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The Effect of Exchange Rate Volatility on Exports: The Case of Canada's Exports to United States

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Abstract

The purpose of this study was to examine the effect of real exchange rate volatility between the Canadian dollar and United States (US) dollar on real exports from Canada. The study made use of quarterly data from 1960-2017; over half a century. The GARCH (1, 1) was used to model real exchange rate volatility. After finding the variables were non-stationary with no evidence of co-integration, a Vector Autoregression (VAR) model was used to investigate the short-run relationship in the variables making use of the Granger causality technique and impulse response functions.

The results reveal that the effect of exchange rate volatility between the Canadian dollar and the US dollar is of mixed signs, with coefficients that are not statistically significant, thus, exchange rate volatility does not have an effect on the real exports of Canada to the US. In addition, the real exchange rate volatility does not Granger cause real exports. This result contradicts economic theory that predicts a negative effect of exchange rate volatility on exports. However, Tenreryo (2007) and Aristotelous (2001) report the same result in their studies.

Keywords: exports, exchange rate volatility, GARCH (1,1), vector autoregression

JEL: F310, F330, F150.

1. Introduction

This study examined the effect of real exchange rate volatility on the real exports of Canada to the US and found that exchange rate volatility does not have any statistically significant effect on Canadian exports. The study is divided into 7 sections; section 2 gives an overview of important literature and contributions by researchers over the years, specifically covering the sign effects and statistical significance of the effect of exchange rate volatility on exports. Section 3 gives a brief on the model and data used, definitions of the variables and the predictions of the model. Section 4 gives a theoretical and econometric overview of the unit root and co-integration tests conducted on the data. Section 5 gives the data output of the empirical results and discussions of test results. This output is presented using graphs and tables. Section 6 is a presentation of the limitations of the model and possible areas of improvement. Finally, section 7 concludes and gives policy recommendations moving forward.

Exchange rates are a key player to any economy that is engaging in international trade, a stable monetary policy system and financial sector play a key role in ensuring the exchange rate stability of the currency of a country. Firms and traders rely on prevailing exchange rates to forecast amounts to produce, import and export, thus, are very much affected by the exchange rate volatility. In addition to this, there is a currency conversion cost in international trade.

There are a number of products in the financial markets that exporters use to hedge against currency fluctuations. This is especially true for short-term hedging than long-term hedging. Obstfeld (1995) states that long-term changes in exchange rates have more significant impacts on trade compared to short-term fluctuations. Doroodian (1999) concludes that hedging is costly in developing countries with imperfect financial markets.

According to statistics from the *Office of the United States Trade Representative*, trade in goods and services between Canada and United States totalled to an estimated value of $673.9 billion in 2017. This makes United States a very important trade partner and destination for Canadian goods. The trade volume between these two countries is very large; this is one of the justifications for this study.

A number of scholars have argued that exchange rate volatility has made trade expensive in North America due to hedging costs and this has reduced trade. It is on this basis that some scholars have put forward the proposition of a common currency (Note 1) in North America; the *Amero*, an equivalent of the *Euro* in Europe. According to a number of scholars, a common currency or fixed exchange rate could lead to lower transaction costs because firms would not need to worry about costs associated to hedging fluctuations. It is estimated that adopting a common currency in North America would eliminate transaction costs of up to $3 billion annually encouraging more trade in the region. Together, the three countries in this region signed an agreement, NAFTA, that created a trilateral trade bloc in North America. The NAFTA (Note 2) came into force on January 1st, 1994.

This study focussed on evaluating whether exchange rate volatility does indeed reduce trade and thus justify the move towards a common currency in the region. The new evidence and findings will help policy makers make informed decisions moving towards further integration in the region. There is also limited literature on studies focusing on Canadian exports to the US, this study will help fill this gap.

2. Literature Review

Common belief among many is that exchange rate risk tends to reduce trade between countries due to the risk averse nature of exporters, however, there is also no single measure of exchange rate risk. McKenzie (1999) argues that there seems to be a general unresolved fundamental ambiguity in this relationship, also exchange rate volatility may impact differently on different markets and argued against the use of aggregate trade data that has the potential to obscure any relationship.

Exchange rate volatility may increase, decrease or even have no effect on the volume of trade (Bahmani-Oskooee & Hegerty, 2007). Sercu and Uppal (2003) argue that the relationship between exchange rate volatility and trade can be positive or negative depending on the source of increase in exchange rate volatility. They use a general equilibrium economy with stochastic endowments constructing a two-country, one-good, complete markets Lucas (1982) model with both trade and exchange rate volatility being endogenous. They use this model to improve on the weaknesses identified in previous work that are partial equilibrium and assume a linear relationship between trade and exchange rate, which may not be the case.
Furthermore, Bacchetta and Wincoop (2000) clearly state that the effect of exchange rate volatility on trade is rather mixed or uncertain depending on the countries, models used, and the period (Note 3) of study just to mention but a few.

Tenreryo (2007) using a panel data analysis of 104 countries and data covering the period 1970-1997 running country pairs with a gravity model found that exchange rate variability has no significant effect on trade.

Aristotelous (2001) conducted a study on UK exports to US covering the period 1889-1999 and found that exchange rate volatility does not have an effect on UK-US exports. The researcher further concluded that volatility may have an effect on other variables like prices or foreign direct investment flows. Bailey, Tavlas and Ulan (1986) in their study of exports of the G-7 (Note 4) OECD countries over the period 1973-1984 indicate that exchange rate variability over the floating exchange rate period had no effect on exports. The result was found to hold whether volatility is assumed to have an immediate or lagged impact on exports.

De Grauwe (1988) concludes in his study that exchange rate variability has a statistically significant negative effect on volume of international trade. He also goes ahead to add that about 20% of the reduction in international trade among the industrial countries can be attributed to exchange rate variability. According to Hooper and Kohlhagen (1978), in a study conducted on US and German trade flows between 1965-1975, it was found that an increase in exchange rate risk; that is an increase in volatility, will unambiguously force trade volumes to go down. Arize, Osang, and Slottje (2008) examined eight Latin American countries selecting the period 1973-2004 using co-integration and error correction techniques found that exchange rate volatility also has a significant negative effect on export volumes in both the short and long run. Dell'Ariccia (1999) also found that exchange rate fluctuations have a significant negative effect on international trade in Western Europe in a study that used a gravity model. Sauer and Bohara (2001) study panel data representing developed and developing countries. Results showed that exports from LDCs are more adversely affected whereas most of those from the DCs are less affected by such exchange rate volatilities. A further analysis shows that the most negatively affected nations are in Africa and Latin America while Asia is not affected to a greater extent.

In a rather interesting result, a study by Giorgioni and Thompson (2002) examining US wheat exports, it was concluded that import volatility and not exchange rate volatility significantly reduces the volume of exports.

Franke (1991) argues that whether the expected export volume of a firm grows with exchange rate volatility depends on the optimal export volume being a function of the exchange rate and on optimal adjustment of entry

and exit rates. From this, he concludes that the expected volume of international trade grows with exchange rate volatility for a firm with comparative disadvantage. Doyle (2001) studied Irish exports to the UK from 1979-1992 on both aggregate and sector specific data because exchange rates tend to affect sectors differently. Her methodology used a first order GARCH process and findings revealed that both nominal and real exchange rate volatility were important determinants of over 35% of Ireland-UK trade with positive effects predominating. She concluded in her study that the positive relationship may be due to the fact that Irish firms operate in a small open economy with a few options in dealing with increased exchange rate risk and have to keep trading for the fear of losing market share. A rather similar sector specific study by Awokuse and Yuan (2006) found that US poultry exports are negatively affected by exchange rate risk, however, only statistically significant for a method that uses the variance of the spot exchange rate as a measurement of volatility. Their study employed a gravity model approach on panel data.

McKenzie and Brooks (1997) analysed German-US bilateral trade data from 1973-1992, observing Germany's exports to and imports from the US using ARCH models to estimate volatility. The results showed that there is a positive effect of volatility, and statistically significant. Calderon (2004) conducted a study on 79 countries covering the period 1974-2003 using a GMM-IV method for panel data and found that the volatility of real exchange rate has a lower impact if the economy is more open to international trade. Olayungbo et al. (2011) conducted a study on 40 developing countries in sub-Saharan Africa over the period 1986-2005 using a gravity model and pooled OLS allowing for fixed effects and panel GMM.

The results revealed a positive relationship between exchange rate volatility and aggregate trade. The positive result implies that traders view volatility as an opportunity to make profit if the exchange rate shifts in their favour. In addition, there is not much difference between the effect of volatility on trade of primary and manufactured products. The authors warn that this result must be interpreted with caution as the history of exchange rate volatility is still relatively young in developing countries compared to developed nations. Asteriou, Masatci, and Pilbeam (2016) in a study covering a number of countries using the GARCH models found that in the short-run volatility affects export and import demand. However, in the long-run, exchange rate volatility has no effect on import and export demand.

The strategy of devaluing or depreciating a currency to promote exports and reduce imports in order to correct a trade balance (J-curve effect) may work for some countries and not work for others. China has always devalued its currency to increase its exports and this has worked. Rose (2000) states in his study that countries with extensive trade may lower exchange rate volatility deliberately in order to increase trade. Hsing (2008) studied US trade with a number of partner states in Latin America over a 30-year period and found the J-curve effect existed for Chile, Ecuador and Uruguay but did not exist for Argentina, Brazil, Colombia and Peru. Onafowora (2003) examines the short-run and long-run effects of real exchange rate fluctuations on real trade balance. The study covered the bilateral trade between three ASEAN countries (Note 5) and the US and Japan. Using a VECM framework that treats variables as endogenous; impulse response functions were used to trace out the effects of exchange rate shocks on bilateral trade ratio. Results revealed the presence of co-integration and thus a long-run relationship among real trade balance, real exchange rate, real domestic income and real foreign income. From this study, it was concluded that the Marshall-Lerner condition holds in the long-run with varying degree of J-curve effects in the short-run.

2.1 Effect of Exchange Rate Regimes

The end of the Bretton Woods Gold Standard in 1973, dubbed the *Nixon shock* meant that countries could no longer redeem gold for their dollars. This gave rise to Fiat money whose value is derived from the confidence investors have in the economy or the monetary system of the country in question. Compared to gold, which is relatively stable in value, this meant that the value of a currency was subject to substantial fluctuations. According to Frieden et al. (2006), the exchange rate is the most important price in the economy and has a ripple effect on all other prices. McKenzie (1999) defined *exchange rate volatility* as the risk associated with unexpected movements in the exchange rate. In his paper, he also pointed out that a debate developed after the collapse of the Bretton Woods pact; the *laissez faire* economists embraced this while others argued that risk averse exporters would reduce their output when faced with exchange rate risk caused by a floating exchange rate.

Von Hagen and Zhou (2005) found that the exchange rate regime employed by a country will depend on variables like level of development, inflation, foreign reserves, and financial market development and so on. The exchange rate regime employed by a country does have an impact on the volume of trade it has with its neighbours and the rest of the world. According to the IMF Annual Report on Exchange Arrangements and

Exchange Restrictions (2016), the de facto classification of exchange regimes are as follows;

No Legal tender (Currency union); here the currency of another country is used as the sole legal tender or a country may belong to a monetary union in which a similar currency is used. A good example here could be the European Monetary Union that can be deemed a very successful union.

Currency board arrangements; here a Board is given the authority to fix the value of the domestic currency in terms of a foreign currency. Tsang (1999) adds that Currency Boards issue money with 100% foreign exchange reserves, somewhat similar to the gold standard.

Fixed peg arrangements; a country usually fixes its currency at ±1 percent in relation to another currency. The exchange rate is allowed to fluctuate with narrow margins of less than ±1.

Pegged with horizontal bands; the exchange rate is maintained at a value of more than ±1 around a fixed rate.

Crawling pegs; the value of a currency is changed periodically in small amounts at a predetermined fixed rate in response to certain economic indicators.

Crawling bands; exchange rate fluctuations are maintained within certain margins of at least ±1 around a central rate, these rates are also adjusted periodically depending on the economic situation.

Managed Float; here the monetary authority tries to influence the exchange rate without having a specific path or target.

Independent Float; the exchange rate in this case is determined within the market by forces of demand and supply. Interventions are only aimed at managing macroeconomic variables like inflation but not determining the price of the currency itself.

Generally, all the above deeper classifications can be broadly grouped into fixed and floating exchange rate regimes.

Rose (2000) shows that countries with a common currency trade more and countries will trade less with each other when their currency exchange rates are volatile. The study also draws a distinction between a currency union and a fixed exchange rate regime; the two have different effects. Findings revealed that countries in a currency union trade 3.35 times more with each other than they do with countries outside the union. He also adds that when Ireland left its long 1:1 parity with the British pound in 1979 to join the European Monetary System, its bilateral trade with the UK fell by fifty percent from 1980 to 1985, and had not attained even its 1975 level before the end of the sample in 1990. This decline occurred despite large increases in both real GDP and real GDP per capita that would ordinarily lead to a substantial increase in trade. Adam and Cobham (2007) confirm that a currency union as an exchange rate regime like the European Monetary Union does increase the amount of trade between nations.

Furthermore, Lopez-Cordova and Meissner (2003) used a gravity model to find out how currency unions and monetary regimes like the gold standard affected globalization in the 19th century. Results indicated that the presence of a similar monetary regime and currency unions do have a significant positive effect on the volume of trade. From this perspective, it is evident that the fixed exchange rate regime does favour trade because some countries especially in the emerging market economies may not have access to forward markets in order to hedge against exchange rate volatility. Aristotelous (2001) argued that the exchange rate regime does not have an effect on export volumes. Coes (1981) studied exchange rate uncertainty under the crawling peg regime for Brazil. The study revealed that the reduction of real exchange rate after the adoption of a crawling peg regime in 1968 had positive effects on exports.

Kenen and Rodrik (1986) (Note 6) analysed the effect of short-term volatility in real exchange rates using data from industrial countries over the period 1975-1984; a floating rate period.

The study deliberately excluded the fixed rate period in order to avoid specification bias arising from the change in the exchange rate regime. Findings revealed that volatility of real exchange rates has not diminished over time as countries have gained experience with the floating exchange rate and more importantly, the volatility of real exchange rate depresses the volume of trade.

2.2 Exchange Rate Target Zones

According to Driffill (2008), a target zone attempts to limit the movement of an exchange rate avoiding the pitfalls of both pegged and a freely floating rate. Svensson (1992) defines exchange rate target zones as fixed exchange rate regimes with bands. The announcement of an exchange rate target zone has the advantage of reducing exchange rate volatility.

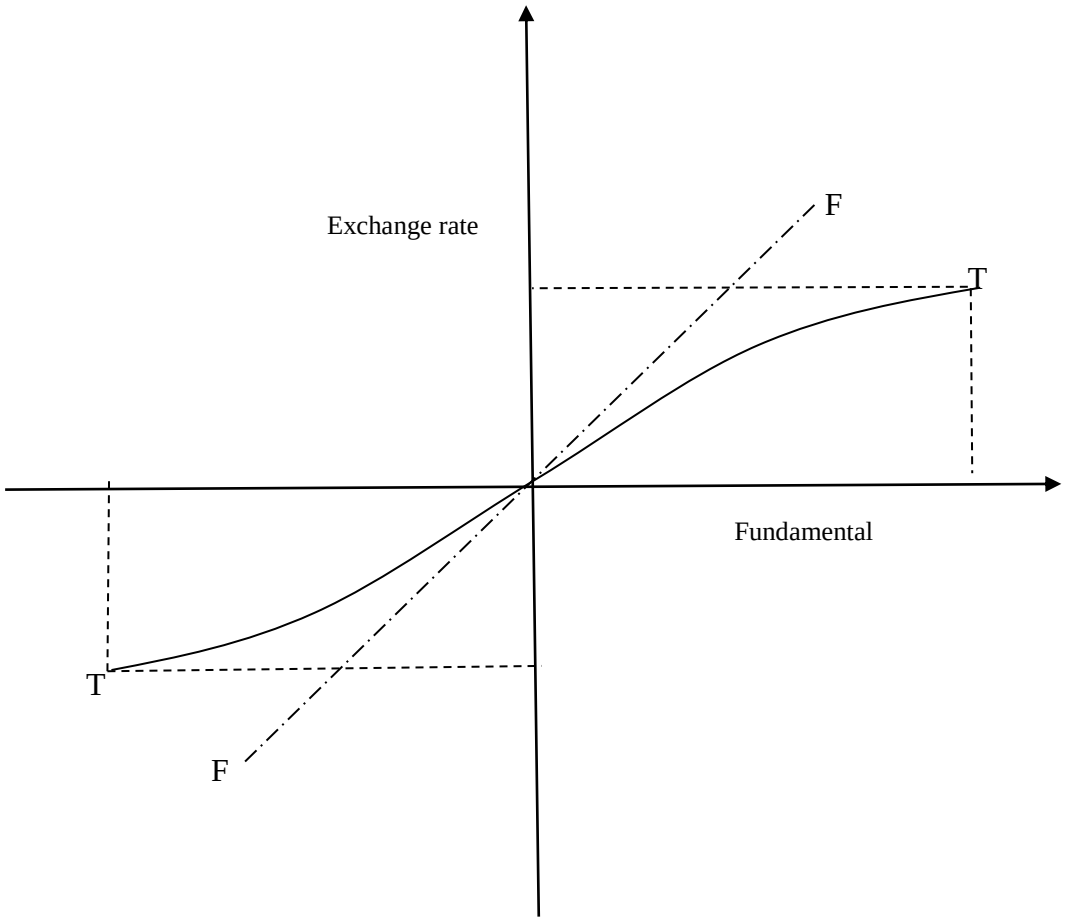

Figure 1. Krugman model

Krugman (1991) (Note 7) developed a fundamental model that became a point of reference for a great deal of research in target zone modelling; his model proposes that the behaviour of the exchange rate within the band depends on aggregate fundamental and its expected rate of change. The model predicts the S-shape non-linear relationship between the exchange rate and its fundamental determinants as shown by the curve TT. The line FF represents the equilibrium exchange rate in the free-floating regime. He assumes the exchange rate depends linearly on macroeconomic fundamental and the expected future value of a currency.

Within the fundamental, there are two components; velocity and domestic money supply where velocity is exogenous and stochastic while the money supply is changed or altered by the Central Bank from time to time to control and manage the exchange rate. As long as the exchange rate lies within the band, the money supply remains unchanged. The stochastic process is assumed to follow a Brownian motion without drift (Note 8).

The main results from the Krugman model are the *honeymoon* effect and *smooth pasting* (Note 9). As revealed in literature by Svensson (1992), if the exchange rate is higher and closer to the upper edge of the exchange rate band, the probability that it will reach the upper edge is higher. Thus, the probability that there will be future intervention to reduce money supply and strengthen the currency is higher.

The target zone exchange rate is less than the free-float exchange rate for a certain level of the fundamental. He further adds that the slope of the target zone exchange rate function is zero at the edges of the band thus the exchange rate at this point is insensitive to changes in the fundamental; this is *smooth pasting*. Duarte et al. (2012) in their study emphasise that the *honeymoon* effect implies that a perfectly credible target zone has the stabilization effect; interventions by the monetary authorities to stabilise the exchange rate within the band make the exchange rate more stable than the underlying fundamental.

Time varying re-alignment risk occurs when we allow the exchange rate band to shift. Bertola and Svensson (1993) were the first to present a target zone model with time varying re-alignment risk. The introduction of time

varying re-alignment risk changes the process by which the interest rate differentials are determined and the interpretation of interest rate differentials against exchange rate plots. The interest rate differential is now equal to the sum of the expected rate of currency depreciation within the band and the expected rate of re-alignment.

Hurley, McCormack and O'Brien (1993) in their study of the appropriate level of reserves required to defend an exchange rate target zone found that; for the case of Ireland, reserves were approximately optimal for most of the 1980s but significantly below optimal during 1989 and 1992. The authors further concluded that foreign exchange reserves should at least be kept above 25% of domestic credit.

2.3 Inflation Targeting and Exchange Rate Volatility

The collapse of the Bretton Woods also led to a rise in inflation rates and the more industrialised countries moved from exchange rate targeting to inflation targeting. Developing countries are also adopting inflation targeting as a good monetary policy framework for economic and general price stability including foreign currency price stability.

Inflation rates do have an effect on the exchange rate, high inflation rates tend to cause currency price volatility and stability in inflation is likely to cause exchange rate stability. Bernanke and Mishkin (1997) define inflation targeting as the announcement of official target ranges for inflation rates at one or more horizons and the inflation rate stability is the overall objective of the monetary policy. Gali and Monacelli (2002) use a small open economy of the Calvo sticky price model to investigate monetary policy and exchange rate volatility. Their findings show that inflation targeting which simultaneously achieves stabilization of domestic prices and output gap may pose a substantially larger volatility of nominal exchange rate and the Terms of Trade.

Aizenman, Hutchison and Noy (2011) in their study conducted among emerging markets find that the countries are not actually practising pure inflation targeting. Central banks are employing a mixture of inflation targeting; responding to both inflation and exchange rate by setting interest rates. They further reveal that emerging economies are simultaneously targeting inflation and exchange rates. Bernanke and Mishkin (1997) point out that exchange rate targets are intermediate while inflation targets are over longer-term horizons hence inflation targeting policy always takes precedence.

Mishkin (2004) points out that weak fiscal and monetary institutions make emerging market countries vulnerable to high inflation and currency crises. Even those that are trying to practise inflation targeting may not necessarily neglect the need to always respond to exchange rate fluctuations as and when the need arises, the Central Banks may focus too much attention on limiting exchange rate fluctuations and at times revise their inflation targets.

3. The Model and Data

This section explains how the data was handled to fit the specified model.

The general model used was of the form below; a simpler version of the one specified by Arize et al. (2000).

$$LnX_{ijt} = \beta_0 + \beta_1 LnG_{jt} + \beta_2 LnP_{ijt} + \beta_3 \sigma_{ijt} + \varepsilon_{ijt} \quad (1)$$

Where X_{ij} real exports from country i to j, G_j is the GDP of importing country j, P_{ij} real bilateral real exchange rate reflecting price competitiveness, σ_{ij} is a measure of the volatility of bilateral real exchange rate, ε_{ij} myriad of other factors affecting exports of i to j and t is the time period.

3.1 Real Exports

Leamer and Stern (1976) suggest that export volume is a more appropriate measure than monetary value. However, despite this suggestion, a number of scholars continue to use monetary value. Meniago and Eita (2017) use import value and export value to investigate the effect of exchange rate volatility on trade in 39 Sub-Saharan African countries.

$$X_{ijt} = \left[\frac{a_{ijt}}{av_{it}} \times 100\right] \quad (2)$$

Where a_{ijt} is the quarterly exports of i to j and av_{it} is the export unit value index of country i.

3.2 Gross Domestic Product

GDP is usually used as a proxy measure for the level of economic activity in the importing country (United States), however, in the study the seasonally adjusted industrial production index was used as a proxy for the level of economic activity. The use of this proxy is further justified by Barkoulas et al. (2002).

3.3 Real Bilateral Exchange Rate

McKenzie and Brooks (1997) in their study conclude that it does not matter whether one uses the nominal

exchange rate or real exchange rate to estimate exchange rate volatility. Akhtar and Hilton (1984) in their study use measures of nominal and real exchange rate. The results show that nominal exchange rate volatility had statistically significant effects and the results for real variability were rather mixed but generally consistent with those of the nominal exchange rate measures. This study specifically used the real exchange rate as computed below.

$$P_{ijt} = E_{ijt} \times \left[\frac{CPI_{jt}}{CPI_{it}}\right] \tag{3}$$

Where E_{ijt} is the nominal exchange rate and CPI the consumer price index.

3.4 Volatility

A number of approaches (Note 10) have been used to estimate exchange rate volatility. Thursby and Thursby (1987) use absolute percentage change of the exchange rate, Hooper and Kohlhagen (1978) use the average absolute difference between the previous forward and current spot rate. Koray and Lastrapes (1989) use the moving average of the standard deviation of the exchange rate. In our sample, Real Exchange rate volatility shows evidence of volatility clustering i.e. periods of low volatility are followed by periods of low volatility and those of high volatility by high volatility thus it was justified that exchange rate volatility was estimated using the GARCH (1,1) (Note 11) model developed by Bollerslev (1986).

$$\sigma_t^2 = \omega + \alpha\sigma_{t-1}^2 + \beta P_{t-1}^2 \tag{4}$$

Where σ^2 is the variance, α-GARCH coefficient, β-ARCH coefficient, P-real exchange rate and α+β<1 is the persistence.

3.5 Predictions

A higher level of economic activity in the importing country means the demand for goods from the exporting country, in this case Canada, will be higher too. The coefficient β_1 is expected to be positive to reflect the relationship described above. The value of β_2 is also expected to be positive; a depreciation in a currency means that the prices of exports will fall thus the demand goes up and the exports of a country will increase. It is only realistic to postulate that β_3 will be negative since the assumption is that exporters are risk averse and will tend to reduce the volume of what they produce if the return is uncertain.

3.6 Data

The data for this study was collected from the International Financial Statistics database of the IMF, UNCTAD and the World Bank. The study used quarterly data covering the period 1960Q1-2017Q4. Quarterly frequency has been shown to be more appropriate when dealing with macroeconomic data like inflation, exchange rates and others. The US and Canada have had relative economic stability over the period covered by the study let alone the economic and financial crises that have had a ripple effect on the global economy as a whole. Given this stability, there was no need to do a sub-period analysis.

4. Tests

This section explains the theory and procedure behind the tests that were conducted on the data.

4.1 Unit Root Tests

It is important to determine whether a time series is stationary or not. If a normal regression is applied to a non-stationary time series, then the results are likely to be biased.

A stationary time series is characterised by a time-invariant mean and time invariant variance. Unit root tests were conducted using the Augmented Dickey-Fuller (1981) and Phillips-Perron (1988) tests. If the variables are found to be stationary the standard regression can be applied, however, if the variables are non-stationary at levels but stationary after the first difference i.e. integrated of order one (same order), I(1), then co-integration tests are carried out. The ADF unit root test is a parametric form that assumes the y series follows an AR(p) process. The regression to perform the test is of the form below;

$$\Delta y_t = \alpha + \beta t + \delta y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + \varepsilon_t \tag{5}$$

The null hypothesis is that the series y_t is *non-stationary* against the alternative that the series is stationary i.e.

$$H_o: \delta = 0 \; and \; H_1: \delta < 0$$

4.2 Co-Integration Tests

Johansen-Juselius (1990) propose a maximum likelihood technique that tests for a long-run relationship between

two or more variables. This technique is also presumed to be superior to the regression-based test for co-integration developed by Engle and Granger (1987). If two or more series have a unit root, that is I(1), but a linear combination of them is stationary, I(0), then the series are said to be co-integrated. If the variables are integrated of the same order and co-integrated, then the OLS estimator is super-consistent and converges to the population parameters much faster than if the variables are stationary. This means that if the variables have a long-run relationship then the normal OLS regression is justified.

The residuals from a regression of variables that are integrated of the same order and co-integrated are stationary while the residuals from non-stationary variables that are not co-integrated are non-stationary. This is a violation of the Gauss-Markov Classical Linear Regression Model assumptions and thus the OLS estimator will not be BLUE.

The co-integration test is based on VAR approach. Let a vector of n variables be specified by the VAR process described herein; this process can be expressed in Error Correction form as in equation (8) below.

$$Z_t = (Z_{it}, Z_{2t}, Z_{3t}, \dots, Z_{nt}) \tag{6}$$

$$Z_t = \Phi + \phi_1 Z_{t-1} + \phi_2 Z_{t-2} + \cdots + \phi_k Z_{t-k} + \varepsilon_t \tag{7}$$

$$\Delta Z_t = \Phi + \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \cdots + \Gamma_{k-1} \Delta Z_{t-k+1} + \Pi ECT_{t-1} + \varepsilon_t \tag{8}$$

Where t=1,2, 3,…,T ; T is the sample size

Co-integration will depend on the rank of matrix Π in equation (8) above. The rank of matrix Π will give the number of co-integration vectors in a system of variables. In addition, the rank of Π will give the number of linear combinations of the vector Z_t that are stationary. If the rank, r, of the matrix Π is zero, then there are no co-integrating relationships in the variables and all the elements in Z_t are non-stationary. If Π is of full rank then all elements of Z_t are stationary. The Johansen test is based on the trace test and maximal eigenvalue test statistics. The trace test is a joint test, where the null is that the number of co-integrating vectors is less than r against the alternative that there are more than r co-integrating vectors. For the maximal eigenvalue test, the null is that there are r co-integrating vectors against the alternative that there are (r+1) co-integrating vectors. The relevant statistics are computed as indicated below;

$$\hat{\lambda}_{trace}(r) = -T \sum_{i=r+1}^{n} In(1 - \hat{\lambda}_i) \tag{9}$$

$$\hat{\lambda}_{max}(r, r+1) = -TIn(1 - \hat{\lambda}_{r+1}) \tag{10}$$

Where $\hat{\lambda}_{r+1}$ is an estimated eigenvalue.

5. Empirical Results and Discussion

This section presents a general discussion of the results of the tests carried out on the data in tables and graphical illustrations.

5.1 GARCH Effects in the Real Exchange Rate

Table 1. Correlogram test results for Autocorrelations (AC), Partial Autocorrelations (PAC) and Box-Pierce Q-statistics

Lag	AC	PAC	Q	Prob>Q
1	0.1997	0.1986	11.382	0.0034
2	0.1447	0.1199	16.324	0.0010
3	0.1485	0.1005	21.55	0.0002
4	0.1260	0.0701	25.328	0.0001
5	0.1789	0.1217	32.989	0.0000
6	0.0230	-0.0545	33.116	0.0000

An extract of the autocorrelations tests on the squared real exchange rate data up to lag 12 indicates the presence of GARCH effects as shown in Table 1 above. The p-values are statistically significant which implies that the null hypothesis of *no autocorrelation* is rejected and thus there is autocorrelation and GARCH effects present in the real exchange rate data. Thus, the use of the GARCH (1, 1) model is justified in this data.

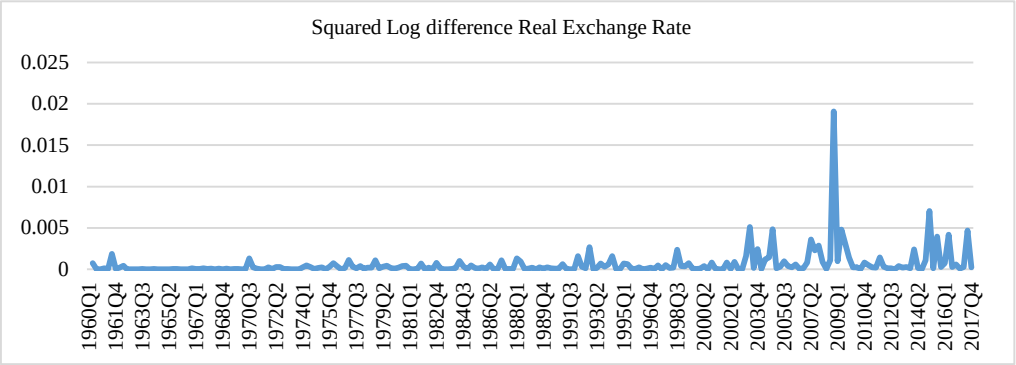

Figure 2. Squared log difference of the real exchange rate

The squared log difference of the real exchange rate graph above indicates volatility clustering; periods of low volatility are followed by periods of low volatility and high volatility by high volatility. This is an indication of the presence of autocorrelation and GARCH effects in the real exchange rate.

5.2 GARCH (1,1) Coefficients

Table 2. GARCH (1, 1) constant, ARCH and GARCH coefficients results

	Coefficient	Std Error	Z-statistic	P-value	Persistence
ω	9.80e-06	4.90e-06	2.00	0.045	**0.998851**
α (GARCH)	0.8654585	0.0383304	22.58	0.000	
β (ARCH)	0.1333927	0.0396095	3.37	0.001	

Table 2 shows that the GARCH (1, 1) model is well behaved with the persistence less than one and none of the coefficients negative. The persistence of less than one implies that the data generating process will exhibit a mean reversion behaviour. There will be mean reversion of the conditional volatilities. The non-negativity of the coefficients ensures the model does not predict a negative variance value since variance is always positive. Also, all the coefficients are statistically significant at 5% level and thus the GARCH (1,1) model is a good fit for estimating volatility. However, the persistence value is very close to one meaning that the process will take a long period to revert to the long run variance (weakly stationary).

5.3 Time-Series Graphs

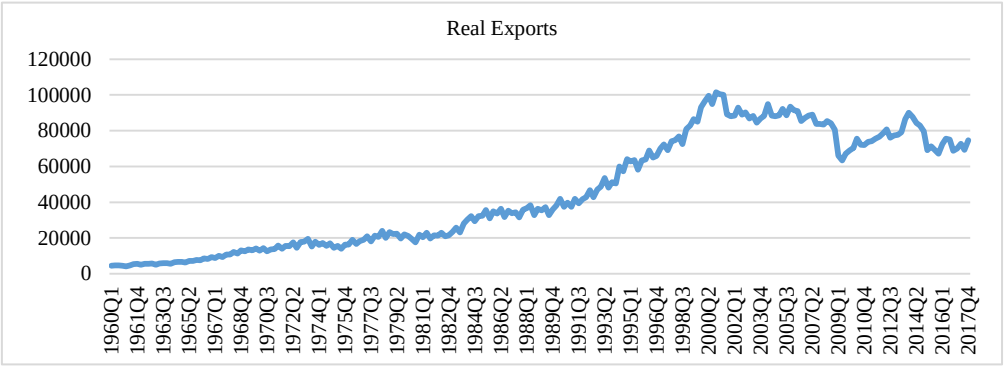

Figure 3. Real exports

Figure 3 above shows the growth trend in the real exports of Canada to the US over the period of study. From the graph it is possible to see that there was a steady increase in exports from 1960Q1 peaking around 2000Q4 after which the exports tended to drop and rise again.

There is a sharp drop around the period 2009Q2. The steady increase in exports can be attributed to the industrialisation of the Canadian economy. With regard to stationarity, it is evident from observation that the series is non-stationary and it trended.

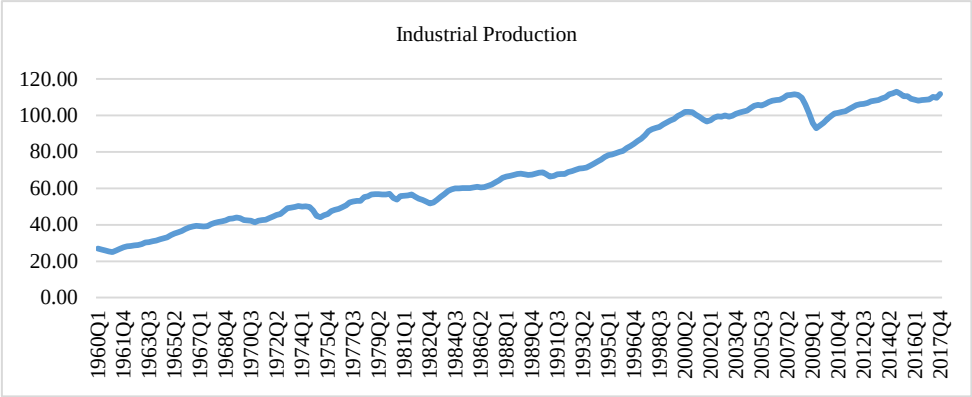

Figure 4. Industrial production

From figure 4 above, it is clear to see the growth in the US industrial production during the research period. Indeed, the US economy has gradually grown over the years though the growth rates registered have been relatively low. This growth has stimulated the demand for Canadian exports by US consumers. The industrial production data series is definitely non-stationary from observation.

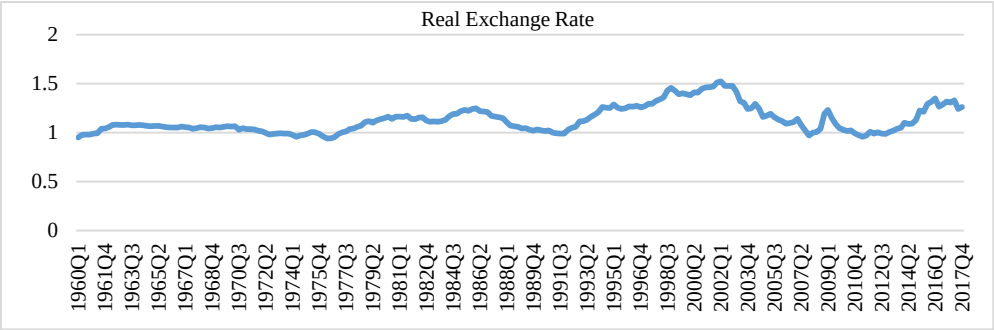

Figure 5. Real exchange rate

Figure 5 reveals the fluctuations in the real exchange rate between the Canadian dollar and US dollar over the 57-year period of study. The Canadian dollar appreciated and depreciated a number of times against the US dollar over the period of study. The exchange rate was characterised by periodical jumps. These jumps can be attributed to the regime shift from the Bretton Woods Gold standard to the floating exchange rate regime during the 1970s and the 2000s financial crises just to mention but a few. The Canadian dollar has also lost value against the US dollar over the years. The CAD was much stronger in the 1960s compared to today. 0.95 CAD was equivalent to 1 USD in 1960, however, as of 2017, 1.27 CAD was equivalent to 1 USD. From the real exchange rate graph, it is very likely that the series is non-stationary.

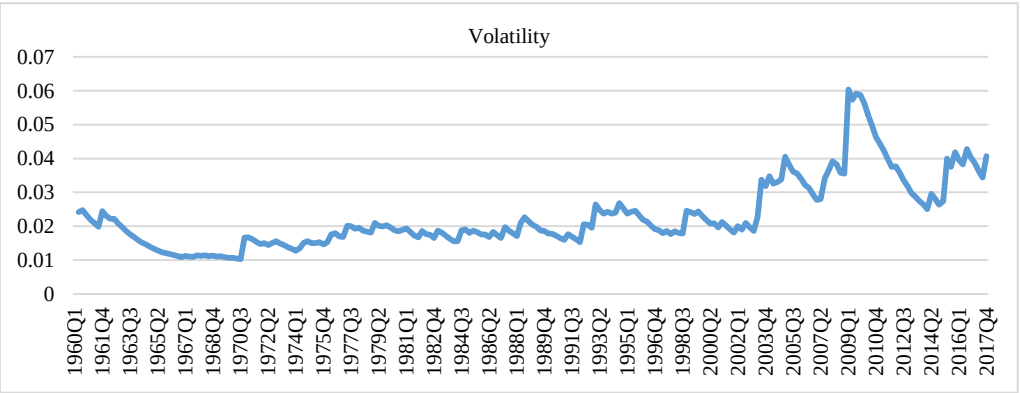

Figure 6. Real exchange rate volatility

Figure 6 above shows the volatility of the real exchange rate between the CAD and USD, the volatilities have not been so big over the years. The currencies have been relatively stable in value. Uncertainties in the exchange rate have been low. There is a sharp jump around 2009Q1; probably due to the financial crisis in that period. The volatility series is also likely to be non-stationary from observation.

5.4 Unit Root Tests

Table 3. ADF and Phillips-Perron test results for Unit Root

	ADF Test		Perron Test	
	Level	**1st difference**	**Level**	**1st difference**
$\boldsymbol{LnX_{ij}}$	0.6480	0.0000	0.9111	0.0000
$\boldsymbol{LnG_{jt}}$	0.9070	0.0000	0.6622	0.0000
$\boldsymbol{LnP_{ij}}$	0.6857	0.0000	0.4723	0.0000
$\boldsymbol{\sigma_{ij}}$	0.0692*	0.0000	0.0464	0.0000

Note. * This result is weakly non-stationary at 5% level of significance.

The results in the Table 3 above show the p-values from the tests using both ADF and Phillips-Perron techniques; the variables are all integrated of order one, I(1); thus have to be differenced once in order to make them stationary. The null hypothesis of *non-stationarity* is easily rejected after the first difference. The tests were performed using the intercept and time trend term in the regression with a lag order of 5.

Despite the fact that the real exchange rate data used to generate the GARCH (1, 1) variance was stationary, the resulting volatility from the model is non-stationary as indicated by the unit root test results in Table 3 above. It can also be noticed from the results that Phillips-Perron and the ADF test results are different. Some of the techniques developed to test for unit root in data have been revealed to have low power (Note 12) and thus it is necessary to use more than one technique especially when dealing with panel data. Results from the ADF test indicate that at 5% level of significance, the variables are non-stationary at levels and stationary after the first difference. Also, the Phillips-Perron results indicate that the variables are I(1) except for the volatility that is I(0) at 5% significance level. Despite this result, the researcher decided to consider mainly the results from the ADF test that indicates that all the variables are I(1) at 5% level of significance. Even after increasing the number of lags in the test, we still fail to reject the null hypothesis and conclude that the variables are non-stationary. This result is consistent with the findings of Nelson and Plosser (1982) who state that macroeconomic and financial time series data are suspect to unit root and most are integrated of order one and may thus share a common stochastic movement.

5.5 Lag Order Selection

In order to move forward to the co-integration tests and apply a relevant technique to the data, it is important to determine the appropriate number of lags to use. The number of lags to use was determined by the various information criteria.

Table 4. Information Criteria results for optimal number of lags

Lag	LL	LR	DF	P	FPE	AIC**	HQIC**	SBIC**
2	2568.63	240.94	16	0.000	2.2e-15	-22.4127	-22.1928	**-21.8678***
3	2573.55	9.8361	16	0.875	2.4e-15	-22.3146	-21.997	-21.5276
4	2625.42	103.74	16	0.000	1.7e-15	-22.6321	-22.2167	-21.6029
5	2675.29	**99.741***	16	0.000	**1.3e-15***	**-22.9318***	**-22.4187***	-21.6605

Note. ** The Akaike, Hannan –Quinn and Schwarz criteria are the ones frequently used.

Table 4 shows that the optimal number of lags to use is either 2 or 5 as given by the relevant information criteria. The majority of the information criteria give 5 as the appropriate lag order though; the researcher thus chose 5 lags to conduct the co-integration test and develop a VAR system. It is important to note that too many lags reduce the degrees of freedom and if the lags are too few then there will be an autocorrelation problem; thus, the lag number has to be optimal.

5.6 Co-Integration Test

According to Mustafa and Nishat (2004), the Johansen test for co-integration is more appropriate when more than two variables are used in a model. The test requires that all the variables be I(1) and this has been confirmed by the ADF test results. The null hypothesis is that there can be ***r*** co-integrating vectors among the four variables

in the system. Tables 5 and 6 show the results from the Johansen test; trace and maximum eigenvalue statistics.

Table 5. Trace statistic for Johansen-Juselius test result

Rank (r)	Parms	LL	Eigenvalue	Trace stat	5% critical
0	**84**	**2654.3156**		**45.3174**	**47.21**
1	91	2666.476	0.10246	20.9965	29.68
2	96	2672.8915	0.05543	8.1656	15.41
3	99	2675.5579	0.02342	2.8328	3.76
4	100	2676.9743	0.01251		

Table 6. Maximum Eigen value statistic for Johansen-Juselius test result

Rank (r)	Parms	LL	Eigenvalue	Max stat	5% critical
0	**84**	**2654.3156**		**24.3209**	**27.07**
1	91	2666.476	0.10246	12.8309	20.97
2	96	2672.8915	0.05543	5.3328	14.07
3	99	2675.5579	0.02342	2.8328	3.76
4	100	2676.9743	0.01251		

The Johansen test reveals that there is no co-integration. Table 5 result shows that we fail to reject the null hypothesis of *no co-integration* because the trace eigenvalue statistic is less than the 5% critical value. Table 6 above also gives the same result; the maximum eigenvalue statistic is less than the 5% critical value hence no co-integration. The result remains unchanged after using 2 lags as suggested by the Schwarz information criteria; there is no co-integration.

5.7 The Regression Model

From the test results above, there is no co-integration (Note 13) in the variables and thus it is appropriate to model the short-run relationship among the variables. The OLS properties only hold when processes are stationary and thus the trend has to be removed usually by taking the first difference. The short-run relationship was modelled using a VAR model taking the first difference of the variables and then developing a VAR system of equations. VARs are bivariate and multivariate linear time-series models designed to capture the joint dynamics of multiple time-series. VARs treat each endogenous variable in the system as a function of lagged values of all endogenous variables.

A regression of the first difference of the variables ensures that the resulting regression is not a spurious one. Regressing two or more integrated or non-stationary processes of the same order on each other tends to yield statistically significant results even when there is no such relationship thus a spurious regression. Granger and Newbold (1974) introduced the concept of spurious regressions stating that serial correlation among the residuals in econometric regression models involving variables at level made the usual significance tests on coefficients invalid. In their study, they also showed that that the estimation of a regression of first difference of I(1) variables does not distort the hypothesis testing of the coefficients. Table 9 gives the regression results from the VAR system. Before the results were interpreted, diagnostic tests on the VAR system were conducted to ensure a well-specified model as discussed below.

Table 7. Lagrange Multiplier (LM) test for residual autocorrelation

Lag	Chi-Square	df	Prob > Chi-Square
1	21.0134	16	0.17800
2	18.6472	16	0.28738
3	24.4095	16	0.08093
4	37.7112	16	0.00166
5	22.3033	16	0.13367

The diagnostic LM test in the residuals indicates that the null hypothesis of *no autocorrelation* is not rejected at lags 1,2,3 and 5 because of the high p-value. In general, it was concluded that the model is well specified with the desirable property of no autocorrelation.

Table 8. Jarque-Bera normality test results

Equation	Chi-Square	df	Prob > Chi-Sqaure
ΔLnX_{ij}	0.489	2	0.78303
ΔLnG_j	21.728	2	0.00002
ΔLnP_{ij}	217.220	2	0.00000
$\Delta\sigma_{ij}$	2468.894	2	0.00000

From the result in Table 8 above, it was concluded that the VAR equation with the exports variable on the left hand side had normally distributed residuals as opposed to other cases. In this case, the null hypothesis of *normally distributed residuals* was not rejected because of the high p-value.

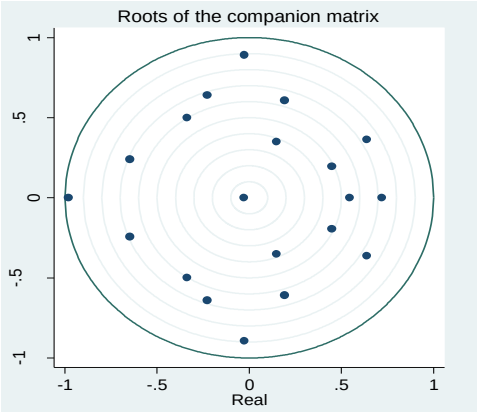

Figure 7. Eigenvalue VAR stability test results

It is evident that all the eigenvalues lie inside the unit circle thus the VAR system satisfies the stability condition.

After the tests, it was concluded that the model is well specified and the results are reliable. Thus, the model can be used for forecasting, generating impulse response functions and variance decomposition estimates.

Table 9. VAR short-run test results

	Coefficient	Std. Error.	Z-stat	P>|Z|
Constant	**0.0089783**	0.0038985	2.30	**0.021**
ΔLnX_{ijt-1}	**-0.1897965**	0.0743301	-2.55	**0.011**
ΔLnX_{ijt-2}	**-0.1297048**	0.0640442	-2.03	**0.043**
ΔLnX_{ijt-3}	**-0.1836206**	0.0617818	-2.97	**0.003**
ΔLnX_{ijt-4}	**0.5553698**	0.0630149	8.81	**0.000**
ΔLnX_{ijt-5}	**-0.1502104**	0.073638	-2.04	**0.041**
ΔLnG_{jt-1}	**0.8620867**	0.3173589	2.72	**0.007**
ΔLnG_{jt-2}	0.3840681	0.357223	1.08	0.282
ΔLnG_{jt-3}	0.2128509	0.3485284	0.61	0.541
ΔLnG_{jt-4}	**-1.02296**	0.3479936	-2.94	**0.003**
ΔLnG_{jt-5}	0.2086791	0.295452	0.71	0.480
ΔLnP_{ijt-1}	**-0.41804**	0.1392776	3.00	**0.003**
ΔLnP_{ijt-2}	0.2847044	0.1515939	1.88	0.060
ΔLnP_{ijt-3}	-0.1155871	0.1491857	-0.77	0.438
ΔLnP_{ijt-4}	-0.1360528	0.1497858	-0.91	0.364
ΔLnP_{ijt-5}	0.2412849	0.1468747	1.64	0.100
$\Delta\sigma_{ijt-1}$	-1.596374	1.250659	-1.28	0.202
$\Delta\sigma_{ijt-2}$	0.2438729	1.258523	0.19	0.846
$\Delta\sigma_{ijt-3}$	1.699401	1.251211	1.36	0.174
$\Delta\sigma_{ijt-4}$	0.6551472	1.266034	0.52	0.605
$\Delta\sigma_{ijt-5}$	-0.9182319	1.234752	-0.74	0.457

From table 9; the lagged differenced proxy for GDP, industrial production, has two coefficients, one positive (lag 1) and the other negative (lag 4) that are statistically significant. This result indicates sign ambiguity. The negative coefficient is inconsistent with economic theory; since an increase in the income of the importing country (US) should lead to an increase in demand for the Canadian exports.

For the real exchange rate, the coefficient (lag 1) that is statistically significant has a negative sign. This is contradictory to economic theory. Economic theory here suggests that a depreciation (increase in the exchange rate) of the exporting country's currency (CAD) will make exports cheaper and thus a positive sign is expected here.

With regard to exchange rate volatility, the sign results predict a positive and negative relationship but none of them is statistically significant at all 5 lags. The positive sign of the coefficient is inconsistent with economic theory given that producers are expected to be risk averse if a currency is volatile. The statistical insignificance of the coefficients led to the conclusion that in the short-run exchange rate volatility does not affect Canadian exports to the US.

Table 10. Granger causality Wald test results

Equation	Excluded	Chi-Square	df	Prob > Chi-Square
ΔLnX_{ij}	ΔLnG_j	24.697	5	**0.000**
ΔLnX_{ij}	ΔLnP_{ij}	14.109	5	**0.015**
ΔLnX_{ij}	$\Delta\sigma_{ij}$	4.4653	5	0.485
ΔLnG_j	ΔLnX_{ij}	4.2911	5	0.508
ΔLnG_j	ΔLnP_{ij}	15.894	5	**0.007**
ΔLnG_j	$\Delta\sigma_{ij}$	1.278	5	0.937
ΔLnP_{ij}	ΔLnX_{ij}	1.7198	5	0.886
ΔLnP_{ij}	ΔLnG_j	3.9058	5	0.563
ΔLnP_{ij}	$\Delta\sigma_{ij}$	7.1768	5	0.208
$\Delta\sigma_{ij}$	ΔLnX_{ij}	3.5625	5	0.614
$\Delta\sigma_{ij}$	ΔLnG_j	1.7651	5	0.881
$\Delta\sigma_{ij}$	ΔLnP_{ij}	23.844	5	**0.000**

Granger (1969) developed a test used to determine predictive causality by testing the ability of a time series to predict future values of another time series. The Granger causality test checks whether the lagged variables as a whole have an effect on the dependent variable in the system of equations. The null hypothesis is that a variable *does not Granger cause* the other in a system; it is thus a joint hypothesis test of the coefficients of the lagged values of the endogenous variables. The Granger test also helps to check whether causation is uni-directional or bi-directional. From the Granger causality results in Table 10 above, it was concluded that the proxy for GDP, industrial production Granger causes exports in the short run.

In addition, the real exchange rate Granger causes real exports. This is so because the p-value is less than 5% level of significance thus the null hypothesis of *no causality* was rejected. Furthermore, from the same results, exchange rate volatility does not Granger cause real exports in the short-run. Also, real exchange rate Granger causes GDP and real exchange rate Granger causes volatility. The causation for all the lagged variables is uni-directional. Most of the reported results make economic sense.

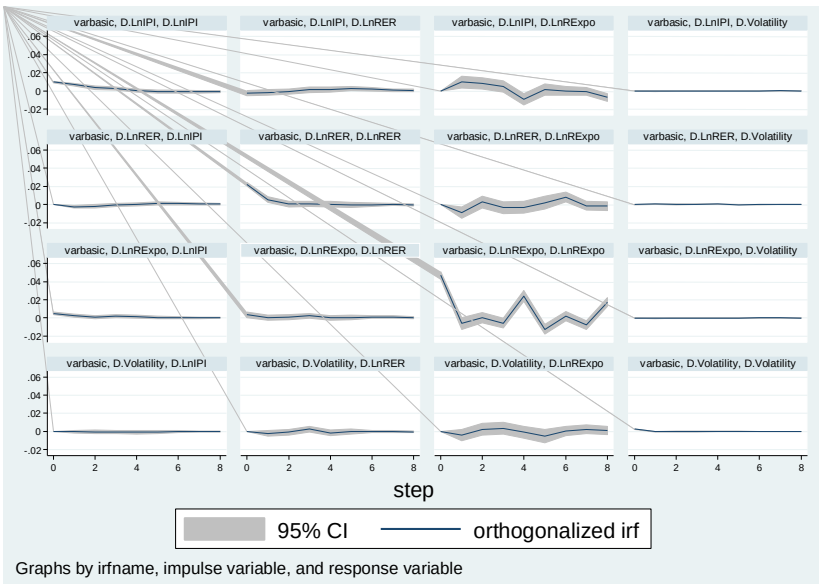

Figure 8. Impulse response functions

Figure 8 above is a representation of the impulse response functions of each variable to an innovation or one standard deviation shock in another variable. The shocks are applied to the error terms. Granger causality may not reveal the entire relationship between the variables in the system and thus it is important to estimate the impulse response functions.

Also, interpretation of the VAR model is at times difficult and not straight forward because of the many coefficients, thus, a visual gives a better and easier explanation.

For example, a shock to the real exchange rate has an immediate negative effect on exports, exports are then positive after one quarter, fall to negative again after two quarters then steadily increases up to the sixth quarter after which exports fall again and the effect of the shock to the real exchange rate steadily dies out.

6. Limitations of the Study and Improvements

As discussed earlier on in the literature, the effect of exchange rate volatility on the exports of different sectors may vary. This study fails to disaggregate the exports of Canada into various sector contributions and considers the aggregate export figures. This in turn has the effect of obscuring the nature and true relationship between exchange rate volatility and exports.

In addition, despite the fact that the economies of these two countries have been relatively stable over the years, it might have also been important to consider a sub-period analysis. Probably splitting the data into two; studying the effect of exchange rate volatility on exports during the pre and post Bretton Woods periods thus including the effect of the exchange rate regime shift from fixed to the floating.

Furthermore, a model that takes into account imports could be employed too. Such a model would simultaneously study the effect of exchange rate volatility on exports and imports thus trade as a whole.

Finally, the study could be expanded to consider the effect of exchange rate volatility on Canadian exports to Mexico since it forms part of the NAFTA; it is a smaller economy though. With the addition of Mexico, a panel data analysis could be employed and a Gravity model used. These modifications may allow bringing in other factors that affect exports and trade to the model. These factors include distance, and dummy variables like language, common border, colonisation by the same country and so on.

7. Conclusion

The study investigated the effect of real exchange rate volatility between the CAD and USD on exports of Canada to United States using over half a century of quarterly data applying a GARCH (1, 1) to model real exchange rate volatility. The variables were found to be non-stationary using the ADF unit root test. After finding no evidence of co-integration in the variables, a VAR was used to model the short-run relationship taking the first difference of the variables. The VAR model was found to be stable and reliable after a number of diagnostic tests deemed it a good fit to the data.

The results revealed that the effect of exchange rate volatility between the CAD and the USD is of mixed signs with coefficients that are not statistically significant; thus, exchange rate volatility does not have an effect on the exports of Canada to the US. In addition, the real exchange rate volatility does not Granger cause real exports. This result contradicts economic theory that predicts a negative and significant effect of volatility on exports. However, this finding is consistent with results from previous studies. Tenreryo (2007) and Aristotelous (2001) report no effect of exchange rate volatility on exports.

Furthermore, this result provides new evidence that policy makers can use to make decisions for further economic integration in the region. Thus, the reasoning that exchange rate volatility reduces Canadian exports to the US should not be used as a premise for moving towards a common currency in the region; real exchange rate volatility has no effect on Canada's exports to the US. Even if it did have an effect on exports, it is negligible.

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Notes

Note 1. Many have argued that if a common currency is to be adopted in North America, it will be the US dollar; Canada and Mexico will have to give up their domestic currencies. This is because the US dollar is an internationally recognised reserve currency and thus the US cannot give it up.

Note 2. NAFTA superseded the Canada-United States Free Trade Agreement and included Mexico thus the bloc comprises of the United States, Canada and Mexico. Canada and United States are very important and strategic trade partners to each other.

Note 3. The period of study may be characterised by exchange rate regime shifts, economic booms and depressions, currency and financial crises and political instability all of which may affect the results of the study. This calls for the application of a sub-period analysis to control for these economic shifts.

Note 4. Canada, France, Germany, Italy, Japan, UK and US.

Note 5. Thailand, Malaysia and Indonesia.

Note 6. The study covered developed countries using three measures to model risk aversion; first is the standard deviation of the monthly percentage change in the real exchange rate. The second measure is the standard deviation of the real exchange rate obtained from a log-linear trend equation and finally the standard deviation of the real exchange rate obtained from a first-order auto-regressive equation. The quadratic measures of volatility are more consistent with the hypothesis of risk –averse behaviour as identified in their paper.

Note 7. $S(t) = f(t) + \alpha E_t[ds(t)]/dt;$ Where s(t) is the log of the nominal exchange rate at time t, f(t) is the fundamental at time t, α is the absolute value of the semi-elasticity of the exchange rate with respect to its expected rate of change and E_t is the conditional expectations operator on the available information at time t.

Note 8. Svensson (1992) stresses that for a Brownian motion without drift, the two things to note are; realised sample paths are continuous over time and do not include jumps; and changes in the variable over any fixed time interval are distributed as a normal random variable with a zero mean and a variance that is proportional to the

time interval's length. He further notes that this assumption is convenient because it means that the free-float exchange rate will also be a Brownian motion, which is consistent with observations that free-float exchange rates follow random walks.

Note 9. A detailed interpretation of the honeymoon and smooth pasting effects in the Krugman model can be found in the paper; Lars E. O. Svensson, *An Interpretation of Recent Research on Exchange Rate Target Zones*, 1992.

Note 10. For a detailed discussion on the approaches to measuring volatility, refer to Michael D. McKenzie, *The Impact of Exchange Rate Volatility on International Trade Flows*, 1999.

Note 11. The volatility is derived from the conditional variance of the first difference of the log of the real exchange rate. It is important to ensure that the log of the real exchange rate is stationary before applying the GARCH (1, 1) model to it.

Note 12. The power of a hypothesis test is the probability of that test correctly rejecting the null hypothesis when a specific alternative is true. An increase in the statistical power decreases the probability of making a type II error.

Note 13. In cases of no co-integration, the short-run relationship can be modelled by taking the first difference of the variables and applying OLS or a VAR model otherwise if co-integrated the long-run relationship can be modelled using the variables at level by applying OLS or VECM.