (0.4682)**   (0.1132)   (0.2469)***
Adjusted R^2: 0.77
Breusch Godfrey Serial Correlation Test:
Lags: 1 F-statistic: 7.64**
White Heteroskedasticity Test:
F-statistic: 0.6191   P-value: 0.7602
Ramsey RESET Test:

Fitted term: $\hat{\tilde{x}}_t^2$ F-statistic: 1.8925   P-value: 0.1716

ii) Measure of volatility: V^{GARCH}

$$\tilde{x}_t = 0.8439\tilde{x}_{t-1} + 1.2151\Delta y_{t-1} - 0.1207\Delta p_{t-1} - 0.6315V_{t-1}^{GARCH}$$

SE*   (0.03857)** (0.4919)**   (0.1073)   (0.2889)**
Adjusted R^2: 0.77
Breusch Godfrey Serial Correlation Test:
Lags: 1 F-statistic: 10.11**
White Heteroskedasticity Test:
F-statistic: 0.1606   P-value: 0.9954
Ramsey RESET Test:

Fitted term: $\hat{\tilde{x}}_t^2$ F-statistic: 1.1290   P-value: 0.2903

* Newey-West HAC Standard Errors & Covariance (lag truncation = 4)
** Significant at the 5% level
*** Significant at the 10% level

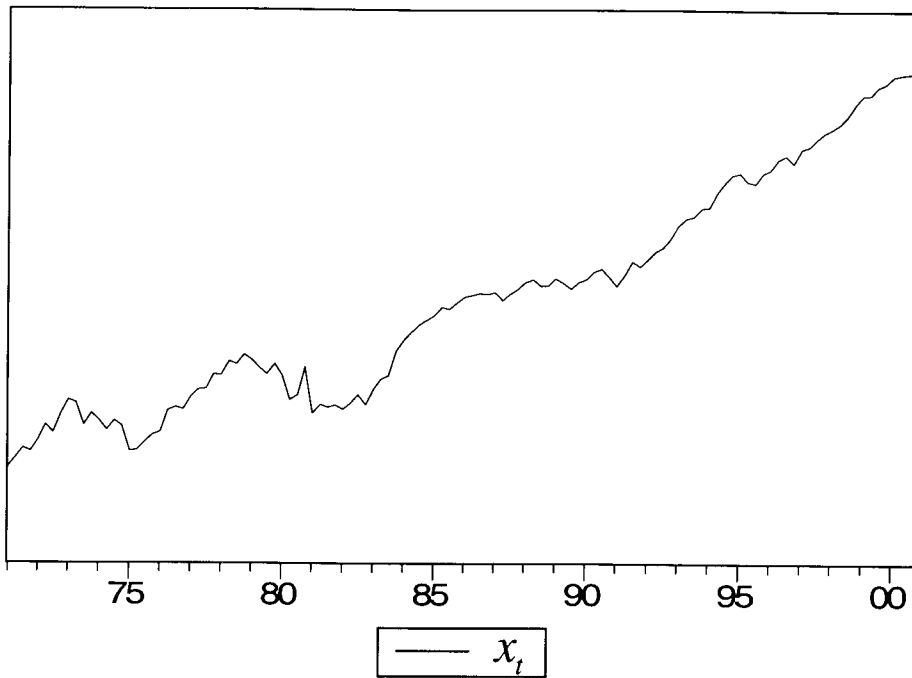**Figure 1. Canada's Export Volume to the US**
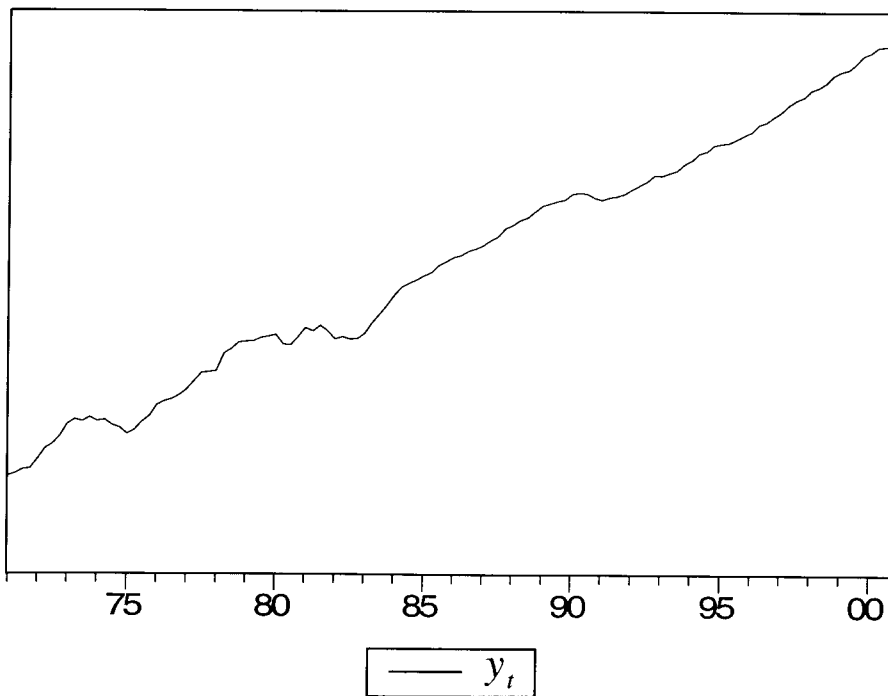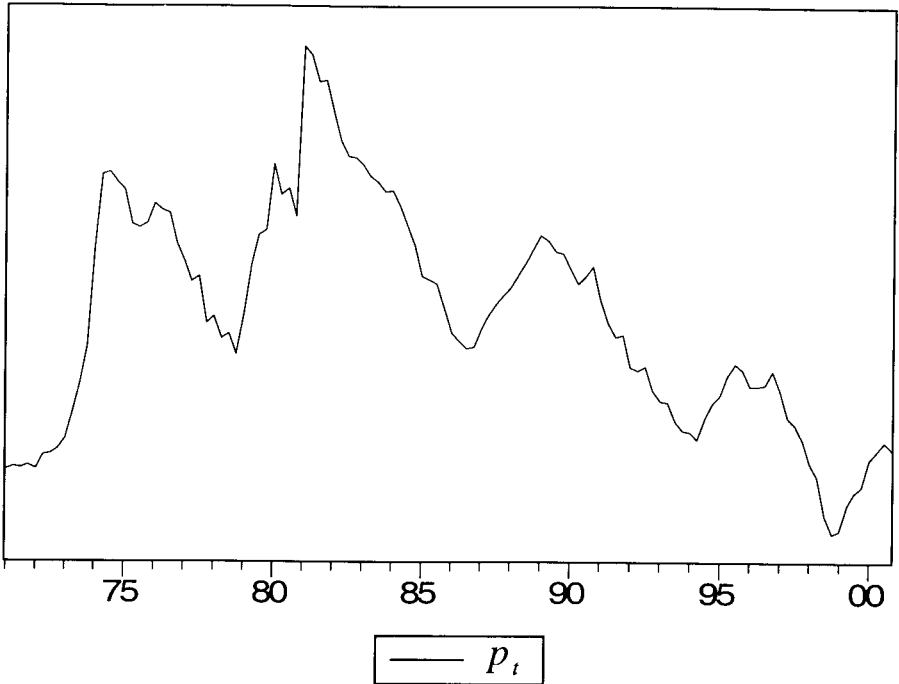

x_t

Figure 2. US Real GDP

y_t

16

Figure 3. Relative Price
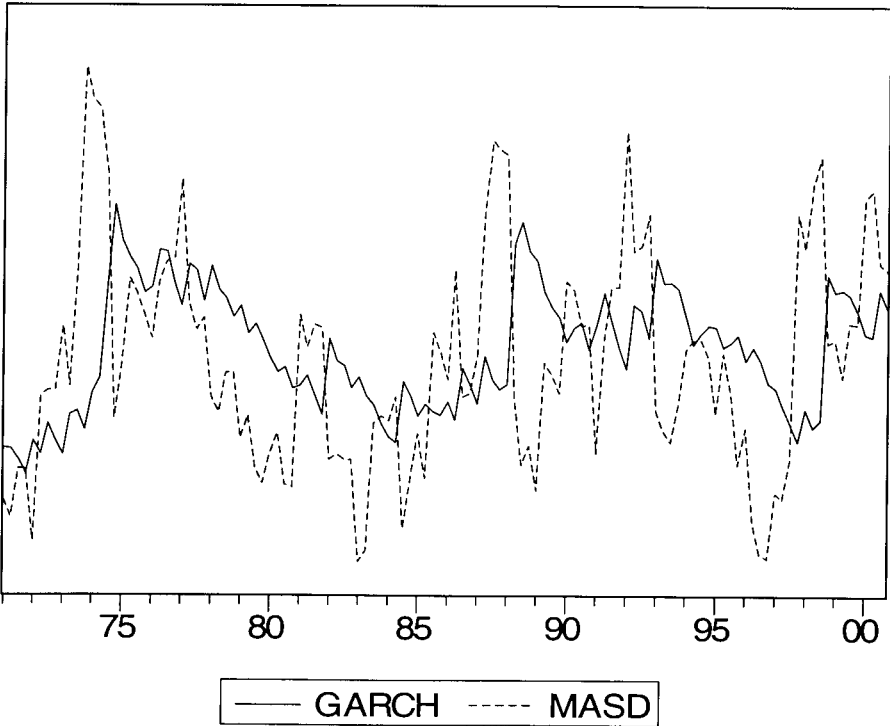

p_t

Figure 4. Exchange Rate Volatility

GARCH ----- MASD

17

Figure 5. Canada's Export Volume to the US, Detrended

$$\underline{\quad\quad} \ \tilde{x}_t$$
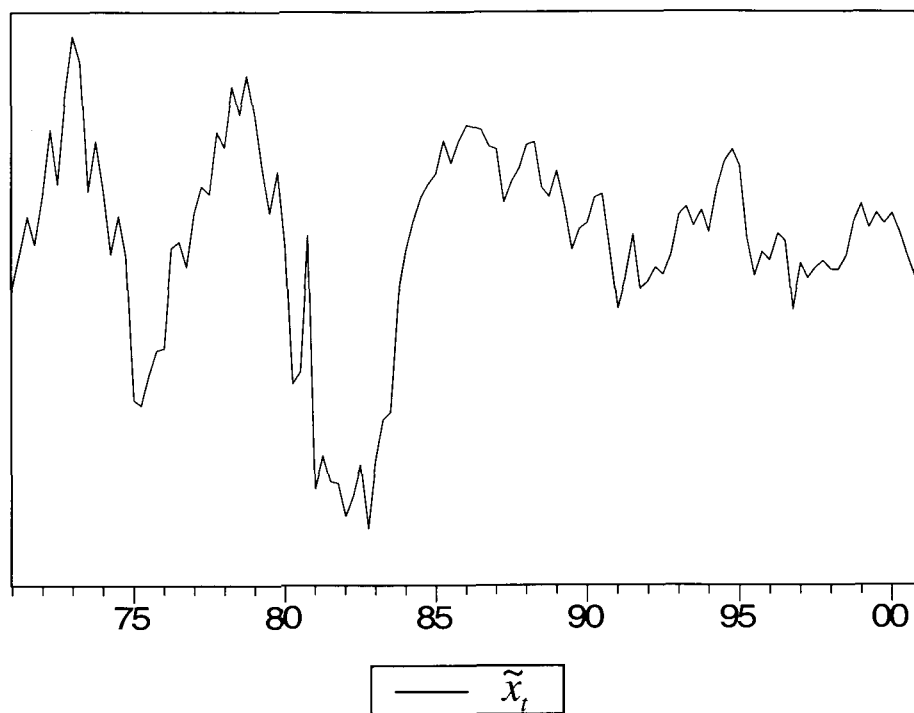
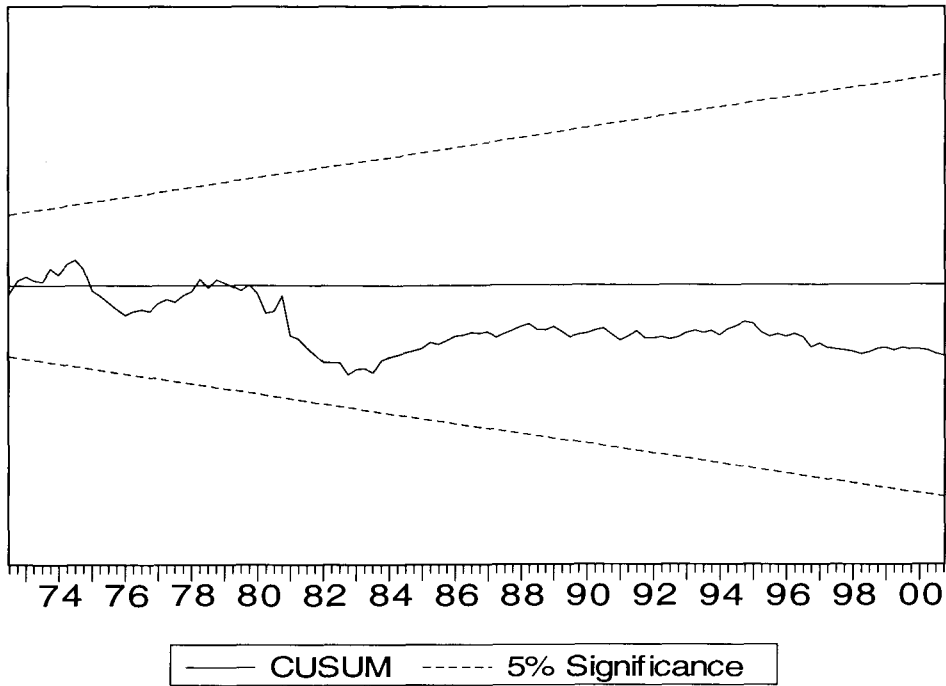**Figure 6. CUSUM Test of Stability**

i) ADRL Using V^{MASD}

——— CUSUM   ------ 5% Significance

ii) ADRL Using V^{GARCH}

74 76 78 80 82 84 86 88 90 92 94 96 98 00

———— CUSUM ------ 5% Significance
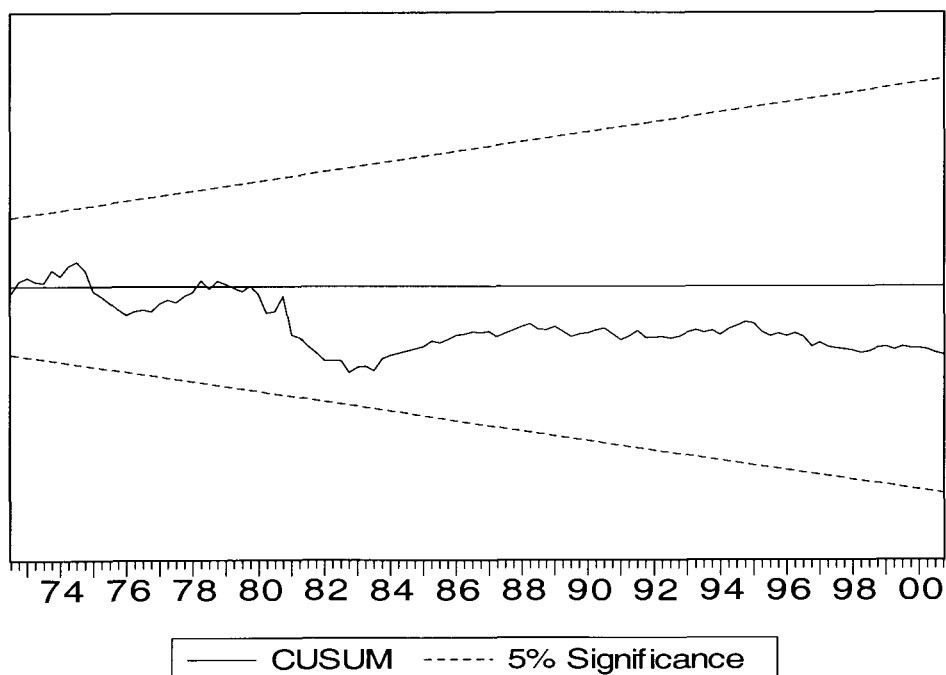
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