The Impact of Exchange Rate Volatility upon Canadian Exports to US

by

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Abstract

This paper examines the impact of exchange rate volatility upon the exports of Canada to the United States at both aggregate and disaggregated levels over the period 1973:01 to 2004:03. The proxy for volatility is generated by a (G)ARCH model based on the real effective exchange rate or nominal exchange rate. The results we obtained suggest that the impact of exchange rate volatility is very inconclusive and, for all cases, is statistically insignificant, although the results of the real and nominal exchange rate cases lead to a similar conclusion. The results are consistent with the general uncertainty about the impact of exchange rate volatility upon the level of exports provided by previous theoretical and empirical studies.

Keywords: (G)ARCH; Exchange rate volatility; Exports

1. Introduction

Since the advent of the flexible exchange rate system in 1973, both real and nominal exchange rates have experienced periods of substantial volatility. At the same time the growth of international trade has declined significantly among industrial countries (Doroodian, 1999, 1), leading many researchers to investigate the impact of exchange rate volatility upon the volume of trade flows. However, no consensus about the effects of exchange rate variability on the flow of trade has been reached at either the theoretical or empirical levels. Broadly speaking, empirical studies have not shown a systematically significant relationship between exchange rate volatility and trade flows. On the other hand, theoretical studies have not reached any consistent conclusion concerning the link between exchange rate volatility and trade flows.

The most interesting and difficult task in an examination of the effect of exchange rate volatility on trade flows is to construct a proper and reliable measure of exchange rate volatility. Many measures have been employed, such as the absolute percentage change, average absolute difference, ARIMA model residuals and so forth. However, none of them has an overwhelming superiority over the others. In this study, we intend to examine the impact of exchange rate volatility upon the exports of Canada to the United States. Since the use of aggregate data usually results in the failure to find a significant link between exchange rate volatility and exports and the results tend to be diluted because of the different natures of sub-markets, we also use disaggregated sectoral exports data to perform our test. The proxy for volatility is generated by a (G)ARCH model based on the real or nominal exchange rate. It is very interesting to note that although most of the developed countries have been investigated frequently in the previous literature, only a few studies take Canada into consideration. Hence, we hope to achieve some beneficial and instructive conclusions by doing this study.

The remainder of this study proceeds as follows. Section 2 is the literature review. Section 3 presents the econometric model, while section 4 explains the data used. Section 5 discusses the empirical results. Finally, section 6 provides a brief conclusion.

2. Literature Review

With the advent of the floating exchange rate system in 1973, there have been numerous studies, theoretical and empirical, focusing on the impacts of exchange rate volatility upon international trade. However, the results of these efforts are inconclusive on both levels.

On the theoretical side, most of the early studies argue that exchange rate uncertainty, usually represented by the variability of the exchange rate, has a negative effect on the level of trade. In his model, Ethier (1973) claimed that, assuming the risk averse firm has full knowledge of the forward exchange rate, exchange rate risk does not influence the volume of trade. After relaxing this unrealistic assumption, however, the level of trade will respond negatively to exchange rate volatility.

Akhtar and Spence-Hilton (1984) analyzed this issue by dividing the effect of exchange rate volatility into a direct effect and an indirect effect. Since there usually exists some "contract period" between the signing of an initial agreement and the final reception of payment, assuming the market participants are averse to risk and the inefficiency of the forward market, they demonstrated that when firms face the choice of purchasing similar goods from foreign or domestic suppliers, they will prefer the domestic substitutes to those that are foreign-made if there is uncertainty concerning what the level of the exchange rate will be when the actual payment is made and if the payment is quoted in foreign currency. Therefore, the volume of a nation's imports will be reduced by an increase in exchange rate uncertainty if there are a considerable number of importers who are in this situation. On the contrary, the buyers will be free from the risk resulting from uncertainty about the exchange rate if the payment is quoted in domestic currency. However, in the latter case, the risk will be transferred to the shoulder of exporters from domestic buyers and the prices of goods will become higher since suppliers will impose a risk premium to avoid the possible loss caused by the volatility of the exchange rate, which, in turn, will be detrimental to trade volume. In the case of exports, the whole logic above is also applicable and a similar result will be reached. In the long run, on the other hand, because of the inability of avoiding the impacts of exchange rate risk, the prices of traded goods will be more volatile than those of domestic substitutes. Firms will give their priorities to the local suppliers over foreign competitors if the cost of switching supply source is considerable, and the likelihood that potential buyers will choose foreign exporters will be also reduced, all of which, in turn, will result in "an underlying propensity to rely on domestic in place of foreign buyers and sellers, and does not necessarily depend on unpredictability of exchange rate over the contract period" (Akhtar and Spence-Hilton, 1984, 11). Consequently, the volume of trade will be impaired by changes in direct investment decisions and trade patterns.

More recently, however, some studies have emerged that argue that the sign of exchange rate volatility in a regression equation is not necessarily negative, that is, under certain presumptions or circumstances, exchange rate uncertainty will have a positive effect on the volume of trade. In Franke's (1991) model, firms whose attitude towards risk is assumed to be neutral treat exporting only as an option to make profits from the price differences of traded goods, and only start exporting when the exchange rate reaches a certain level. They also exit the foreign market once the exchange rate falls below some level. Under this circumstance, firms will benefit from an increase in exchange rate volatility if they have a comparative advantage in international markets, because their expected cash gains from exporting are greater than the costs of entering and exiting the foreign market. Given some conditions, the volume of exports of the firm will respond positively to the variability of the exchange rate, and the expected level of international trade will increase with exchange rate uncertainty if these conditions are applicable to most of the firms in the market.

Viaene and De Vries (1992) conclude that when forward markets are lacking, the volatility of the exchange rate is detrimental to both exporters and importers. However, with an effective forward market, one side of trade gains and the other side necessarily loses from exchange rate risk since they are on opposite sides of the forward market. Specifically, in the presence of forward markets, in order to hedge against exchange rate uncertainty, both importer and exporter may buy a forward foreign currency contract against the forward exchange rate. Since exporters expect to receive some foreign currency while importers have to pay in foreign currency, the hedge part enters the optimal solutions of importers and exporters with opposite signs, which, in turn, implies that exchange rate uncertainty has opposite impacts upon importers and exporters. Hence, it is possible that variability of the exchange rate has a positive effect upon trade volume. They reached the above conclusions by solving the equilibrium implications of a forward market.

Dellas and Zilberfarb (1993) reinforced the theoretical argument that the volume of trade may grow with an increase in exchange rate volatility by using a standard asset portfolio model. The key point of this model is that "nominal unhedged trade contracts are standard risky assets that can be analyzed in a conventional asset portfolio model" (Dellas and Zilberfarb, 1993, 642). They claimed that, with or without a forward market, international trade will be affected by the volatility of the exchange rate, and the directions of this impact will be generally determined by the risk aversion parameter assumed. In their model, for instance, the nominal profit of a producer is a function of supply, domestic and foreign nominal prices, the exchange rate and the share of the good that is sold on the foreign market. The producer maximizes real profits by choosing the share of the good sold on the foreign market. The sufficient condition to ensure that higher uncertainty of the exchange rate reduces exports is that the risk aversion parameter is less than unity, which means the producer is risk averse. Otherwise, it is possible that higher uncertainty will cause an increase of exports.

Broll and Eckwert (1999) obtained a stronger conclusion by analyzing the exporting strategy of a price-taking, risk-averse international firm. In particular, the firm is assumed to be flexible enough to switch its products for sale between foreign and domestic markets, and production decisions must be made before the realization of the foreign spot exchange rate. With the increase in exchange rate volatility, the uncertainty in the foreign market will increase and the expected gains from trade will decrease, which will cause a negative movement in the volume of exports. But the potential gains from international trade will become considerably higher with the realization of an extremely high foreign spot exchange rate, and the firm could avoid the losses induced by a low realization of the exchange rate since the sale of its products can be switched to the local market with negligible cost by assumption. The net effect will be determined by the firm's attitude towards risk. If the degree of relative risk aversion of the firm is less than unity, exchange rate volatility will have a positive impact on the average export volume of the firm.

Just as the conclusions reached in the theoretical field have been mixed, the evidence obtained thus far from empirical studies that focus on the relationship between trade flows and the volatility of the exchange rate shows that the results in the real world are, at best, as inconclusive as at the theoretical level. Generally speaking, the results of empirical studies mainly depend on the data, sample periods, measures of volatility, explanatory variables, and estimation techniques employed, as well as the countries under study. First, various proxies have been adopted to measure the volatility of the exchange rate, such as the average absolute difference between the previous forward and the current spot rate, the absolute percentage change, a moving average of the standard deviation of the exchange rate, ARIMA model residuals, and ARCH models. Meanwhile, the question of whether the real or nominal exchange rate is the appropriate indicator to assess the variability of exchange rate has also aroused great concern; but fortunately, as McKenzie (1999) maintains "the empirical results suggest that this distinction does not impact significantly on the results achieved" (85). Second, it seems that studies using post-Bretton Woods era (after 1973) data are more successful in finding statistically significant, either negative or positive, impacts of the volatility of the exchange rate upon trade flows than those focusing on data prior to 1973 or those including both periods. On the other hand, the data employed by most studies so far are aggregate and bilateral. However, the evidence suggests that disaggregated sectoral data are more likely to be able to capture the nature of the relationship between trade and the volatility of the exchange rate. As summarized by McKenzie (1999), "this is because using national trade data implicitly assumes the impact of exchange rate volatility is uniform between countries and commodities both in terms of direction and magnitude. If this assumption is incorrect, then the examination of aggregate trade data is likely to 'dilute' the true nature of the relationship and lessen the probability deriving a significant result" (85). Third, the vast majority of early studies usually investigate the impact by employing Ordinary Least Squares (OLS) regression analysis. However, recently time series techniques, including the vector autoregression (VAR) approach and autoregressive conditional heteroscedasticity (ARCH) models as well as their subsequent extensions, have been become more popular and dominate the field. Fourth, except for a few studies, most authors agree on the form of regression equations in which trade flow is a function of an income proxy, prices, and the exchange rate as well as the volatility of the exchange rate. Finally, compared to the attention paid to the experiences of developed countries, the impact of the volatility of the exchange rate on trade flows among less developed countries (LDC) has not been given equal consideration, but this situation has been changing with the availability of relevant data and the progress of LDCs' economies.

Specifically, the OLS regression methodology is the most popular approach in the early empirical studies. Within this category, Hooper and Kohlhagen (1978) examine the short-run effect of exchange rate risk upon bilateral and multilateral trade flows among the United States, Germany and several other industrial countries. In their model, exchange rate uncertainty is measured as the average absolute difference between the current spot exchange rate (nominal) and the forward rate 90 days earlier, the sample is from 1965 to 1975, quarterly, and in the regression equations the price of exports and export supply are represented by exporters domestic unit cost of production, import unit costs, the price of other goods in the domestic market, domestic money income, capacity utilization, the expected value of the weighted average of the cost of foreign exchange to the importer and the volatility of the exchange rate. The results suggest that there is no statistically significant relationship between exchange rate uncertainty and the volume of trade.

Bailey, Tavlas and Ulan (1987) use quarterly data over the period 1962:2 to 1985:3 for 11 OECD countries to examine the impact of exchange rate uncertainty on export growth. The aggregate data are divided into pre-floating and post-floating periods. The volatility of the exchange rate is measured as, in real and nominal terms respectively, both the absolute percentage change and the log of the standard deviation. The explanatory variables in their model include real GDP/GNP, relative prices, and real export earnings of oil-producing countries, as well as exchange rate variability. Using the OLS approach, they find that only three of the 33 regressions tested support the hypothesis that the volatility of the exchange rate has a negative effect on trade flows.

On the other hand, however, they also find a positive relationship between exports and the volatility of the exchange rate in some instances.

Asseery and Peel (1991) argue that one reason why early studies fail to find a significant impact of exchange rate volatility upon trade is they ignore the non-stationary characteristics of trade flows. Therefore, they use the Augmented Dickey-Fuller test to check the stationarity of the data and adopt a regression equation including income, relative prices, the exchange rate and volatility as explanatory variables to investigate this issue for Australia, Japan, Germany, the U.S. and the U.K. over the period from 1972 to 1987, measuring volatility as the residuals from an ARIMA model of the real exchange rate. After performing DF (Dickey-Fuller) and ADF (Augmented Dickey-Fuller) tests with quarterly aggregate data, they are unable to reject the hypothesis that exports, relative prices, real income and the real exchange rate contain a unit root for all countries. The results of OLS estimation show that for most countries examined real exchange rate volatility has a significant positive effect on exports.

On the other hand, Koray and Lastrapes (1989) and Chowdhury (1993) have both employed the VAR technique. The former authors test bilateral imports of the U.S. from five other countries and only find a weak relationship between exchange rate variability and trade flows. In their study, exchange rate volatility is measured as a moving standard deviation of the growth rate of the real exchange rate; the period of bilateral monthly data is 1959 to 1985, and in each system, the explanatory variables include the US money supply, output level, price level, and interest rate; these variables of the foreign counter partners; and bilateral US imports, a measure of real exchange rate volatility, and the nominal exchange rate. Except for the VAR model of France, they find that the volatility of the exchange rate has a negative effect upon imports in the other four countries. Similarly, Chowdhury tests the impact of exchange rate volatility, measured as a moving sample standard deviation of the growth rate of the real exchange rate, upon the trade of OECD G-7 countries over the period from 1973 to 1990 using quarterly aggregate data. Specifically, the long run equilibrium function is derived; in it, real export volume is a function of real foreign income, the relative price, and a measure of exchange rate volatility. After performing the ADF (Augmented Dickey-Fuller) test and the Kwiatkowski test, he finds that all variables are integrated of order one, and then an error-correction model for exports is constructed for each country. The results suggest that in each country there exists a negative relationship between the volume of exports and exchange rate volatility.

However, ARCH (AutoRegressive Conditional Heteroskesasticity) approaches have appeared more and more frequently in recent empirical studies since the ARCH model was invented by Engle (1982). For example, Kroner and Lastrapes (1993), using monthly aggregate data, investigate the impact of exchange rate volatility, measured as the GARCH conditional variance of the residuals of a system including three equations, on multilateral export volume and prices for Germany, Japan, France, the U.S. and the U.K. over the post-Bretton Woods era using a multivariate GARCH-in-mean model. The first two equations of the model explain real exports and export prices as functions of relative prices, real foreign income, domestic real unit labor costs, and a measure of exchange rate volatility; the last equation explains the spot exchange rate. The results suggest that the impact is generally stronger for export prices than the volume and directions of effect are different across countries.

Doroodian (1999), using quarterly aggregate data, studies the relationship between real exchange rate risk, measured by the conditional variance from a GARCH model, and trade volume for India, South Korea and Malaysia over the period 1973 to 1996. With export price, the consumer price index, world income and real exchange rate volatility as explanatory variables, the result supports the hypothesis that exchange rate uncertainty has a significantly negative effect upon trade volume.

McKenzie and Brooks (1997) reexamine the U.S. and Germany bilateral trade flows over the period 1973 to 1993 using an ARCH model to measure the volatility of the exchange rate. In their model, trade flows depend on income, prices, the exchange rate and volatility. A significant positive effect of exchange rate uncertainty on trade is found. However, in another study conducted by McKenzie (1998), using a similar measure of exchange rate risk and a similar regression equation, the author examines both aggregate and sectoral trade flows for Australia over the period 1988 to 1995. Limited and conflicting evidence of impacts are obtained when aggregate data are used, but he does find a significant relationship between exchange rate volatility and trade when disaggregated data are employed, in which the direction and magnitude of effect are different across different sectoral markets.

Chou (2000) estimates the impact of exchange rate variability on total exports and disaggregated exports of China. In his study exchange rate variability is estimated by an ARCH model, and exports are a function of real foreign income, relative prices and exchange rate volatility. The data are quarterly over the period 1981: 01 to 1996: 04. Prior to estimation, he examines the data for non-stationarity using unit root tests and finds that most series contain a unit root. Therefore, an error-correction model is employed to examine the long run equilibrium between these non-stationary variables. The results show that exchange rate variability has a negative effect on total exports, exports of manufactured goods, and exports of mineral fuels.

Of particular interest is the study by Caporale and Doroodian (1994), who examine the bilateral trade flows between the U.S. and Canada using monthly data over the period from 1974 to 1992. A GARCH (1, 1) model is used to capture the time-varying conditional variance of the real exchange rate, and the volume of imports is a function of real income and the real exchange rate as well as volatility. The results show that there exists a negative and significant relationship between exchange rate uncertainty and trade volume.

In summary, although a conclusive result has not been reached on either the theoretical or the empirical level, the evidence suggests that studies which adopt either the ARCH methodology or disaggregated data, or both, are more likely to find a statistically significant, either positive or negative, impact of exchange rate volatility upon volume of trade. First, specifically, the proxy of the volatility of the exchange rate generated from an ARCH or GARCH model is a more appropriate measure of exchange rate uncertainty since it allows us to capture the time-varying conditional variance as a parameter generated from a time series model of the conditional mean and variance of the exchange rate. Second, the adoption of disaggregated trade data gives us more power to recognize the nature of the relationship between the trade flows and exchange rate volatility, because the use of aggregate data assumes that different sub-markets have the same nature and elasticity, which, however, is not a very realistic assumption. These observations may be a guide to further studies.

3. Econometric Model

Following the literature and international trade theory, export demand in this study is assumed to be determined by foreign income, relative prices and exchange rate volatility. Therefore, the model we adopt in this study is

$$\ln RE_{it} = \alpha_1 + \alpha_2 \ln USIIP_t + \alpha_3 \ln CANREER_t + \alpha_4 SV_t + \varepsilon_{it}, \quad (1)$$

where $\ln RE_{it}$ is the logarithm of Canadian real exports at aggregate and disaggregated levels respectively, for sector $i = 0,\ldots,7$; $\ln USIIP_t$ is the logarithm of real output in the U.S, which is used to represent the real foreign income; $\ln CANREER_t$ is the logarithm of the real effective exchange rate of Canada, which proxies the relative prices between Canada and the U.S; SV_t is a measure of the exchange rate volatility generated by an (G)ARCH model; and ε_{it} is a disturbance term. t refers time period t. According to the theory of international trade, the sign of foreign income is expected to be positive, while that of relative prices should be negative. However, the sign of exchange rate volatility can not be determined prior to estimation, since there is no consensus on the impact of the volatility of the exchange rate upon exports.

The most important step in estimating the effect of exchange rate volatility on exports is to find an appropriate proxy for the volatility of the exchange rate (SV_t). Although many alternative approaches have been used to accomplish this task in previous studies, such as statistical variance, standard deviation, deviations from trend, ARIMA model residuals etc., we employ the conditional variance of the exchange rate, using either the real effective exchange rate or the nominal spot exchange rate, derived from a (G)ARCH model, to proxy the exchange rate volatility. Generally speaking, the (G)ARCH model allows the conditional variance of the disturbance term to be dependent on the its past values and those of the disturbance term, instead of a constant. As Enders (2004, 114) notes "conditional forecasts are preferable, since they take into account the known current and past realizations of series." An ARCH model, on the other hand, is a special case of the GARCH model where the conditional variance of the error term only depends on the past values of the error term itself. To explain, consider the following model

$$\mathrm{dlnEXRATE}_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \mathrm{dlnEXRATE}_{t-i} + e_t + \sum_{i=1}^{p} \beta_i \, e_{t-i}, \tag{2}$$

$$h_t = \chi_0 + \sum_{i=1}^{q} \chi_i e_{t-i}^2 + \sum_{i=1}^{p} \delta_i h_{t-i}, \tag{3}$$

where $\ln\text{EXRATE}_t$ denotes the logarithm of either the real effective exchange rate or the nominal exchange rate, which is generated by an autoregressive moving-average (ARMA) model; e_t is the disturbance term; and h_t is the conditional variance of e_t, which is estimated using a (G)ARCH model. If $\delta_i = 0,\ i=1,\cdots,\ P$, then the model becomes an ARCH model.

In order to derive a (G)ARCH based measure of exchange rate volatility, we have to first examine the stationarity of the logs of both the real effective exchange rate and the nominal spot exchange rate, which is done using the Dickey-Fuller GLS test of Elliott, Rothenberg and Stock (1996) and the augmented Dickey-Fuller (ADF) test for unit roots. The modified Akaike criterion is used to choose the lag length.[1] After differencing the logs of series to correct the non-sationarity, if it exists, we follow the Box-Jenkins (1976) approach to identify and estimate the most appropriate ARMA model for both series, as indicated in equation (2). Then, based on the fitted ARMA models, Engle's (1982) Lagrange multiplier tests for the presence of (G)ARCH effects are applied to identify the appropriate (G)ARCH measures of the exchange rate volatility, as indicated in equation (3).

Prior to estimating equation (1), it is necessary to examine the stationarity of each series in the equation, which is also done using the Dickey-Fuller GLS and the augmented Dickey-Fuller (ADF) tests for unit roots. Actually, there are many alternative ways to do this, including the sequential ADF tests developed by Zivot and Andrews (ZA) (1992) and the modified ZA tests proposed by Lumsdaine and Papell (1997). The last two tests allow us to test for possible break points rather than to assume that there is no structural break, but we choose the first two tests because of the limitations of the

[1] The maximum lag length allowed is 16.

software package we have access to.[2] To be specific, we first plot each series to obtain a visual impression of them. Then, for all series that display a trend, both the Dickey-Fuller GLS test and the ADF test are carried out with intercept and trend included. Next, the tests are applied again to the first difference of each series, with only an intercept included in the test equation. The modified Akaike criterion is used to choose the lag length for both tests, and the maximum lag length allowed is 16. If we can not reject the null hypothesis that the series has a unit root at the conventional level of significance, the series is non-stationary. In this case it is necessary to difference the series to correct the non-stationarity before we estimate equation (1) using OLS, since a series containing a stochastic trend will not revert to a long-run level and differencing can remove a stochastic trend from a non-stationary series.

Equation (1) is similar to the equation estimated in the previous study done by Caporale and Doroodian (1994), in which they examine the effect of the exchange rate uncertainty upon the imports of the U.S. from Canada using monthly data over the period 1974:01 to 1992:10. They choose a GARCH (1, 1) model based on an MA (1) mean equation to capture the time-varying conditional variance of the real exchange rate. However, they do not examine the stationarity of real income and the volume of imports as well as the real exchange rate, and the three variables are not differenced when they appear in the regression equation. On the other hand, McKenzie (1998), who studies the impact of exchange rate volatility upon the trade flows between Australia and the U.S. at both the aggregate and the disaggregated levels using the quarterly data from 1947:1 to 1995:4, also uses an ARCH model to generate a measure of exchange rate volatility. However, all the series in the regression equation, except for the exchange rate volatility, are differenced after the results of unit root tests show that all of them are non-stationary.

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[2] The econometric analysis was carried out using EViews 5.

McKenzie finds that the signs of exchange rate volatility are very indecisive, and only few of them are statistically significant.

The different results provided by these two studies may, at least partly, be caused by their different treatment of the non-stationarity of the series. Therefore, in our study, it is appropriate to follow McKenzie's procedure, differencing the series if they are non-stationary. Additionally, to avoid the impact of the seasonality in the data, it is necessary to test equation (1) with and without monthly dummies and compare the results to reach a complete and reasonable conclusion.

4. Data

Ideally, one would like to investigate the impact of exchange rate volatility upon Canadian total exports at the aggregate and disaggregated levels, instead of just its exports to the US. In order to do this, we would have to construct a foreign income index for the major trading partners of Canada, which is usually calculated using the weighted average of the real GDP index of the major trading partners of Canada. Then, it would be necessary to construct a relative price index using a similar approach. But data on the exports of Canada to its major trading partners, both at the aggregate and disaggregated levels, would be indispensable to finishing such a study. Unfortunately, such data are either not available or not easily collected for a few major trading partners of Canada, such as China, the Netherlands and Italy. After some examination of Canadian exports data, however, we find that the exports of Canada to the US account for almost 80% of its total exports over the period 1971:01 to 2005:12, which, undoubtedly, is impressively overwhelming. Hence, it is appropriate to examine the effect of exchange rate volatility upon the exports of Canada to the US, and the results should provide us with a proper and instructive conclusion.

In equation (1), RE_{it} is real exports of Canada to the US, at aggregate and disaggregated levels respectively, for sector $i = 0,...,7$, which is defined as exports divided by the consumer price index (CPI) of Canada. The data on Canadian exports to the US are collected from CANSIM,[3] and are categorized by summary export groups (SEG) and other aggregations, customs based and not seasonally adjusted. The data are monthly, over the period 1973:01 to 2004:03, and the unit is thousands of dollars. More specifically, RE_{0t} is real total exports of Canada to the US, RE_{1t} is real exports of live animals, RE_{2t} is real exports of food, feed, beverages and tobacco, RE_{3t} is real exports of inedible crude materials, RE_{4t} is real exports of inedible fabricated materials, RE_{5t} is real exports of inedible end products, RE_{6t} is real exports of transportation and communication, and RE_{7t} is real exports of special transactions, which are mainly low-valued transactions, value of repairs to equipment and goods returned to country of origin.

$USIIP_t$ is the seasonally unadjusted industrial production index of the US collected from the International Financial Statistics (IFS),[4] with a base year of 2000, which is used to proxy the real income of the US. Most previous empirical studies have chosen real GDP to measure real foreign income, but we intend, in this study, to use a (G)ARCH model to capture the conditional variance of the exchange rate residuals to proxy the exchange rate volatility. To generate a reliable (G)ARCH based measure of the exchange rate volatility, it is necessary to have a relative large sample period, and almost all previous studies using a (G)ARCH model chose the industrial production index to represent real foreign income because it is easier to obtain monthly data on this

[3] The data table number is 226-0001. The data were retrieved on Nov 12, 2006.
[4] http://ifs.apdi.net/imf/, Nov 10, 2006.

index than on GDP. Therefore, we follow this convention and use the US industrial production index to measure its real income.

The variable $CANREER_t$ in equation (1) measures the relative prices between Canada and the US. Drawing on the literature, we use the real effective exchange rate of Canada with respect to the US dollars. Since the exports of Canada to the US account for almost 80% of its total exports over the period 1971 to 2005, it is appropriate to use the real effective exchange rate to measure the relative prices, although some previous studies adopt the real exchange rate. The difference between these two measures can be ignored in our case because of the overwhelming weight undertaken by the US. Data for this variable are obtained from the Source OECD database,[5] and the base year is once again 2000.

Finally, SV_t is a measure of exchange rate volatility generated by a (G)ARCH model. Since McKenzie (1999) concludes that the choice between the nominal and real exchange rate does not impact significantly on the empirical results achieved, and we intend to compare our results with similar previous empirical studies to obtain some beneficial insights, it is necessary to construct the (G)ARCH model of exchange rate volatility using both the real effective exchange rate and the nominal exchange rate. Following this idea, we collect the nominal spot exchange rate, $CANNRATE_t$, which is defined as Canadian cents per United States dollar, from CANSIM[6] as well Therefore, exchange rate volatility, SV_t, is constructed using (G)ARCH models based on the real effective exchange rate and the nominal spot exchange rate respectively.

It should be noted that the reason why we exclude the data prior to 1973 from our study is that Canada switched its fixed exchange rate system to the floating system

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[5] http://titania.sourceoecd.org, Nov 19, 2006.
[6] The table number is 176-0049. It was accessed on Dec 05, 2006.

beginning in 1973, and the insights gained from reviewing the literature indicate that the use of floating exchange rate data is more conducive to find a statistically significant effect, either positive or negative, of exchange rate volatility upon trade flows. Hence, we use data starting from 1973 in our study. In summary, all data in equation (1) are monthly and over the period 1973:01 to 2004:03, comprising 375 observations in total. All variables are converted to natural logarithms.

Table 1 contains some descriptive statistics (means and standard deviations) for the untransformed variable while Figure 1 contains graphs of the levels and first differences of the logarithms of the variables. In examining the graphs of variables, we find the logarithms of the various real exports series for Canada share some common features. That is, they all seem to contain a deterministic time trend plus a stochastic trend, since they all increase over time, which indicates that all real exports series contain a deterministic time trend, but their variances are not constant, which suggests that they contain a stochastic trend. After the first difference of each real export series is taken, the means of all of the series seem to converge to zero, but the variances are still very big, which suggests that all of the real exports series possibly contain a unit root. A similar impression is obtained from an examination of the graph of the US industrial production index series, which suggests that the USIIP series is also non-stationary. However, the pictures are very different when we look at the graphs of the real effective exchange rate and the nominal spot exchange rate. More specifically, the former seems to be decreasing over time, but the latter has an increasing time trend, although neither trend is very deterministic. The reason for this difference is probably that the methods used to construct these two variables are different. Specifically, real effective exchange rate is "the weighted average of a country's currency relative to an index or basket of other major currencies adjusted for the effects of inflation. The weights are determined by comparing the relative trade balances, in terms of one country's currency, with each other country within the index."[7] Nominal exchange rate, however, is simply "the ratio of at which the unit of currency of one country is or may be exchanged for the unit of currency of another country."[8] Both means also seem to be zero after being differenced. Additionally, all of the series have a non-zero initial value. Hence, as mentioned in the previous section, it is extremely necessary to examine the non-stationarity of all series. Specifically, we should apply unit root tests to the levels with both a trend and an intercept, and with only an intercept for the first differenced series.

5. Results Section

It is an undeniable fact that the impact of exchange rate volatility upon exports has been drawing a great of attention at both the theoretical and the empirical levels since the emergence of the floating exchange rate system in 1973. No consensus, however, has been reached at either level. In order to produce some beneficial insights, it is instructive to do some comparisons to previous studies in our study. Following this idea, we choose two similar previous studies, to replicate and extend for the purposes of comparison. One of them is contributed by Caporale and Doroodian (1994), who examine the effect of exchange rate uncertainty upon the imports of the US from Canada using monthly data over the period from 1974:01 to 1992:10. In their study, a GARCH (1, 1) model based on an MA(1) mean equation is used to capture the time-varying conditional variance of the real exchange rate, and the volume of imports is a function of real income and the real exchange rate as well as volatility. Their results show that there exists a negative and significant relationship between exchange rate uncertainty and trade volume.

[7] http://www.answers.com/topic/real-effective-exchange-rate-reer.
[8] http://www.answers.com/topic/rate-of-exchange.

The study of Caporale and Doroodian (1994) is the most similar previous one to which we can compare ours, and we summarize some similarities and differences between our studies before starting the estimation. Firstly, the countries under their study are exactly the same as ours, but they investigate the imports of the US from Canada only at the aggregate level, instead of, as in ours, the exports of Canada to the US at both the aggregate and disaggregated levels. Secondly, the US imports demand equation in their study is a function of the real income of the US and the relative prices between two countries, as well as a measure of exchange rate volatility, which is same as our Canadian exports demand equation. More specifically, they use the US industrial production index to measure real foreign income and a proxy of exchange rate volatility generated by a GARCH model, as do we, but the relative price in their study is defined as the nominal exchange rate multiplied by the ratio of the Canadian and the US CPI. In contrast, the measure of relative prices we adopt is the real effective exchange rate. Thirdly and most importantly, prior to estimation, they do not examine the non-stationarity of US imports, the US industrial production index or the real exchange rate. Consequently, these three variables are not differenced when they appear in the regression equation. This is an undeniable limitation of their study and a potential cause of a difference in results, if there is any, between our studies. Finally, we both use the data for the period after the introduction of the floating exchange rate system, although we have a relatively longer sample, which is another possible cause of differences in results between our studies.

The other similar previous study was done by Mckenzie (1998), who examines impact of exchange rate volatility on the imports and exports of Australia by employing both aggregate and disaggregated trade data. The import and export demand equations in his study are a function of foreign and domestic real incomes, relative prices, and a measure of exchange rate volatility. This specification differs slightly from ours, since we do not include domestic real income in our export demand equation. The reason behind this difference is that Mckenzie investigates both the imports and exports of Australia, and the real domestic income of Australia is an indispensable determinant when imports are the dependent variable. The proxy of exchange rate volatility in his study is also generated by an ARCH model, but the frequency of the data is quarterly over the period 1947:1 to 1995:4 because he adopts GDP as a measure of real foreign and domestic income. It is noticeable that he does not follow the convention of constructing a real foreign income index using the weighted average of the real GDP index of the major trading partners of Australia, or a relative prices index constructed using a similar method. Instead, he argues that since the US is one of Australia's trading partners and 55% of all exports contracts of Australia are written against the US dollar, real US GDP and the real US-Australia exchange rate can be chosen to proxy foreign income and relative prices respectively. In contrast to Caporale and Doroodian (1994), Mckenzie tests each series for non-stationarity and the results suggest that real imports, exports and GDP contain a unit root. Hence the data are differenced prior to estimation. The results are very inconclusive since at the aggregate level exports are positively affected by exchange rate volatility, but imports are impacted in a negative fashion. At the disaggregated level, similar relationships are found, but only a few coefficients of exchange rate volatility are statistically significant.

Keeping these two previous studies in mind, we proceed with our own empirical analysis. The first and most important thing to do is to construct the measure of the volatility of the exchange rate. As mentioned above, we complete this task by using two data series, that is, the real effective exchange rate and the nominal spot exchange rate respectively. It is first appropriate to test these two series for non-stationarity. The results of these tests are shown in Table 2. For the real effective exchange rate, the results of the Dickey-Fuller GLS test suggest that we can not reject the null hypothesis that there is a unit root at the 5% and 10% significance levels, but we can reject the same hypothesis at both significance levels for its first difference. Using the ADF test, we obtain the same conclusion. For the nominal exchange rate series, both tests reach the same conclusion; that is, we can not reject the same null hypothesis at conventional significance levels, but for its first differenced series the null hypothesis can always be rejected at the 5% and 10% significance levels. Therefore, it is necessary to difference both series prior to testing for (G)ARCH effects.

Next, we estimate autoregressive moving average (ARMA) models to fit the exchange rate data, since when we estimate the (G)ARCH models we have to estimate the mean equation and the variance equation simultaneously. To find an appropriate mean equation, it is necessary to test the data for the ARMA model without considering the (G)ARCH effects first. Then, based on the proper mean equation, the conditional variance can be captured by estimating the variance equation. Table 3 (for the real effective exchange rate) and table 4 (for the nominal exchange rate) contain the results of this procedure. Following the literature and the Box-Jenkins (1976) approach, we first, for the real effective exchange rate series, choose an AR model with the lag length 16. The t-statistics suggest that only the coefficients of AR (1), AR (10) and AR (13) are statistically significant at conventional levels.[9] For the three F-statistics, including lag 2 to lag 9, lag 11 to lag 12 as well as lag 14 to lag 16, we can't reject the null hypothesis that all the coefficients are equal to zero.

Then, we fit an MA model to the data with a lag length 16. The t-statistics for this model show that the coefficients of MA (1), MA (8), MA (10), MA (11) and MA (13) are statistically significant at conventional levels. The F-statistics that the coefficients of lag 2 to lag 9 equal zero is 1.46 with degrees of freedom (8, 357), so we can't reject the null

[9] The mean equation based on AR and MA models with lags 1, 10 and 13 has similar results, which are not reported in Table 3.

hypothesis at the 5% significant level, which means that the coefficient of MA(8) can be excluded. Also, we estimate an ARMA (1, 1) model for the real exchange rate series, but the coefficients are not statistically significant.[10] The coefficients of the "best" ARMA models for the real effective exchange rate are presented in Table 3.

In summary, since both the Akaike info criterion and the Schwarz criterion are very close for the different AR or MA models, it is preferable to choose the most parsimonious model, according to the Box-Jenkins (1976) approach and the experiences of previous studies. Therefore, at this time, we choose the AR (1) and MA (1) models as the mean equations when we test for (G)ARCH effects. However, if we cannot find a statistically significant coefficient in the variance equation, it may prove necessary to use another correct, but less parsimonious, ARMA model instead to find the appropriate variance equation.

The same procedures and logic apply to the case of the test for the nominal exchange rate and the results are reported in Table 4. More specifically, after first differencing the data series, we try the AR and MA models with a lag length of16, as well as an ARMA (1, 1) model. For the AR mean equation, the t-statistics suggest that only the coefficients of AR (1), AR (10) and AR (13) are statistically significant at conventional levels, and the F-statistics show that the null hypothesis that all other coefficients equal zero can not be rejected. For the MA mean equation, the coefficients of MA (1), MA (10), MA (11) and MA (13) are statistically significant at conventional levels suggested by the t-statistics, and the F-statistics give us the same conclusions. The ARMA (1, 1) model is also examined, but none of its coefficients are statistically significant. Just as for the real effective exchange rate, the Akaike info criterion and the Schwarz criterion are very close for the different AR and MA models. Hence, preference will given to the AR (1) and

[10] The parameter estimates for this model are not reported in Table 3.

MA (1) models when we test for (G)ARCH effects, unless we can not find the statistically significant coefficient in the variance equation.

The final step in generating the measure of exchange rate volatility is to estimate both the mean equation and the variance equation simultaneously based on the mean specification we have chosen in the previous step, and the results are reported in Tables 5 (for the real effective exchange rate) and 6 (for the nominal exchange rate). We first examine the (G)ARCH effects for the real effective exchange rate based on the most parsimonious mean equations we chose, that is, the AR(1) and MA(1) models. For the variance equations, we try the ARCH (1) and GARCH (1, 1) models following the previous studies. The estimating approach used is that of Engle (1982). However, under all four cases, which are the ARCH (1) and GARCH (1, 1) variance equations based on the AR (1) mean model and the MA(1) mean equation, none of them has significant coefficients to confirm the presence of (G)ARCH effects. Therefore, we have to use other correct but less parsimonious mean equations to detect (G)ARCH effects, using the same specification for the variance equations. The results suggest there is only one model which has significant (G)ARCH effects at the10% level of significance but not at the 5% level, that is, the GARCH(1,1) variance equation based on the MA(1,13) mean model.[11] The t-statistics of the coefficients for the autoregressive component (e_{t-1}^2) and moving average component (h_{t-1}) in the variance equation are 1.72 and 3.29 respectively, and the former is statistically significant at the10% level but not at 5% level. All the rest of the models are failed to yield significant t-statistics for e_{t-1}^2 at conventional levels. Consequently, it seems that this model is the only appropriate option for us if we want to use the conditional variance of the real effective exchange rate to proxy exchange rate volatility.

[11] The model only includes lags 1 and 13 of the moving average components.

For the nominal exchange rate we follow the same logic and steps, and the results give us a surprisingly similar conclusion. Specifically, when we employ the parsimonious mean equations, AR (1) and MA (1), and ARCH (1) and GARCH (1, 1) variance equations to test for the presence of (G)ARCH effects, none of them yield significant t-statistics at conventional levels for the autoregressive component (e_{t-1}^2) in the variance model, although the coefficients of the moving average component (h_{t-1}) are always statistically significant at conventional levels. Hence, again we turn to other correct but less parsimonious mean models to examine (G)ARCH effects. Similarly, the results show that there is only one model which has significant ARCH effects. The mean equation is MA (1, 13) as for the real exchange rate, but the variance model is ARCH (1) rather than GARCH (1, 1). The t-statistic of the coefficient of e_{t-1}^2 is 2.067, which is statistically significant at 5% level. So, the only choice for nominal exchange rate volatility has to be the ARCH (1) model based on the MA (1, 13) mean equation. Figure 2 plots the measures of exchange rate volatility with respect to real and nominal exchange rates, which denote SV_t in equation (1). They look somewhat different.

To increase our confidence in the (G)ARCH models we have chosen for the real and nominal exchange rates, it is necessary to apply more tests to them. First, we use the Jarque-Bera (JB) statistic to test whether the error term is normally distributed. As shown in Tables 5 and 6 the JB statistics for the real and nominal exchange rate (G)ARCH models are 0.231 and 15.48 respectively. With 2 degrees freedom, we can't reject the null hypothesis that data are from a normal distribution for the real exchange rate equation. Also, the means for both model are very close to 0. Then we apply unit root tests to the conditional variance series for the both models. According to the results in Table 7, for the nominal exchange rate, the Dickey-Fuller GLS test, with intercept, suggests that the conditional variance has a unit root, but its first differenced series does not. The result of the ADF test with intercept suggests that we can reject the null hypothesis that the series has a unit root. The Dickey-Fuller GLS test, with intercept, for the real exchange rate conditional variances provide the same conclusion. However, the ADF test shows that the series contains a unit root, but its first differenced series has not. The modified Akaike info criterion and a maximum lag length 16 are used for all these tests. From the results of these additional tests, it is hard to say that the (G)ARCH models we choose are the most satisfactory measures of the exchange rate volatility. However, the significant statistics for the coefficients in the variance equations give us a relatively convincing reason to employ them as a proxy for exchange rate volatility in our export demand regression equations.

After completing the construction of the exchange rate volatility measure, we first estimate equation (1) using aggregate data. Although estimating the equation in levels of variables does not account for non-stationarity, it allows us to compare our results with those of Caporale and Doroodian (1994). Following them, we use the volatility measure based on the real effective exchange rate (see table 5), which is very similar but not identical to their proxy for volatility. We also use exactly same sample period as they do, 1974:01 to 1992:10. These results (which are not reported in this paper) suggest conclusions similar to theirs. Specifically, the signs of the coefficients of real foreign income and relative prices are positive and negative respectively as expected, and both of them are statistically significant. The sign of the coefficient of exchange rate volatility is negative and significant at the1% level, as is theirs. However, since the data have not yet been tested for non-stationarity, it is hard to claim that these results are convincing. Therefore, it is necessary to examine the non-stationarity of each series in equation (1) prior to estimation.

Accordingly, we should apply unit root tests to each series, except for the exchange rate data which have already been tested. Following the same steps applied above, we use both the Dickey-Fuller GLS test and the ADF test with trend and intercept to test the levels of the variable, and with only an intercept for their first differences. Again, the modified Akaike criterion is used to choose the lag length and the maximum lag length allowed is 16. All of data are converted to logarithms before the tests.

The results of the unit root tests are presented in table 2. For the real exports data, the results of the Dickey-Fuller GLS test and the ADF test are very different. Specifically, the former suggests that we can not reject the null hypothesis that the series has a unit root for all real exports series and their first differences, except for RE_3 and RE_7, while the ADF test shows that the same null hypothesis cannot be rejected for the levels of all series except for RE_7, but can always be rejected for their first differences. For RE_3, both tests reach the same conclusion that it has a unit root, but not in its first difference. For RE_7, the null hypothesis of a unit root can be rejected at the 10% significance level, but not at the 5% level, by the Dickey-Fuller GLS test, and can be rejected at the both levels by the ADF test. The results are a little confusing, since the Dickey-Fuller GLS test is more powerful. But if we follow the literature, then we can claim that all real exports series, except for RE_7, are non-stationary, since most previous studies choose the ADF test to examine the non-stationarity. Consequently, all exports series will be differenced prior to estimation, excluding RE_7. The results are similar for the industrial production index of the US, $USIIP_t$, so it will be treated as non-stationary as well.

Now that the (G)ARCH based measured of exchange rate volatility has been constructed and tests for non-sationarity have be carried out, we can proceed to the last step of our study, which is to estimate the exports demand equation (1) and investigate the impact of exchange rate volatility upon the exports of Canada. More specifically, as we mentioned before, we plan to test this effect at both the aggregate and disaggregate levels. The measure of exchange rate uncertainty, SV_t, is one of the two (G)ARCH models we have chosen above: the GARCH(1,1) variance equation based on the MA(1,13) mean model for the real effective exchange rate, denoted $SVLNCANREER_t$; or the ARCH (1) model based on the MA (1, 13) mean equation for the nominal spot exchange rate, denoted $SVLNCANNRATE_t$. It is very important to make it clear that the proxies for volatility in the equation are the square roots of the conditional variances generated by the (G)ARCH models (i.e., the standard deviations), rather than the conditional variances themselves. All series except for RE_7, $SVLNCANREER_t$ and $SVLNCANNRATE_t$ should be first-differenced; the last two were already differenced prices to construction of the volatility measure. Thus equation (1) should be transformed into the following forms:

$$\Delta \ln RE_{it} = \beta_1 + \beta_2 \Delta \ln USIIP_t + \beta_3 \Delta \ln CANREER_t + \beta_4 \; SVLNCANREER_t + \varepsilon_{it}, \qquad (4)$$

and

$$\Delta \ln RE_{it} = \delta_1 + \delta_2 \Delta \ln USIIP_t + \delta_3 \Delta \ln CANREER_t + \delta_4 \; SVLNCANNRATE_t + \varepsilon_{it}, \qquad (5)$$

where, Δ indicates the series has been differenced once and all other variables are same as in equation (1). The data we use for equations (4) and (5) are monthly data over the period 1973:02 to 2004:03, 374 observations in total after adjustments for lags.

We begin our discussion with equation (4).[12] According to the results in table 8, at the aggregate level, the signs of the coefficients of real foreign income and relative prices are positive and negative respectively, which are as we expected, and both are significant at conventional levels. The sign of the coefficient of exchange rate volatility is

[12] For both equation (4) and (5), we use the Newey-West correction to the standard errors to correct for autocorrelation.

negative, but it is not statically significant. The explanatory power of this exports demand equation is low because R^2 is just 0.35. The Breusch-Godfrey LM test suggests that it has an autocorrelation problem, but the t-statistics are still valid as they have been constructed using Newey-West's corrected standard errors.

At the disaggregated level, except for RE_{7t}, the signs of coefficients of real foreign income and relative prices are as expected, positive and negative respectively. Most of them are statistically significant at conventional levels. More specifically, for real foreign income, its coefficient in the equations for RE_{1t}, RE_{2t}, RE_{4t}, RE_{5t} and RE_{6t} are all significant at conventional levels. The coefficient of relative prices is statistically significant at conventional levels in the equations for RE_{1t}, RE_{4t}, RE_{5t} and RE_{6t}. However the Breusch-Godfrey LM tests suggest that most of these disaggregated equations have autocorrelation problems. In addition, the R^2 s are very low for some equations. Finally, none of coefficients of exchange rate volatility are statistically significant at conventional levels. Specifically, its sign is negative in the equations for RE_{1t}, RE_{3t}, RE_{5t} and RE_{6t}, and is positive in the rest of the equations.

The export demand equation for RE_{7t} is a special case that stands out from the others. We do not difference real exports in this equation since the unit root tests suggest that it is stationary. But the foreign income and relative price series are still differenced, and in this case the level of RE_{7t} depends on changes in explanatory variables. Here the coefficient of volatility is positive and significant at conventional levels. However, the sign of real foreign income and relative prices is positive. The latter result conflicts with the predictions of international trade theory, and neither coefficient is statistically significant. Exchange rate volatility has an insignificant positive effect on real exports in this case, but the Breusch-Godfrey LM test suggests there is again an autocorrelation problem. Recall that RE_{7t} is real exports of total special transactions of Canada, and the abnormal results are possibly caused by the nature of this category, which is mainly low-valued transactions, value of repairs to equipment and goods returned to country of origin.

Overall, the explanatory powers for all equations are not very satisfactory. The uncertainty of the real exchange rate has no significant impact upon the real exports of Canada at both aggregate and disaggregated sectoral levels. More importantly, the nature of this relationship is extremely confusing because of the different signs of the results. Therefore, it is necessary to examine this impact using the nominal exchange rate-based measure of volatility.

To test the impact of nominal exchange rate volatility upon the exports of Canada, we use equation (5), in which the volatility is generated by an ARCH (1) model based on a MA (1, 13) mean equation for the nominal spot exchange rate. Again real exports of special transactions, RE_{7t}, are not differenced when estimating by OLS. After examining the results reported in table 9, we find that they are similar to those for equation (4), which confirms McKenzie's (1999) contention that the use of the nominal or real exchange rate does not impact significantly on the empirical results achieved. More specifically, at the aggregate level, the signs of the coefficients of real foreign income and relative prices are positive and negative respectively, which are same as we expected, and both of them are significant at conventional levels. The sign of exchange rate volatility is positive and not statistically significant. The explanatory power of this export demand equation is low because R^2 is 0.346. Similarly, the Breusch-Godfrey LM test suggests that autocorrelation exists, so the t and F statistics were computed using the Newey-West correlation to the standard errors. Looking at the results at the sectoral level, with the exception of the sign for RE_{7t}, the signs of coefficients of real foreign income and relative prices are consistent with our expectations, positive and negative respectively. The coefficient of real foreign income is significant at conventional levels in the equations for RE_{1t}, RE_{2t}, RE_{4t}, RE_{5t} and RE_{6t}, while the coefficient of relative prices is statistically significant at conventional levels in the equation for RE_{1t}, RE_{4t}, RE_{5t} and RE_{6t}. Again the Breusch-Godfrey LM tests suggest that most of these disaggregated equations have autocorrelation effects, and the R^2 s are very low for some equations. None of coefficients of exchange rate volatility is statistically significant at conventional levels.

As before, the special case is the export demand equation of RE_{7t}. In this equation, the coefficient of volatility is positive and significant at conventional levels; however, the sign of real foreign income is negative and that of relative prices is positive, and neither of them is significant at conventional levels. Exchange rate volatility has a significant positive effect on the real exports in this case, but the Breusch-Godfrey LM test also suggests it has a serious error autocorrelation problem.

In summary, the explanatory powers for all equations are not very satisfactory. The uncertainty of the real exchange rate, as the case of the real exchange rate, has no significant impact upon the real exports of Canada at both aggregate and disaggregated sectoral levels, and the signs of the sings are very indecisive.[13]

Broadly speaking, our study based on the exports demand equations (4) and (5) is similar to that done by McKenzie (1998), except for the data period and frequency, the choice of the proxy for real foreign income and the specification of the export demand equation. The specifications are similar, except for the inclusion of real domestic income

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[13] Additionally, since all data used are seasonal unadjusted, to avoid seasonal effects, we also estimate equations (4) and (5) with 11 monthly dummies, and there is not any noticeable difference produced.

in his equations. Hence, the comparison between our studies should provide, to some extent, some instructive and beneficial conclusions. In detail, in his study, for the aggregate export data, the real foreign income has a counter-intuitive negative impact on the level of exports but the coefficient is not significant. The coefficient of the relative price is negative and still insignificant at conventional levels, which suggests that depreciation either has no effect or reduces the level of exports. Finally, the ARCH model-based measure of exchange rate volatility has a statistically significant positive impact on exports. In our study, the signs of the coefficients of relative prices and volatility are same as his, but the former is significant and the latter is not. Furthermore, we do find a positive effect of real foreign income upon exports, and it is significant. At the disaggregated level, it is not very appropriate to compare our studies since the categories of exports are different. However, there is one thing we can say: the results of our and Mckenzie's sectoral exports equations are very inconclusive, and few of the coefficients of the volatility measures are statistically significant.

6. Conclusion

In this study, we investigate the impact of exchange rate volatility upon Canadian exports to the US, at both aggregate and disaggregated levels, using ARCH and GARCH models to generate a proxy for exchange rate volatility. A GARCH (1, 1) model for the real exchange rate and an ARCH (1) model for the nominal exchange rate are used to measure volatility. Unit root tests are adopted to examine the non-stationarity of each series prior to estimation, and find that almost all series are non-stationary. After differencing the series to correct the non-stationarity, we examine the relationship between exchange rate volatility and Canadian exports. For all cases except for the case of special transactions exports, we find that US real income has a positive effect on Canadian exports, a depreciation of relative prices reduces the level of Canadian exports, and most coefficients are statistically significant, which is consistent with the theory of international trade. However, the results with respect to volatility are very inconclusive. At the aggregate level, volatility has a positive impact on the level of exports, but it is insignificant. At the disaggregated level, the sectors of live animals and crude materials are affected negatively by exchange rate uncertainty. However, there is a positive relationship between volatility and the rest of the export categories. For all cases, the coefficients of volatility are insignificant. Also, the results of the real and nominal exchange rate cases lead to an extremely similar conclusion.

Although our results are consistent with the general uncertainty and indecisiveness of the impact of exchange rate volatility upon the level of exports provided by previous theoretical and empirical studies, it is not equivalent to say that our study is completely satisfactory, especially with respect to the construction of the volatility measure and the estimation methods used to deal with non-stationary data series. First of all, it is necessary to find a more suitable export demand equation, since the explanatory power of most our equations are not high enough and there is evidence of autocorrelation and non-normality of the error distribution. Second, finding a more appropriate proxy for exchange rate volatility is necessary, although it is also possible that exchange rate volatility has no impact upon trade flows. Last but most importantly, a richer dynamic structure in the model estimated, such as an error-correction model, might improve the quality of estimation, since it is possible that there exists a long-run equilibrium between non-stationary variables if they are integrated of the same order.

REFERENCES

Akhtar, M. A and Spence-Hilton, R. (1984) "Effects of exchange rate uncertainty on German and U.S. trade." *Quarterly Review*, (New York: Federal Reserve Bank of New York, Spring) 7-16.

Asseery, A. and Peel, D. A. (1991) "The effects of exchange rate volatility on exports: some new estimates." *Economics Letters* 37, 173–77.

Bailey, M. J., Tavlas, G. S. and Ulan, M. (1987) "The impact of exchange rate volatility on export growth: some theoretical considerations and empirical results." *Journal of Policy Modeling* 9, 1, 225-43.

Box, George, and Jenkins Gwilym. (1976) *Time Series Analysis, Forecasting, and Control.* (San Francisco: Holden Day).

Broll, U. and Eckwert, B. (1999) "Exchange Rate Volatility and International Trade." *Southern Economic Journal* 66, 1, 178–85.

Caporale, T. and Doroodian, K. (1994) "Exchange rate variability and the flow of international trade." *Economics Letters* 46, 49–54.

Chou, W. L. (2000) "Exchange rate variability and China's exports." *Journal of Comparative Economics* 28, 61-79.

Chowdhury, A. R. (1993) "Does exchange rate volatility depress trade flows? Evidence from error-correction models." *The Review of Economics and Statistics* 75, 4, 700-06.

Dellas, H. and Zilberfarb, B.-Z. (1993) "Real exchange rate volatility and international trade: a reexamination of the theory." *Southern Economic Journal* 59, 4, 641–647.

Doroodian, K. (1999) "Does exchange rate volatility deter international trade in developing countries?" *Journal of Asian Economics* 10, 465-74.

Elliott, Graham, Rothenberg Thomas, and Stock James. (1996) "Efficient tests for an autogressive unit root." *Econometrica* 64, 813-36.

Enders, Walter. (2004) *Applied Econometric Time Series.* (John Wiley and Sons: New York) Second edition.

Engle, R. F. (1982) "Autoregressive conditional heteroscedasticity with estimates of the variance of the United Kingdom inflation." *Econometrica* 50, 4, 987-1007.

Ethier, W. (1973) "International trade and the forward exchange market." *American Economic Review* 63, 3, 494-503.

Franke, G. (1991) "Exchange rate volatility and international trading strategy." *Journal of International Money and Finance* 10, 292–307.

Hooper, P. and Kohlhagen, S.W. (1978) "The effect of exchange rate uncertainty on the prices and volume of international trade." *Journal of International Economics* 8, 483–511.

Koray, F. and Lastrapes, W. D. (1989) "Real exchange rate volatility and U.S. bilateral trade: a Var approach." *The Review of Economics and Statistics* 71, 4, 708-12.

Kroner, K. F. and Lastrapes, W. D. (1993) "The Impact of Exchange Rate Volatility on International Trade: Reduced Form Estimates using the GARCH in Mean Model." *Journal of International Money and Finance* 12, 298–318

Lumsdaine, Robin L. and Papell, David H. (1997) "Multiple Trend Breaks and the Unit-Root Hypothesis." *The Review of Economics and Statistics* 79, 2:212–218.

McKenzie, M. D. (1998) "The impact of exchange rate volatility on Australian trade flows." *Journal of International Financial Markets, Institutions and Money* 8, 21-38.

McKenzie, M. D. (1999). "The impact of exchange rate volatility on international trade flows." *Journal of Economic Surveys* 13, 1, 71–106.

McKenzie, M. D. and Brooks, R. D. (1997) "The impact of exchange rate volatility on German-U.S. trade flows." *Journal of International Financial Markets, Institutions and Money* 7, 73-87.

Viaene, J.-M. and De Vries, C. G. (1992) "International trade and exchange rate volatility." *European Economic Review*, 36, 1311–21.

Zivot, Eric, and Andrews, Donald W. K. (1992) "Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis," *Journal of Business and Economic Statistics.* 10, 3:251–271.

Table 1. Descriptive statistics for each variable

Series	Mean	Standard deviation
RE_{0t}	142045.5	74824.5
RE_{1t}	844.5	590
RE_{2t}	5773.1	3353.3
RE_{3t}	17280.4	9010
RE_{4t}	41640	16763.6
RE_{5t}	67122	39233
RE_{6t}	48897	26105.4
RE_{7t}	1754.7	1960.4
$CANREER_t$	122.3	15.9
$CANNRATE_t$	126.7	16.4
$USIIP_t$	68.1	17.3

Table 2. Unit root test output

Series	DF-GLS	Lag Length	ADF	Lag Length	Conclusion
$\ln RE_0$	-2.09	16	-2.13	16	I (1)
Δ	-.74	16	-22.67*	0	
$\ln RE_1$	-2.49	10	-2.34	10	I (1)
Δ	-.46	13	-19.69*	0	
$\ln RE_2$	-1.55	16	-2.90	16	I (1)
Δ	-.016	16	-25.0*	0	
$\ln RE_3$	-1.86	16	-1.41	16	I (1)
Δ	-2.96*	13	-19.95*	0	
$\ln RE_4$	-2.36	16	-2.37	16	I (1)
Δ	-.82	16	-26.6*	0	
$\ln RE_5$	-2.27	16	-2.26	16	I (1)
Δ	-1.15	16	-22.2*	0	
$\ln RE_6$	-1.98	12	-1.96	12	I (1)
Δ	-.93	16	-22.89*	0	
$\ln RE_7$	-2.69***	15	-3.57**	4	I (0)
Δ					
$\ln USIIP_t$	-1.84	15	-2.58	15	I (1)
Δ	-.53	16	-3.1**	11	
$\ln CANREER_t$	-2.37	13	-2.35	13	I (1)
Δ	-1.68***	16	-4.01*	10	
$\ln CANNRATE_t$	-1.48	1	-1.30	2	I (1)
Δ	-2.78*	10	-3.63*	10	

1. Δ indicates that the series is first differenced. All series are logarithms. * is significant at the 1% level, ** at the 5% level, and *** at the10% level.

Table 3. ARMA Models of the Real Effective Exchange Rate

Model	coef	estimate	t-statistic	AIC	SBC
AR (1)	Int	-.000785	-1.074		
	AR(1)	.185514	3.639**	-6.0889	-6.0679
AR	Int	-.000737	-.799		
(1,10)	AR(1)	.192	3.76**	-6.0937	-6.0616
	AR(10)	.157	3.0**		
AR	Int	-.00088	-1.411		
(1, 13)	AR(1)	.1822	3.55**	-6.087	-6.0546
	AR(13)	-.1545	-2.86**		
MA (1)	Int	-.000813	-1.16		
	MA(1)	0.1794	3.51**	-6.089	-6.068
MA	Int	-.00082	-1.07		
(1,10)	MA(1)	.1673	3.28**	-6.0998	-6.0684
	MA(10)	.1357	2.61**		
MA	Int	-.00086	-1.44		
(1,13)	MA(1)	.1787	3.54**	-6.1066	-6.0751
	MA(13)	-.1723	-3.27**		

1. "coef" indicates the coefficients of the lags included in the each model. "Int" is the intercept, AR (.) means the lag of autoregressive parts and MA (.) means the lag of moving average parts.
2. * means significant at the 10% level, and ** means significant at the 5% level.
3. AIC is the Akaike info criterion.
4. SBC is the Schwarz criterion.

Table 4. ARMA Models of the Nominal Exchange Rate

Model	coef	estimate	t-statistic	AIC	SBC
AR (1)	Int	.000776	1.09		
	AR(1)	.2072	4.08**	-6.1924	-6.1713
AR	Int	.00076	.86		
(1,10)	AR(1)	.2031	3.99**	-6.1858	-6.1536
	AR(10)	.1461	2.76**		
AR	Int	.0009	1.48		
(1, 13)	AR(1)	.2039	3.99**	-6.1815	-6.1491
	AR(13)	-.1446	-2.61**		
MA (1)	Int	.00076	1.09		
	MA(1)	0.2241	4.42**	-6.1983	-6.1774
MA	Int	.00075	1.02		
(1,10)	MA(1)	.2023	4.0**	-6.2040	-6.1725
	MA(10)	.1159	2.23**		
MA	Int	.00082	1.37		
(1,13)	MA(1)	.2226	4.44**	-6.2117	-6.1802
	MA(13)	-.1611	-3.01**		

1. “coef” indicates the coefficients of the lags included in the each model. “Int” is the intercept, AR (.) means the lag of autoregressive parts and MA (.) means the lag of moving average parts.
2. * means significant at the 10% level, and ** means significant at the 5% level.
3. AIC is the Akaike info criterion.
4. SBC is the Schwarz criterion.

Table 5. GARCH (1, 1) model based on MA (1, 13) mean equation for real exchange rate

$$d\ln CANREER_t = \alpha_0 + \alpha_1 e_{t-1} + \alpha_2 e_{t-13} + e_t$$

$$e_t \mid I_{t\text{-}1} \sim N\,(0,\ h_t)$$

$$h_t = c_0 + c_1 e_{t\text{-}1}^2 + h_{t-1}$$

$$d\ln CANREER_t = \underset{(-1.56)}{-.0009} + \underset{(2.89)}{.1589}\, e_{t-1} + \underset{(-3.41)}{-.1859}\, e_{t-13} + e_t$$

$$h_t = \underset{(1.16)}{.000025} + \underset{(1.72)}{.1094}\, e_{t\text{-}1}^2 + \underset{(-3.41)}{-.1859}\, h_{t-1}$$

JB = 0.231	P-value = 0.89

1. T-statistics are in the parentheses. JB is the Jarque-Bera statistic testing for normality. And the both series are first differenced

Table 6. ARCH (1) model based on MA (1, 13) mean equation for nominal exchange rate

$$d\ln CANNRATE_t = \alpha_0 + \alpha_1 e_{t-1} + \alpha_2 e_{t-13} + e_t$$

$$e_t \mid I_{t\text{-}1} \sim N\,(0,\ h_t)$$

$$h_t = c_0 + c_1 e_{t\text{-}1}^2$$

$$d\ln CANNRATE_t = \underset{(1.73)}{.00096} + \underset{(2.77)}{.1533}\, e_{t-1} + \underset{(-2.87)}{-.1611}\, e_{t-13} + e_t$$

$$h_t = \underset{(8.76)}{.000092} + \underset{(2.07)}{.223}\, e_{t\text{-}1}^2$$

JB = 15.48	P-value = 0.0004

1. T-statistics are in the parentheses. JB is the Jarque-Bera statistic testing for normality. And the both series are first differenced

Table 7. Unit root test for volatility of real and nominal exchange rate

Series	DF-GLS	Lag Length	ADF	Lag	Conclusion
$SVLNCANREER_t$	-2.56	16	-2.67	16	I (1)
Δ	-2.48**	16	-21.2*	0	
$SVLNCANNRATE_t$	-2.58	16	-5.22*	8	I (0)
Δ	-33.66*	0		0	

1. The series are the squared roots of conditional variance for real and nominal exchange rates.

Table 8. Results of equation (4)

$\Delta \ln RE_{it}$	β_1	β_2	β_3	β_4	R^2	F	JB	LM	WH
$\Delta \ln RE_{0t}$	-.0076	2.48	-.92	-.77	.35	66.6	.09	.00	.33
	(-.33)	(14.8)*	(-3.29)*	(-.38)					
$\Delta \ln RE_{1t}$	.118	2.0	-3.1	-10.76	.057	7.44	.00	.0009	.40
	(1.15)	(3.06)*	(-2.6)*	(-1.2)					
$\Delta \ln RE_{2t}$	-.011	1.92	-.26	1.03	.135	19.23	.01	.00	.003
	(-.28)	(7.9)*	(-.74)	(.31)					
$\Delta \ln RE_{3t}$	.025	.077	-.533	-1.87	.0048	.60	.00	.07	.42
	(.73)	(.37)	(-1.4)	(-.63)					
$\Delta \ln RE_{4t}$	-.004	.959	-.86	.45	.08	11.1	.9	.00	.049
	(-.16)	(5.59)*	(-3.06)*	(.21)					
$\Delta \ln RE_{5t}$	.0118	4.49	-1.1	-1.48	.385	77	.00	.00	.098
	(.30)	(15.9)*	(-2.4)**	(-.45)					
$\Delta \ln RE_{6t}$	.02	5.6	-1.1	-2.4	.41	86.5	.00	.0007	.024
	(.41)	(15.9)*	(-1.99)**	(-.59)					
$\ln RE_{7t}$	4.6	.09	5.2	185.6	.033	4.2	.00	.00	.26
	(3.5)*	(.048)	(.74)	(1.58)					

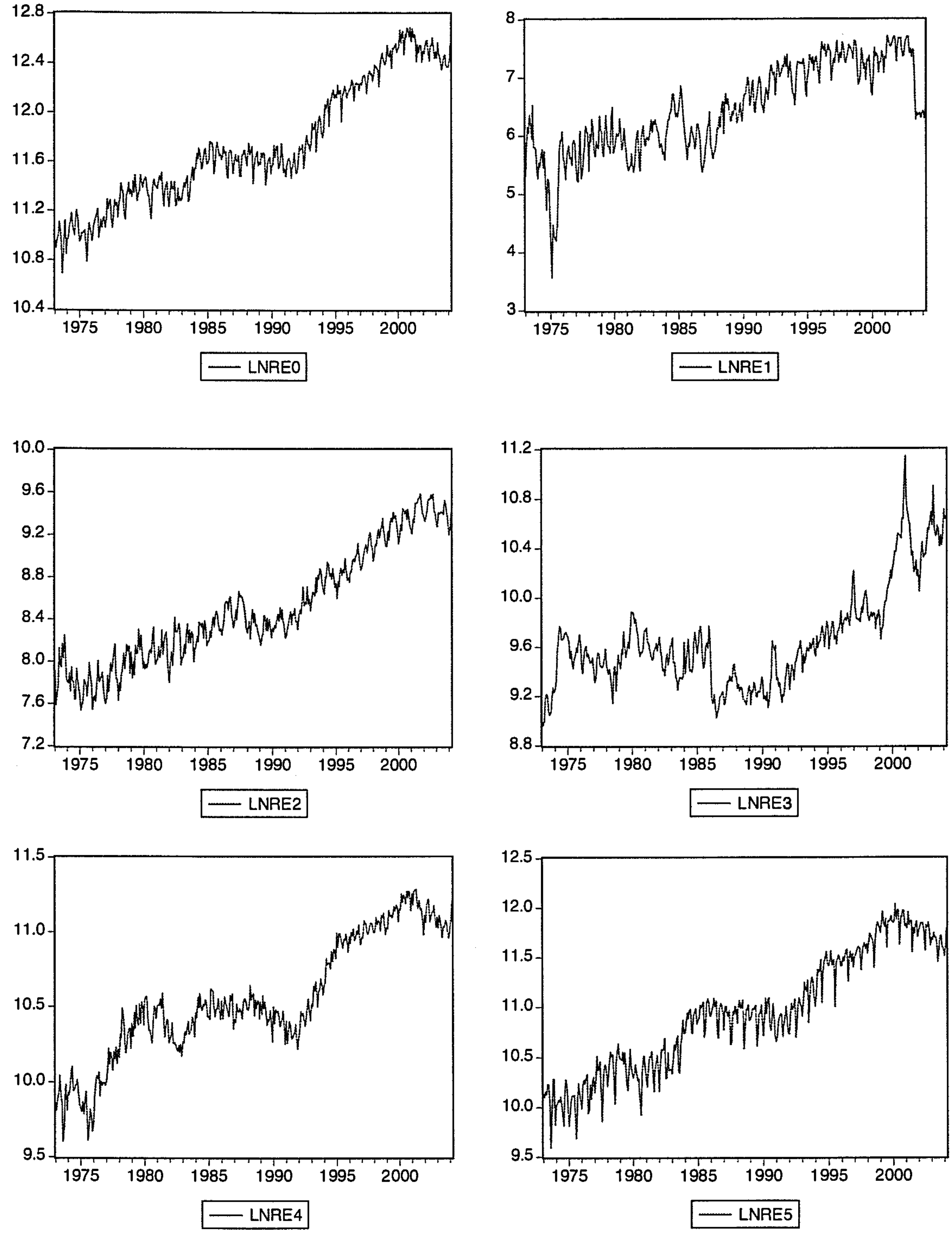
1. t-statistics are in the parentheses. JB is the Jarque-Bera statistic testing for normality. LM is the Breusch-Godfrey serial correlation LM test with 2 lags. WH is the White Heteroskedasticity test without cross terms. * is significant at the 1% level, ** at the 5% level, and *** at the 10% level.
2. For JB, LM and WH, the P-values are reported.

Table 9. Outputs of equation (5)

$\Delta \ln RE_{it}$	δ_1	δ_2	δ_3	δ_4	R^2	F	JB	LM	WH
$\Delta \ln RE_{0t}$	-.0187	2.452	-.9283	1.604	.346	65.2	.11	.00011	.36
	(-.624)	(14.37)*	(-3.29)*	(.58)					
$\Delta \ln RE_{1t}$	.0741	2.058	-3.01	-7.214	.059	7.71	.00	.0007	.20
	(.68)	(3.16)*	(-2.63)*	(-.72)					
$\Delta \ln RE_{2t}$	-.0249	1.85	-.247	2.318	.123	17.38	.059	.00	.016
	(-.71)	(7.28)*	(-.68)	(.73)					
$\Delta \ln RE_{3t}$	.0168	.0672	-.503	-1.204	.0045	.56	.00	.057	.34
	(.55)	(.33)	(-1.27)	(-.43)					
$\Delta \ln RE_{4t}$	-.0157	.942	-.870	1.55	.082	10.95	.94	.00	.17
	(-.61)	(5.47)*	(-3.09)**	(.66)					
$\Delta \ln RE_{5t}$	-.0283	4.45	-1.10	2.11	.38	76.1	.00	.00	.06
	(-.59)	(15.6)*	(-2.3)**	(.48)					
$\Delta \ln RE_{6t}$	-.0276	5.57	-1.093	1.788	.408	85.2	.00	.00	.01
	(-.48)	(15.6)*	(-1.97)**	(.34)					
$\ln RE_{7t}$	5.22	-.260	2.87	140.48	.0297	3.78	.00	.00	.76
	(9.28)*	(-.13)	(.41)	(2.8)*					

1. t-statistics are in the parentheses. JB is the Jarque-Bera statistic testing for normality. LM is the Breusch-Godfrey serial correlation LM test with 2 lags. WH is the White Heteroskedasticity test without cross terms. * is significant at the 1% level, ** at the 5% level, and *** at the 10% level.
2. For JB, LM and WH, the P-values are reported.

Figure 1.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LNRE0
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3
1975 1980 1985 1990 1995 2000
LNRE1
10.0
9.6
9.2
8.8
8.4
8.0
7.6
7.2
1975 1980 1985 1990 1995 2000
LNRE2
11.2
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10.4
10.0
9.6
9.2
8.8
1975 1980 1985 1990 1995 2000
LNRE3
11.5
11.0
10.5
10.0
9.5
1975 1980 1985 1990 1995 2000
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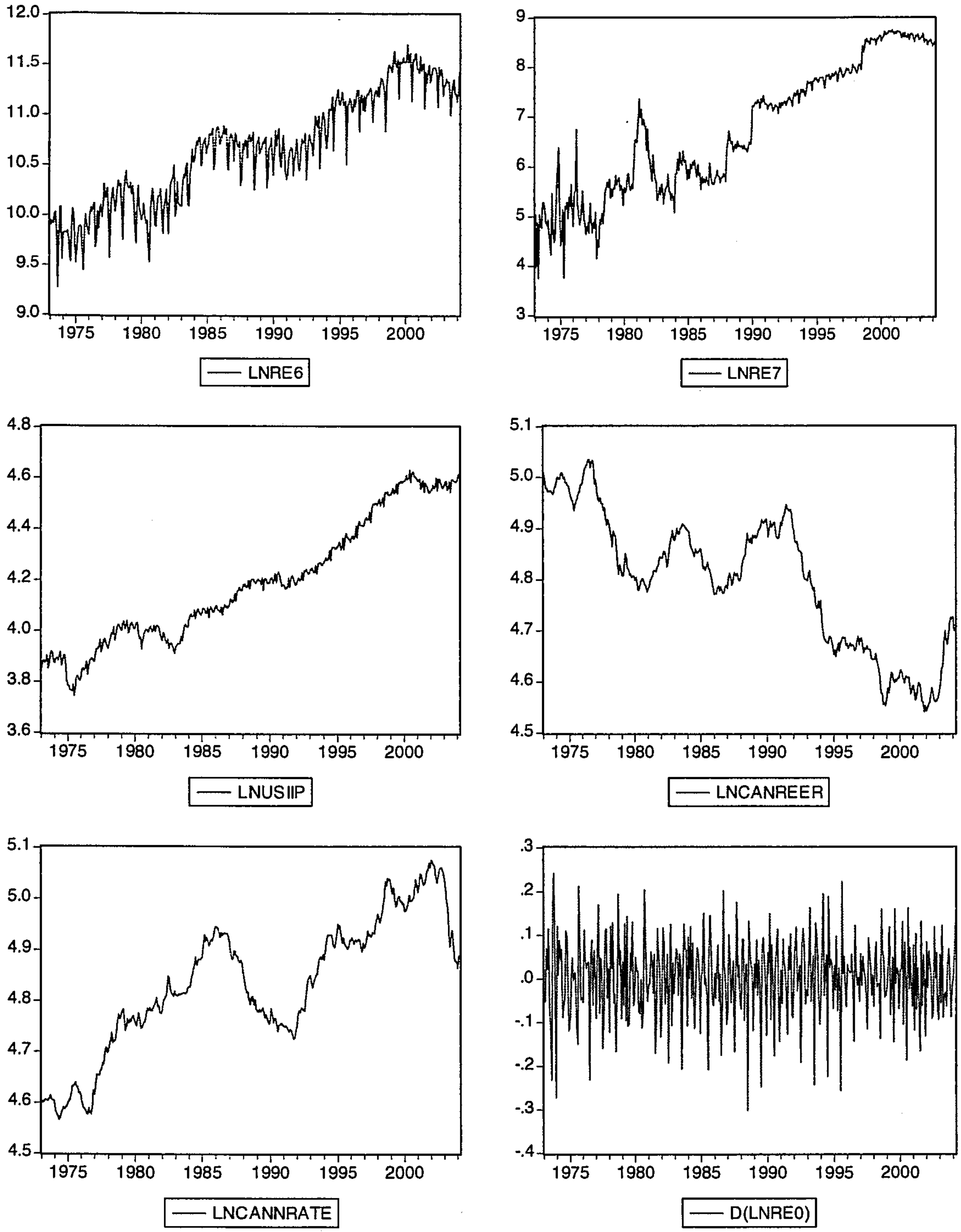
10.5
10.0
9.5
1975 1980 1985 1990 1995 2000
LNRE5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1975 1980 1985 1990 1995 2000
LNRE6
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5
4
3
1975 1980 1985 1990 1995 2000
LNRE7
4.8
4.6
4.4
4.2
4.0
3.8
3.6
1975 1980 1985 1990 1995 2000
LNUSIIP
5.1
5.0
4.9
4.8
4.7
4.6
4.5
1975 1980 1985 1990 1995 2000
LNCANREER
5.1
5.0
4.9
4.8
4.7
4.6
4.5
1975 1980 1985 1990 1995 2000
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.0
-.1
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-.3
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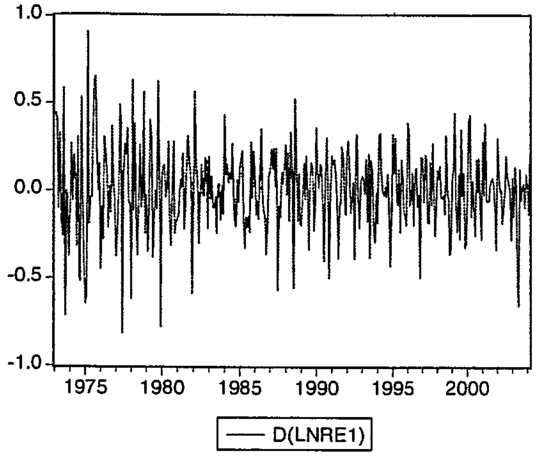
1975 1980 1985 1990 1995 2000
D(LNRE0)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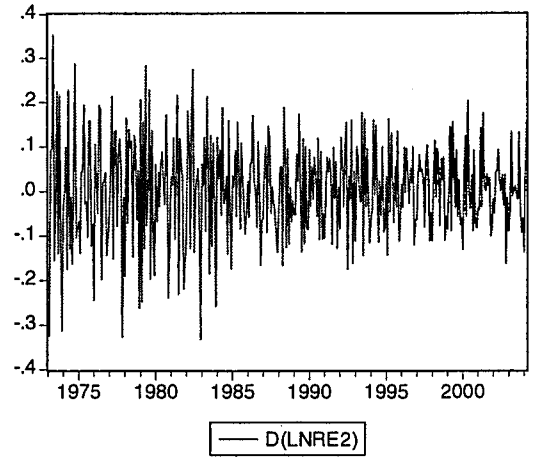
D(LNRE1)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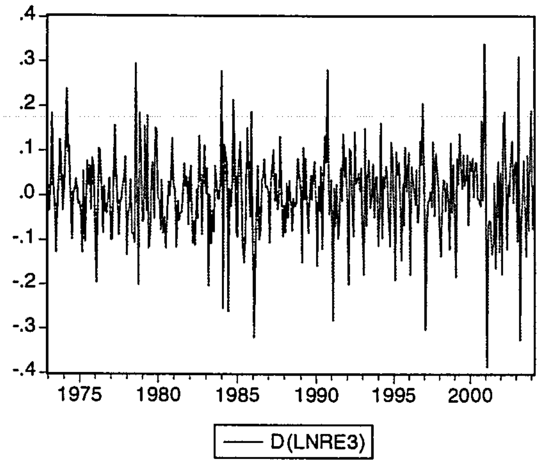
-.4
1975 1980 1985 1990 1995 2000
D(LNRE2)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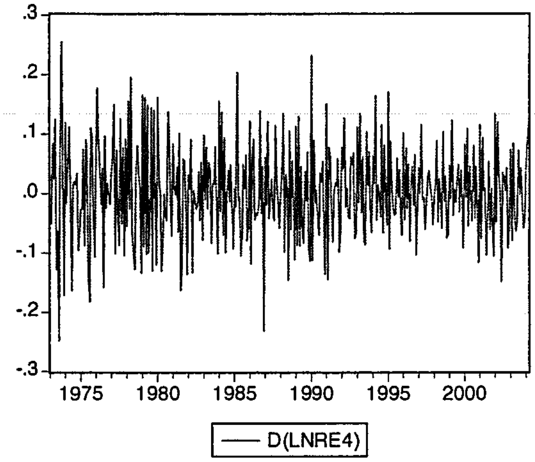
D(LNRE3)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-.2
-.3
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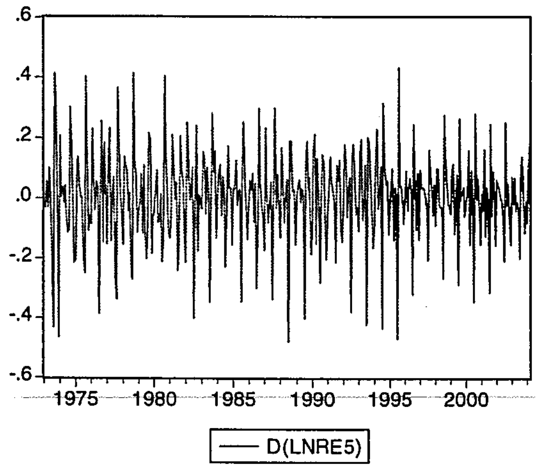
D(LNRE4)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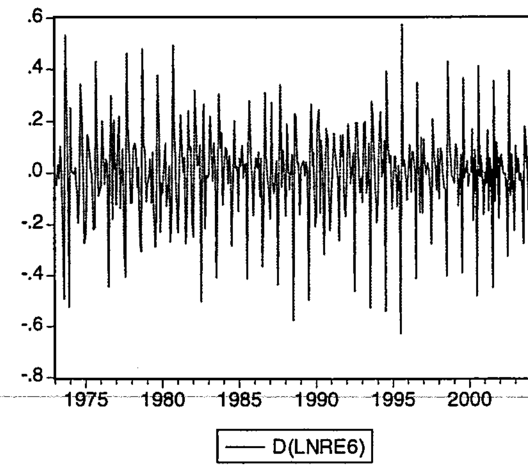
-.4
-.6
1975 1980 1985 1990 1995 2000
D(LNRE5)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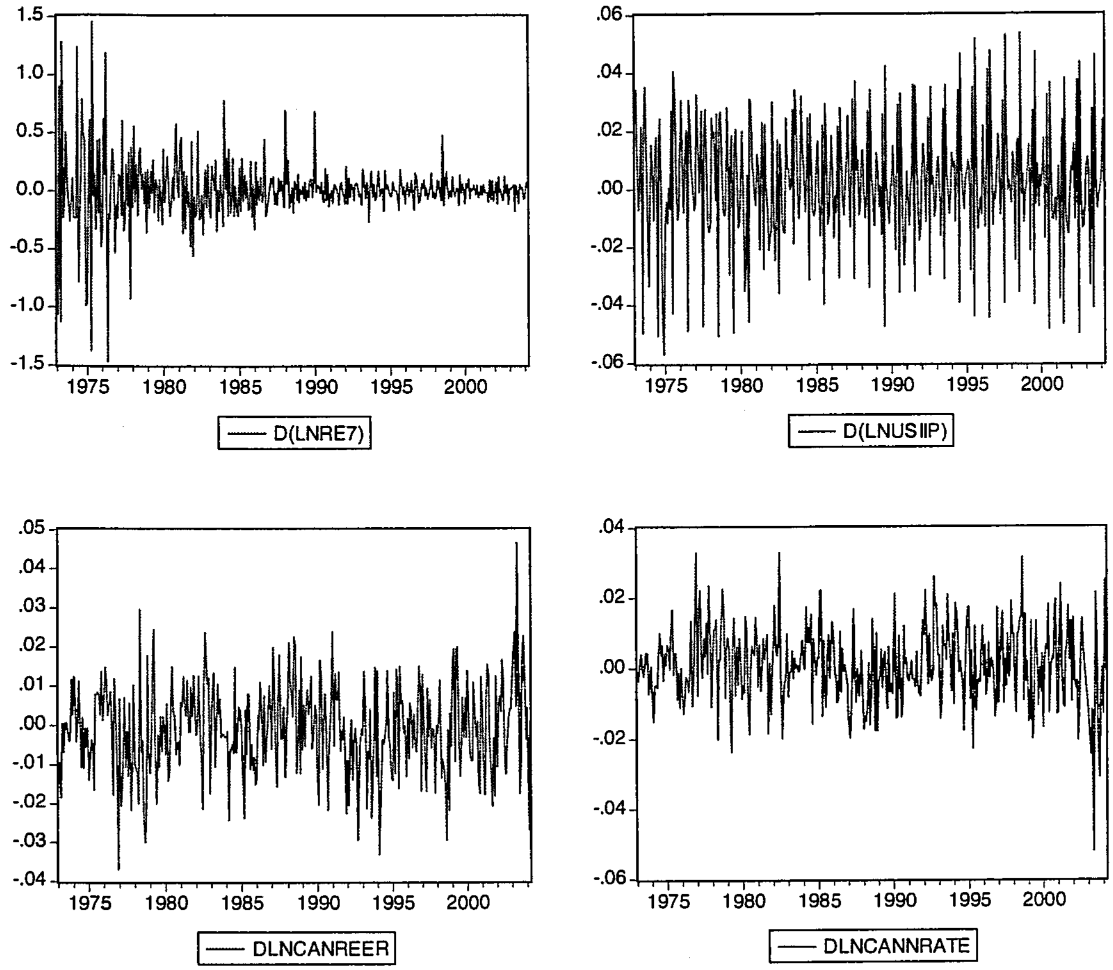
-.2
-.4
-.6
-.8
1975 1980 1985 1990 1995 2000
D(LNRE6)



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0.5
0.0
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-1.0
-1.5
1975
1980
1985
1990
1995
2000
D(LNRE7)
.06
.04
.02
.00
-.02
-.04
-.06
D(LNUSIIP)
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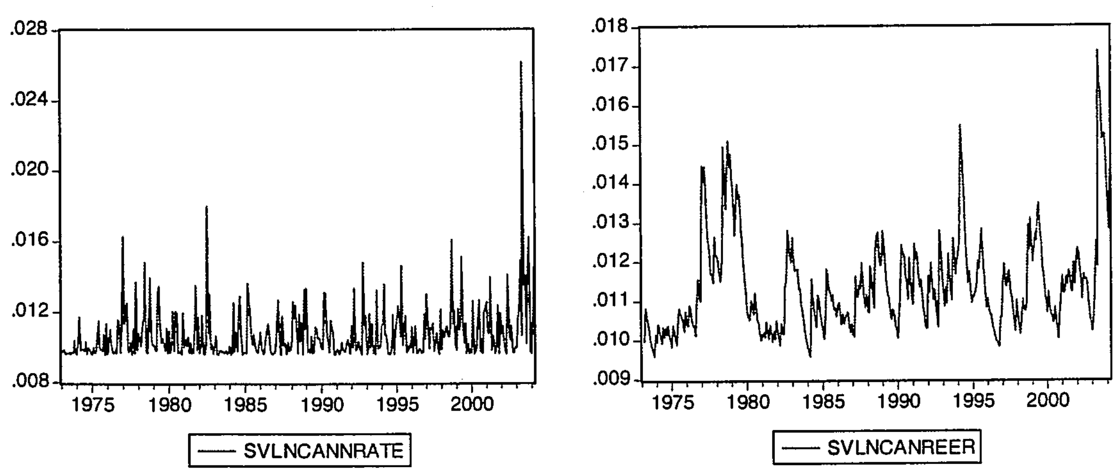
.03
.02
.01
.00
-.01
-.02
-.03
-.04
DLNCANREER
DLNCANNRATE

Figure 2.



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1975
1980
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1990
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SVLNCANNRATE
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.010
.009
SVLNCANREER