Evaluation of An Equation for the Canada-U.S. Real Exchange Rate

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Abstract

Amano and van Norden first developed an equation for the Canada-U.S. real exchange rate in 1993, that empirically verified the existence of a relationship between commodity terms-of-trade variables, the interest rate differential and the real value of the Canadian dollar. Two years later, Lafrance and van Norden modified this equation, and reached a similar conclusion using quarterly data from 1972Q2 to 1993Q4. Using quarterly data retrieved from Federal Reserve Economics Data (FRED) and Statistics Canada, this paper revisits Lafrance and van Norden's equation and empirically examines its feasibility from 1972Q1 to 2017Q1. First, I try to replicate the Lafrance and Van Norden's (1995) results using the same sample period as they used (1972Q2 to 1993Q4). I also estimate the same equation with an extended sample period (1993Q4 to 2017Q1). The results show that the signs of the coefficients are consistent with those of Lafrance and van Norden, but their magnitudes are not; also, this equation has less explanatory power when the latest data are used. Next, after dividing the whole sample into five subsamples, each longer than the previous one, the major findings correspond to my expectation that the non-energy commodity terms of trade place upward pressure on the value of the Canadian dollar. However, the impact of the energy commodity terms of trade has shifted from depreciating to appreciating. Last, two modifications of the original equation aiming to improve the results demonstrate that the interest rate differential is a puzzling variable when it comes to explaining the movements of the real exchange rate; further research is needed to explain the

unexpected finding that the interest rate differential no longer seems to influence the real exchange rate.

1. Introduction

The exchange-rate regimes of different countries can be classified into floating, pegged float, and fixed systems. Except for the period from 1962 to 1970, Canada has operated under a flexible exchange rate system. The resulting abundance of data on Canada's floating exchange rate has led to numerous studies aiming to account for its fluctuations and build a forecasting model. Briefly speaking, a forecasting model for the exchange rate is based on a set of macroeconomic series considered to be determinants of the exchange rate. In a backgrounder which was published by the Bank of Canada (2012), eight major determinants of the Canadian exchange rate are proposed. These determinants include the world price of commodities, the trade and current account balances, the relative economic performance of Canada and the U.S., short-run capital flows, Canada's political turmoil, and relative inflation rates, interest rates, productivity record and public debt. Given that Canada is a net exporter of commodities compared to the U.S., which can be considered to be a net importer, a rising commodities price index tends to appreciate the Canadian dollar. Also, according to the definition of uncovered interest rate parity (UIP), higher Canadian interest rates should lead to a higher value of the Canadian dollar. Amano and van Norden (1993) choose the commodities terms of trade and the interest rate differential from among all potential determinants to predict the movements of the value of Canadian dollar against the U.S. dollar. Their equation, called the AvN equation, tracks most of significant changes in the real exchange rate over the period 1973M1 to 1992M2. Also, they found that the energy commodity terms of trade places downward pressure on the value of the Canadian dollar, while in contrast, increases in the non-energy commodity terms of trade and the interest rate differential tended to appreciate the Canadian dollar.

This paper empirically analyzes the movements of the Canada-U.S. bilateral real exchange rate using the model proposed by Lafrance and van Norden (1995), who adds an extra explanatory variable to the AvN equation and simplify the construction of the interest rate differential term. They find that the direction of the effect of these determinants on the real exchange rate is the same as in Amano and van Norden (1993), but different in magnitude. Also, they show that their equation performs well during their sample period from 1972Q2 to 1993Q4.

Recently, fewer researchers have paid attention to these two equations because improved models of the exchange rate have been built. Also, the finding that the energy commodity terms of trade is negatively related to the real exchange rate is controversial, given theoretical and some empirical evidence that points out that the energy commodity terms of trade should positively affect the value of the Canadian dollar. Moreover, some more recent studies propose that the direction of the effect has changed over time from negative to positive. Therefore, two major issues will be discussed in this paper: first, how well the Lafrance and van Norden (1995) equation works using more recent data; and second, how the signs of these determinants of the real exchange rate have changed over time. Additionally, Amano and van Norden (1993) believe that the choice of price deflator will not have a substantial effect on the estimation results, a view which is supported by many researchers; however, one subsequent study (Laidler and Aba 2001) comes to the opposite conclusion. So this paper will also address the minor issue of whether the findings are sensitive to the choice of deflator.

In general, my estimation results show that both commodity price indices have a statistically significant effect on the real exchange rate. A rising non-energy commodity terms of trade has sustained upward pressure on the value of the Canadian dollar. However, the impact of the energy commodity terms of trade has shifted from depreciating to appreciating. Unexpectedly, my findings point out that the interest rate differential plays an insignificant role in explaining the movements of the real exchange rate. Since the analysis in this paper cannot adequately explain the unexpected results, further research is needed. Additionally, Lafrance and van Norden's equation does not work very well when more recent data are included. In particular, when the whole sample period (1972Q1 to 2017Q1) is used, the Lafrance and van Norden equation can only describe 8.2 percent of fluctuations in the real exchange rate, which is probably why researchers are less interested in this equation today. Lastly, my findings also demonstrate that estimation results are insensitive to the choice of price deflator.

The remaining sections of this paper are divided as follows: section 2 describes several relevant literatures. Section 3 includes information on data sources, the construction of model variables, and summary statistics. Section 4 reveals my empirical analysis including all necessary tests, the estimated model and results. Two extended models and their empirical results are exhibited in section 5. Finally, section 6 concludes.

2. Literature review

This section will be divided into three parts. The first part will describe the historical movements in the value of the Canadian dollar since 1970. Then, some popular models in this field of study will be discussed in the second part. Finally, in the last part, a Canada-specific exchange rate equation will be introduced.

2.1 A brief history of the Canadian dollar since the 1970s[1]

For ease of interpretation, the term "exchange rate" in this paper refers to the amount of U.S. dollars required to buy one Canadian dollar, which can be labeled as USD/CAD. So the Canadian dollar appreciates when it can be exchanged for more U.S. dollars, and vice versa. Figure 1 provides the movements of the U.S. dollar to Canadian dollar exchange rate since 1972Q1.

Once the government announced the re-introduction of the floating exchange rate on May 31, 1970, the Canadian dollar appreciated sharply, increasing about 5 percent to roughly 0.97 U.S. dollars for 1 Canadian dollar. After that, the value of the Canadian dollar continued to drift upward and reached a maximum of 1.0443 U.S. dollars in April of 1974. During the period from 1974 to 1975, a depreciation in the Canadian dollar caused higher inflation; therefore, in late 1975, to abate these inflationary pressures, the Bank of Canada adopted a target for the narrow monetary aggregate. Then, the Canadian dollar recovered in 1976. However, in the following two years, the value of the Canadian dollar fell significantly to 0.84 U.S. dollars by the end of 1978.

Throughout the 1980s, the Canadian dollar fluctuated in a wider range. The Canadian dollar continued to depreciate from 1978 until February 1986 and reached a then-record low of 0.6813

[1] This section relies heavily on Powell (2005).

U.S. dollars for one Canadian dollar, even though many other countries' currencies began to appreciate against the U.S. dollar after the implementation of the dollar-weakening Plaza Accord in September 1985. Then, the value of the Canadian dollar began to strengthen after the federal government aggressively intervened in the foreign exchange market, and the upward trend lasted through the remaining five years. The major drivers of the appreciation through 1988 and 1989 were a rebound in the price of commodities, expansionary fiscal policy, contractionary monetary policy and the signing of the Free Trade Agreement. Thus, at the end of the 1980s, 0.8632 U.S. dollars could purchase one Canadian dollar.

The Canadian dollar appreciated because of a contractionary monetary policy through 1990 until November 1991. After reaching a high of 0.8934 U.S. dollars for one Canadian dollar in November 1991, the Canadian dollar began to depreciate, and sustained its decline through 1993 and 1994. Due to the effects of federal budget deficits, weaker commodity prices and the international crisis in 1998 in the emerging markets of Latin America and Russia, the Canadian dollar depreciated and then reached a new low, of 0.631 U.S. dollars, over the 1990s in August 1998.

In the 21st century, the value of the Canadian dollar hit an all-time low in January 2002: 0.6179 U.S. dollars for one Canadian dollar. From 2003 to 2006, the Canadian dollar began to appreciate because of the well-developed global economy. On November 20, 2007, the value of the Canadian dollar reached its intraday high of 1.10 U.S. dollars. In the first half of 2008, the Canadian dollar traded near parity with the U.S. dollar, but then began to depreciate and fell sharply below 0.8 U.S. dollars. Also, in December 2008, the Bank of Canada cut its overnight lending rate three-quarters of a percentage point to 1.5 percent; as the value of the Canadian dollar started to rise, and by October 2009 one Canadian dollar was worth 0.9861 U.S. dollars.

Lastly, at the height of the commodity boom, one Canadian dollar could purchase 1.06 U.S. dollars in July 2011, but then because of the rapid fall in commodity prices, the value of the Canadian dollar declined 35 percent from its peak to 0.6868 U.S. dollars in January 2016. In 2017, the first semiannual exchange rate (in average) is around 0.7497 U.S. dollars.[2]

In summary, January 2002 recorded the lowest exchange rate ever. So based on this extreme value, two time periods could be discussed separately. The general trend before 2002 was depreciation, except for the period from 1986 to 1992. However, the exchange rate fluctuated wildly after 2002, and it appreciated sharply to parity within four years (from 2002 to 2006). Then, following a drastic depreciation which was triggered by the financial crisis, the exchange rate recovered to parity in 2011-2012. Since then, the value of the Canadian dollar has persistently weakened.

2.2 Structural exchange rate equations

A macroeconomic model of the exchange rate is a function of different variables, which could include prices, the money supply, the interest rate and net foreign assets, government debt, terms of trade and so on. Also, these macroeconomic fundamentals are characterized by differences between the two countries. Therefore, by focusing on different macroeconomic

[2] The first semiannual exchange rate is calculated by taking the average of the monthly exchange rates from January to June. The data source is the Bank of Canada.

fundamentals, this sub-section will briefly introduce two popular approaches to modeling the bilateral exchange rate: the monetary approach, and the portfolio-balance approach.

Frenkel (1976) states that monetary policy plays an essential role in exchange rate determination in a floating exchange rate system; hence the monetary approach is based on domestic and foreign money supply and money demand. In other words, the exchange rate here is defined as the relative price of two countries' currencies, and then a model for the relative price and the relative supply and demand for those currencies is constructed. This model is called the flexible-price monetary model, and it has some crucial assumptions, including that prices are perfectly flexible and that domestic and foreign capital are perfect substitutes. Additionally, Dornbusch (1976) proposed a sticky-price monetary model by relaxing some assumptions from the flexible-price monetary model. He demonstrated that the short-term effect of a decline in interest rates would overshoot the long-run depreciation effect on the exchange rate. More recently, Wilson (2009) provides evidence that the weakness of the monetary approach is the effect of fiscal variables on the demand for money and policy regime changes.

The portfolio-balance approach, an extension of the monetary approach model, relaxes the assumption that domestic and foreign assets are perfect substitutes. This approach is based on the idea that the exchange rate is determined by the behaviors of those economic agents who have a portfolio of domestic and foreign assets and that these assets provide arbitrage opportunities. Both the monetary and portfolio-balance approaches give rise to structural VAR models, and both of them fail to empirically explain the fluctuations of the exchange rate in the post-Bretton Woods system era.

In particular, Meese and Rogoff (1983) estimated reduced forms of the random walk model, the flexible-price monetary model and the portfolio-balance model during the period from March 1973 to June 1981, and reveal that neither of the structural exchange rate models performs better than a simple random walk model in out-of-sample forecasting. Their study examines only the bilateral exchange rates of Germany, Japan, and UK versus the U.S. Among empirical studies of the Canadian exchange rate, Backus' (1984) paper is one of the most cited. Like Meese and Rogoff (1983), he estimates all three models, but for Canada, using quarterly data from January 1971 to October 1980. His findings also indicate that the random walk model is best able to explain exchange rate behaviour. Nevertheless, Rajashree (1995) estimated all three models using quarterly data from 1971 to 1992, and points out that at least one of the structural exchange rate models is capable of out-performing the random walk model. Therefore, since the empirical validity of structural models is controversial, the next sub-section will introduce a Canada-specific exchange rate equation.

2.3 An equation for Canadian dollar

2.3.1 Equation

Amano and van Norden (1993,1995), researchers at the Bank of Canada, develop a single equation for the Canadian dollar, based on an Error Correction Model (ECM), namely the Amano-van Norden (AvN) equation. It investigates the relationship among the Canada-U.S. real exchange rate *(RPFX)*, the interest rate differential *(RDIFF)*, and Canada's terms of trade --

which are divided into energy commodity terms of trade *(TOTENRGY)* and non-energy commodity terms of trade *(TOTOMOD)*. Notably, they define the exchange rate as CAD/USD, which measures how many Canadian dollars must be exchanged for one unit of U.S. dollar. Before the AvN equation was devised, most economists believed a random walk model would provide better predictions of exchange rate movements. However, Amano and van Norden's study shows that out-of-sample forecasts based on the AvN equation are significantly better than predictions from a random walk model.

Moreover, they mention that the real bilateral exchange rate, energy terms of trade and non-energy terms of trade follow unit-root processes and that these series are cointegrated; however, the interest rate differential is not. Thus, in the ECM, both energy and non-energy commodity terms of trade capture the long run effects, and the Canada-U.S. interest rate differential affects the deviation from expected long-run equilibrium. The standard AvN equation is as follows:

$$\Delta RPFX_t = \alpha(RPFX_{t-1} - \beta_0 - \beta_c TOTCOMOD_{t-1} - \beta_e TOTENERGY_{t-1}) + \gamma RDIFF_{t-1} .$$

In their studies, the sample period is from 1973M1 to 1992M2, and all the variables except RDIFF are expressed in logarithms. *RPFX* represents the logarithm of the real Canada-U.S. exchange rate, which is deflated by the CPI. Nevertheless, some papers use the GDP deflator to convert nominal factors to real ones, such as Lafrance and van Norden (1995). Amano and van Norden (1995) argue that the results based on either the CPI or the GDP deflator are not very different. Additionally, *RDIFF* is the interest rate differential, defined as (i_{CA} - I_{CA})-(i_{US}-I_{US}), where *i* is the 30-day prime corporate rate, and *I* is the long-term industrial bond yield.

Lafrance and van Norden (1995)'s study examines the 1972Q2 to 1994Q3 period and redefines the interest rate differential *(INT)* to be the difference between the Canadian 30-day prime corporate rate and the U.S. 90-day commercial paper rate, instead of the difference between the short-run and long-run interest rate spreads in these two countries. They argue that this simpler modification of inter-country interest rates is not critical to the findings obtained. Also, they use the crude oil price index to represent the energy commodity terms of trade, and the Bank of Canada's production-weighted U.S. dollar commodity price index for non-energy commodity terms of trade. Noticeably, the real exchange rate in this paper *(RFX)* refers to the amount of U.S. dollars required to purchase one Canadian dollar (USD/CAD), which is the inverse of *RPFX* in the AvN equation. Finally, to further capture the short-term effects, they modify the AvN equation by adding a one-period lag of the dependent variable to the right-hand side, as follows:

$$RFX_t - RFX_{t-1} = \alpha(RFX_{t-1} - \xi_0 - \xi_1 COM_{t-1} - \xi_2 ENE_{t-1})$$

$$+\phi_1(RFX_{t-1} - RFX_{t-2}) + \phi_2 INT_{t-1} .$$

Thus, this modified AvN equation will be used in this paper. The empirical findings from these two papers and other literature in this field of study are discussed in the next sub-section.

2.3.2 Empirical results

Amano and van Norden (1993,1995) show that a one percent increase in commodity terms of trade tends to appreciate the Canadian dollar by 0.811 percent against the U.S. dollar; however, a one percent increase in the energy terms of trade leads to a 0.233 percent depreciation. They also indicate that if there is a 100 basis points increase in the interest rate differential, the Canadian dollar tends to appreciate by 0.187 percent. Also, these three explanatory variables significantly explain the behaviour of the Canadian dollar over the sample period, and the model appears remarkably stable. Then they also conclude that compared to a random walk model, this equation outperforms with respect to out-of-sample forecasts.

Lafrance and van Norden (1995) find that the direction of the effect of these determinants on the real exchange rate is the same as in Amano and van Norden (1993, 1995), but of different magnitudes. For example, they conclude that if the non-energy price index rises by one percent, the value of the Canadian dollar will increase by 0.474 percent; however, the Canadian dollar will depreciate by 0.08 percent when there is a one percent increase in the energy price index. Compared to Amano and van Norden (1993,1995), the importance of both terms of trade declines. Moreover, a 100-basis points improvement in the interest rate differential leads to a 0.533 percent appreciation of the real exchange rate. In all, they conclude these three determinants can explain 35 percent of the variation of quarter-to-quarter movements in the real bilateral exchange rate. Table 1 summarizes the estimation results from both studies.

Remarkably, the Canadian dollar is well known as petro-currency because Canada is one of the world's largest energy exporters, so when the price of energy goes up, an appreciation is expected. Bayoumi and Muhleisen (2006) empirically support this idea by estimating an extended AvN equation using quarterly data from 1972 onwards. Then they show that both energy and non-energy commodity prices have a significant positive impact on the value of the Canadian dollar. However, the regression results of both aforementioned studies indicate that higher energy prices lead to a depreciation of Canadian dollar, which is inconsistent with the prevailing view that the Canadian dollar is a petro-currency.

In another study, based on a sample from 1973Q1 to 2000Q3, Laidler and Aba (2001) propose that the importance of both commodities' terms of trade declines every decade. During the 1990s, both terms of trade play a statistically insignificant role in determining the real exchange rate. However, the coefficient of the non-energy commodity terms of trade is statistically significant when the GDP deflator is used instead of the CPI. In contrast to Amano and van Norden (1995) and most existing studies, they point out that the choice of deflator does matter. They also show that, when the GDP deflator is used, the decrease in non-energy commodity prices was the primary factor leading to the decline in the value of the Canadian dollar in the late 1990s.

One of the more recent studies, Issa, Lafrance and Murray (2008), indicates that the sign of the relationship between energy prices and the value of Canadian dollar shifted in the early 1990s from negative to positive. They also mention that the turning point accords with significant changes in energy prices and in domestic energy and trade policies at that time.

The above discussion reveals that the AvN equation has raised some questions, such as the ambiguous relationship between energy prices and real exchange rates; also Helliwell, Issa, Lafrance and Zhang (2005) point out that a variant of the AvN equation failed to explain the appreciation of the Canadian dollar in 2003.[3] Therefore, besides explaining the real bilateral exchange rate, Helliwell, Issa, Lafrance and Zhang (2005) estimate a nominal bilateral exchange rate model, namely NEMO (Nominal Exchange rate MOdel). The main difference between the AvN equation and the NEMO is the that the Canada-U.S. labour productivity differential is incorporated. They find that a real depreciation follows higher relative productivity growth in the manufacturing sector. Also, they demonstrate that their model can successfully account for most of the Canadian dollar's behaviour since 1975, with two notable exceptions: the first one is late 1998, while the other is around the period from 2001 to 2002.

In all, because many revamped forecasting models have been built, recent studies are less interested in estimating Lafrance and van Norden's equation. Therefore, in this paper, their work is extended by including the most recent data. Then, based on my findings, three questions will be answered. First of all, whether a significant difference in results could be triggered by using the different deflators. Second, how this equation works with the most recently updated data. In other words, whether my estimation results can demonstrate that the Lafrance and van Norden equation performs poorly in explaining the recent movements of the value of the Canadian dollar. Third, how determinants in the Lafrance and van Norden equation affect the real exchange rate. In particular, I will comparing the coefficients from different subsamples and check whether the direction of the effect of the non-energy commodity terms of trade on the real exchange rate switches sign. Also, I will discuss how other estimated values change over the different

[3] The only difference in this variant of the AvN equation is that the short-run dynamics are captured not only by the Canada-U.S. short-run interest rate differential, but also by the ratio of Canadian to U.S. public sector debt/nominal GDP.

subsamples.

3. Data

The reason for choosing quarterly data is that most existing studies use it, such as Lafrance and van Norden (1995), Djoudad, Murray, Chan, and Daw (2001), Martin (2001), Issa, Lafrance and Murray (2008), Aguilar and Gloria (2013), and so on. All quarterly data were downloaded from the Canadian Socioeconomic Database of Statistics Canada (CANSIM) and the Federal Reserve Bank of St. Louis (FRED). Also, the whole sample period used for estimation in this paper is 1972Q1 to 2017Q1. Additionally, I followed the study of Lafrance and van Norden (1995) in constructing most model variables.

Briefly, the FRED provides the U.S. CPI and 3-month Commercial/Corporate Paper rates for both countries. Then, the Canadian CPI is obtained from Statistics Canada; they also offer the nominal Canada-U.S. exchange rate (CAD/USD) following the definition used in the AvN equation. Lastly, the Fisher commodity price index from the Bank of Canada provides the nominal energy and non-energy price indices (1972=100).[4] The data construction is separately described as follows.

Instead of choosing the GDP deflator, which is used by Lafrance and van Norden, many researchers use the CPI, such as Amano and van Norden (1993), Aguilar and Gloria (2013), Djoudad, Murray, Chan, and Daw (2001), and so on. Also, Amano and van Norden (1995) point

[4] All data were downloaded on June 14th.

that the results are not sensitive to the different deflators, so the CPI is chosen as the major deflator in this paper. Additionally, in order to replicate Lafrance and van Norden (1995), the GDP deflator will also be taken into account.[5]

The U.S. consumer price index (1982-84=100) is non-seasonally adjusted for all urban consumers and all items. It is obtained from the FRED, with series name CPIAUCNS. The Canadian CPI (2002=100) is also non-seasonally adjusted for all commodities. In CANSIM, the series number is v41690973. Before deflating the nominal variables, both price indices are re-based with 1972 as the base year to make them consistent with the commodity price indices.

The nominal bilateral exchange rate is the quarterly average of the monthly noon spot rate, which was recorded by the Bank of Canada, and expressed in U.S. dollars. The data are published by Statistic Canada as the series v37426 in CANMIS. Following Lafrance and van Norden (1995), the inverse Canada-U.S. exchange rate (CAD/USD) will be used. Then, the real exchange rate (*Rex*) can be calculated as:

$$Rex = (Nominal\ USD/CAD) * \frac{CPI\_ca(1972 = 100)}{CPI\_us(1972 = 100)}$$

Next, CANSIM table 176-0075 provides the Fisher commodity price index (1972=100), which is calculated from the transaction prices in U.S. dollars of 24 goods produced in Canada and sold globally. These 24 commodities can be classified as forestry, agriculture and fisheries products, metals and minerals, and energy. For the purposes of this paper, two nominal

[5] The Fred provides the GDP Implicit Price Deflator for both the U.S. and Canada, with series names USAGDPEFQISMEI and CANGDPDEFQISMEI respectively, and both deflators are indexed as 2010=100. Therefore before deflating the nominal variables, both price indices are re-based with 1972 as the base year. Then replacing CPI with GDP in the calculation to construct the new model variables.

commodity price indices are extracted from this table. Then, the real energy price index (*Ener*) and the real non-energy price index (*Com*) are deflated by the U.S. CPI:

$$Ener = (Nominal\ energy\ price\ index)/(\frac{CPI\_us_{(1972=100)}}{100})$$

$$Com = (Nominal\ non - energy\ price\ index)/(\frac{CPI\_us_{(1972=100)}}{100})$$

Finally, the choice of interest rate is the 3-month Commercial/Corporate Paper rate for each country.[6] The FRED provides the quarterly average of the non-seasonally adjusted rates for Canada and the U.S. (*i_ca and i_us*), with the unit as percent.[7] Therefore, based on Lafrance and van Norden (1995), the interest rate differential (*Intdiff*) is measured by the formula

$$Intdiff = (\frac{i\_ca}{100} - \frac{i\_us}{100})$$

In all, my sample data includes seven original series and 181 observations. The frequency of all variables is quarterly. Summary statistics are provided in table 2, which suggests that the mean of the real value of the Canadian dollar is 0.885 U.S. dollars, compared with that of the nominal exchange rate equals 0.834. In addition, given the base year of the commodity price index is 1972 (1972=100), the means of non-energy and energy commodity price indices are 244.506 and 740.415 respectively. Lastly, Canada's 3-month Commercial Paper rates have a mean of 6.387 percent, and the average of U.S. 3-month Corporate Paper rates is 5.309 percent; therefore, on average, the short-run interest rate differential is 1.078 percent.

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[6] An alternative choice of interest rate could be the Canadian overnight interest rate and the U.S. federal funds rate.

[7] I use Canada's 3-month Commercial Paper rates from the FRED instead of CANSIM because CANSIM only provides the data from 1997, in series v122141.

4. Empirical analysis

In this section, three major sample periods will be considered separately. To compare with the study of Lafrance and van Norden (1995), the same sample period (1972Q2 to 1994Q3) will be used. From now on, this sample is named *Sample A1*. Then estimating the same equation with an extended sample period from 1993Q4 to 2017Q1 (*Sample A2*) can reveal how this equation works recently. Finally, my whole sample period is from 1972Q1 to 2017Q1, called *Whole sample.*

For each sample period, the estimating model follows Lafrance and van Norden's equation:

$$\Delta lnRex_t = \alpha(lnRex_{t-1} - \beta_0 - \beta_c lnCom_{t-1} - \beta_e lnEner_{t-1}) + \gamma Intdiff_{t-1}$$

$$+ \phi \Delta lnRex_{t-1} + \varepsilon_t \,, \qquad (1)$$

where *lnRex* is the logarithmic form of the real bilateral exchange rate (USD/CAD), *lnCom* is the logarithmic form of the non-energy commodity price index, *lnEner* is the logarithmic form of the energy commodity price index, and *Intdiff* is the Canada-U.S. short-run interest rate differential.

In this paper, the Granger and Engle (1987) two-step method is used to estimate the model.[8] First, however, I test each model variable for stationarity, and then test for cointegration; if the results demonstrate that *lnRex, lnCom* and *lnEner* are cointegrated, an error correction model can be estimated using the two-step method proposed by Engle and Granger. The first step is to estimate the long-run relationship; i.e., to regress *lnRex* on *lnCom* and *lnEner* using OLS. This

[8] All estimation and testing is carried out using EViews 9.

step provides the estimated values of β_0, β_c and β_e. The second step is then to estimate specification (1) under the assumption that *Intdiff* is stationary. In this step, *ΔlnRex*,is regressed on *Intdiff*, $\Delta lnRex_{t-1}$, and the residual from step 1. This step tells us the estimated coefficients of the error correction term, the interest rate differential and the lagged first difference of the real exchange rate. Theoretically, the coefficient of the error correction term is expected to be between -1 and 0.

Therefore, sub-sections 4.1 and 4.2 will present the test results for each sample, and the findings will be provided in sub-section 4.3.

4.1 Tests for unit-root and stationarity

Due to the fact that individual tests for stationarity lack power, three kinds of tests -- the augmented Dickey–Fuller (ADF) test, the Phillips–Perron (PP) test, and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test -- will be considered for each model variable. The null hypothesis of the ADF and the PP tests is that the variable contains a unit root, but the KPSS is used for testing the null hypothesis of stationarity against the alternative of a unit root. Hence, these three tests can help us to determine whether the variables are non-stationary. Additionally, in order to qualify as long-run prospective explanatory variables, those non-stationary time series should be integrated of order one. If non-stationary variables can be first-differenced to render them stationary, then they are integrated of order one.

For each sample, according to graphs 5, 6 and 7, an intercept and trend should be included when testing *lnRex*, *lnCom* and *lnEner*. When testing *Intdiff*, graph 8 indicates that an intercept needs to be included for the whole sample. Because both an intercept and trend seem to exist in sample A1, but neither in sample A2, I include an intercept and trend in testing *Intdiff* in sample A1, but remove them in sample A2.[9] Also, graphs 9 to 11 present the first differences of *lnRex*, *lnCom* and *lnEner*, revealing that there are no more trends in each graph; however, the existence of an intercept is unclear. Because of some outliners around 2008, I believe their first-difference testing models should contain an intercept for each sample. Additionally, the lag length is automatically chosen according to the modified Akaike Info Criterion (AIC) in the ADF test, and Newey-West Bandwidth will be the automatically chosen bandwidth for the PP and KPSS tests. The testing results from sample A1 and A2 are provided in table 3, and those of the whole sample are in table 4.

First of all, both tables suggest that *lnRex*, *lnCom* and *lnEner* contain a unit root. In table 4, these non-stationary variables are well characterized as I(1) because the ADF and the PP tests fail to reject the null hypothesis for the level but not first difference of each series. The KPPS test also suggests that these three series are stationary in first differences, but not levels. From table 3, in sample A1, all three tests show that *lnRex* and *lnCom* are well characterized as I(1), but only the PP and the KPSS tests imply that *lnEner* is stationary in first differences. In sample A2, the significant evidence from these three tests indicates that *lnCom* and *lnEner* are I(1). In contrast to the ADF test, which rejects the stationarity of *lnRex* in first differences, both the PP and the KPSS tests suggest that *lnRex* can be considered to be I(1) as well.

[9] In sample A2, including an intercept in a testing model when the KPSS test is implemented because there is no option to choose neither intercept nor trend under the KPSS test in E-views.

For the interest rate differential, table 3 shows that, generally, *Intdiff* is stationary in both samples A1 and A2. Only the ADF test fails to reject the nonstationarity in sample A1; the remaining tests in both samples support the stationarity of *Intdiff*. Then, for the whole sample, the PP test states that *Intdiff* is stationary, but the findings from the ADF and the KPSS tests imply the contrary. Therefore, the tests were also applied to the individual interest rate variables (Canada and U.S.). The results suggest that, in general, both interest rates are stationary. Specifically, all these tests demonstrate that the U.S. interest rate does not contain a unit root. However, except for the KPSS test which rejects stationarity at five percent, the ADF and the PP tests yield evidence that the Canadian interest rate is stationary. Also, Issa, Lafrance and Murray (2008) simply assume that the interest rate differential is stationary because they believe the interest rate differential is unlikely to be explosive. Therefore, *Intdiff* seems to be stationary in all samples.

Overall, because of its stationarity, *Intdiff* can be described as a variable that captures the short-run effect. In contrast, *lnRex*, *lnCom* and *lnEner* are found to have a unit root and be integrated of order one. Next, cointegrating relationships among these I(1) variables will be examined.

4.2 Tests for cointegration

Testing for cointegration involves a system approach (Johansen cointegration test) or a single-equation method (Hansen cointegration test). The Johansen cointegration test examines the total number of cointegrating equations in the system. The Hansen cointegration test simply examines whether the real exchange rate is cointegrated with the non-energy and energy price index under the null hypothesis that the series are cointegrated. Because that is the question of interest here, the Hansen test will be used. The lag length is automatically selected using the AIC and BIC.[10]

The test results are provided in table 5. Remarkably, the Hansen test suggests that the cointegrating relationship is significant in sample A1, regardless of the choice of AIC or BIC. In contrast, in sample A2, using either the AIC or BIC shows that the null hypothesis is rejected at the five percent significance level, which implies that the long-run relationship among *lnRex*, *lnCom* and *lnEner* no longer exists during the sample period from 1994Q4 to 2017Q1. Furthermore, when considering the whole sample period, row 3 of the table indicates that when the lag length is selected by the AIC, one can reject the null hypothesis that these I(1) series are cointegrated at the ten percent significant level; however, *lnRex*, *lnCom* and *lnEner* are significantly cointegrated when the BIC is used.

Therefore, for the purposes of estimating an error correction model, the real exchange rate and terms-of-trade variable (price indices) are temporarily assumed to have a long-run relationship for all three samples. Then, the next step is to separately estimate the specification (1) and the regression results in the next sub-section.

4.3 Empirical results

[10] E-views 9 does not provide the option to choose modified AIC, BIC. Therefore, AIC and BIC will be considered instead.

In this section, the estimation results for samples A1 and A2, which use different deflators (CPI and GDP deflator), are presented. Following the model of Lafrance and Van Norden (1995),[11] I compare the difference in coefficients between my results and their findings for the same period using the two deflators, as well as for the more recent period from 1994Q4 to 2017Q1, in order to observe whether the impact of each variable on the real exchange rate will be consistent. Also, the reason for considering both deflators is to check whether the different deflators lead to a significant difference in results.

The estimation results are provided in table 6. In addition, in table 7, I divide my sample into five sub-groups -- 1972Q1 to 1992Q1, 1972Q1 to 1998Q1, 1972Q1 to 2006Q1, 1972Q1 to 2010Q1, and 1972Q1 to 2017Q1 -- to measure the extent of variation of specification (1) when sample size cumulatively increases.

In general, my estimation results are consistent with those of Amano and van Norden (1995) in that different deflators do not cause significant differences in the coefficients. However, the model fits the data better when the GDP deflator is used. In sample A1, R-squared shows that 26.4 percent of the movements in the real exchange rate can be explained by variables constructed using the GDP deflator in specification (1), compared with only 17 percent when the CPI deflator is used. Moreover, the results from both deflators suggest that the signs of the coefficients are in accordance with those of Lafrance and van Norden (1995), which implies that these determinants affect the value of the Canadian dollar in the expected direction. However,

[11] In this paper, Lafrance and Van Norden's equation is also called specification (1).

my estimates differ in magnitude from those of Lafrance and van Norden. In particular, in sample A1, the real exchange rate appreciates by 0.124 percent when the commodity price index increases by one percent; this change is relatively small compared to the 0.474 percent appreciation of the real exchange rate in Lafrance and Van Norden. Similarly, a one percent rise in the non-energy price index results in a 0.04 percent drop in the value of the Canadian dollar, which is exactly the half of the 0.08 percent obtained by Lafrance and Van Norden.

As a variable that captures short-run effects, the change in the real exchange rate in the previous period puts larger upward pressure on the current exchange rate; an increase of around 0.454 percent in the current real exchange rate is associated with a one percent rise of the real exchange rate in the previous period. The corresponding coefficient in the study of Lafrance and Van Norden is 0.328 percent. It is also noteworthy that the speed of adjustment, which represents the scale of the deviation that could be eliminated within one quarter, has an estimated value of -0.089 in sample A1, which is slower than what might have been expected given the estimate of -0.151 obtained by Lafrance and Van Norden. Moreover, although the sign of the coefficient of the interest rate differential is positive as expected, the magnitude of 0.098, which shows that Canadian dollar would appreciate by 9.8 percent when the real exchange rate differential rises by one percentage point, is insignificant and different from the 0.533 obtained by Lafrance and Van Norden, which is also statistically significant at the one percent level. Despite the fact that the negative sign in sample A2 indicates that the real exchange rate is affected by the interest rate differential in the reverse direction, the coefficient of -0.077 is still statistically insignificant. In all, by estimating the same equation for the same period, my estimation results could only replicate the sign but not the magnitude of the impact of these determinants.[12]

Taking sample A2 into account, the coefficient of the non–energy terms of trade is 0.569, which implies that the real exchange rate tends to appreciate by 0.569 percent when the non-energy price index rises by one percent. This estimated value is more than four times larger than the corresponding coefficient from the pre-1994 Q3 sample, 0.124. Moreover, according to Issa, Lafrance and Murray (2008), the impact of the energy terms of trade on the real exchange rate is expected to change from depreciation to appreciation. In table 6, before 1994Q3 increases in the energy commodity price index tend to depreciate the real exchange rate because of the negative sign; however, after 1994Q4 a one percent increase in the energy commodity price index would cause the real exchange rate to appreciate by 0.165 percent and 0.202 percent using the CPI and GDP deflator respectively. The impact of the speed of adjustment on the real exchange rate is also different between sample A2 and sample A1; compared with the magnitude of -0.089, which is significant at the one percent level using the GDP deflator in the first period, the positive and statistically insignificant coefficient of 0.039 under the GDP deflator from period 1994Q4 to 2017Q1 may be attributed to the rejection of the existence of cointegration at the five percent significance level. When the CPI is used as the deflator, the adjustment coefficient of 0.014 is also insignificant. Thus neither deflator provides evidence that the model could adjust to a deviation within one quarter when the real exchange rate is out of long-run

[12] I cannot figure out why the interest rate differential has a puzzling coefficient. There are two potential explanations for the different findings are provided. The first could be data revisions, because the previously published data source could be revised when new information or a new computing method is available. Second, different estimation methods will trigger the diverse results as well. For example, I used a two-step procedure for cointegration analysis in this paper. Instead of clarifying their estimation method, Lafrance and van Norden (1995) simply mention that the exchange rate equation is estimated using OLS.

equilibrium.

Table 7 depicts the variation of the coefficients in five subsamples, all of which begin in 1972Q1. Because the results are insensitive to the choice of deflator (CPI or GDP) as shown in table 6, only the estimation results based on the CPI are provided due to the fact that the GDP deflator is more frequently revised. First, the speed of adjustment experiences a diminishing trend over time. The magnitudes fall from -0.089 in column (i) to -0.040 in column (v), implying that the change in the real exchange rate moves more slowly toward its long-run equilibrium in each quarter when more time periods are added. All coefficients are statistically significant at, at least, the ten percent level.

Next, when the non-energy commodity price index is changed by one percent, the real exchange rate initially increases by 0.16 percent according to column (i), rising to 0.328 percent in column (iii), where it reaches its peak; after that, the magnitude of the change drops to 0.288 percent in column (v). According to Issa, Lafrance and Murray (2008), the coefficient of the energy price index is expected to shift from negative to positive over time (when the real exchange rate is defined as the number of U.S. dollars required to purchase 1 Canadian dollar). My estimation results reveal that this does in fact happen in my samples; the values of -0.105 in column (i) to -0.005 in column (iii) all imply that the real exchange rate is negatively affected by the energy price index. When the coefficient of the energy commodity price index reaches 0.039 in column (iv) and 0.074 in column (v), the positive relationship implies that the Canadian dollar would appreciate as the energy price index goes up.

Note that in table 7 as well, the interest rate differential, which is included to capture short-run effects, does not appear to effectively influence the real exchange rate during the 1972Q1 to 2017Q1 period, except in column (iii) where the coefficient estimate is statistically significant at the ten percent level. This result indicates that the real exchange rate would appreciate by 15.8 percent as the interest rate differential increased by one percentage point. Unfortunately, the rest of the interest rate differential coefficients are statistically insignificant.

Moreover, the coefficients of the lagged first difference of the real exchange rate do not display a regular pattern as the sample period changes in table 7; the estimated effect on the real exchange rate fluctuates around 0.330 percent across the five subsamples, and all the estimated coefficients are statistically significant at the one percent level. Lastly, recall that the value of R-squared is 0.351 in the study of Lafrance and van Norden (1995), and 0.123 from the study of Amano and van Norden (1993). Here, table 7 shows that when sample size cumulatively increases, the value of R-squared drops from 0.205 to 0.082, which demonstrate that the model of Lafrance and Van Norden (1995) tends to be less convincing when further time periods are included in the sample; this situation will slightly improve when a constant term is added to the model, as I will discuss in section 5.2.

5. Extensions of the model

The results from the previous section show that I have failed to completely replicate the Lafrance and Van Norden version of the model. Thus, aiming to improve my estimation results, two modified equations will be separately discussed as follows.

5.1 Adding a deterministic trend

Chaban (2010) re-examines the cointegrating relationship between the real exchange rate and commodity prices, and demonstrates that a deterministic trend should be included in the cointegrating equation.[13] This point contradicts the assumption of Amano and van Norden (1995) that there is no deterministic trend. Therefore, following his study, specification (2) is formulated as follows:

$$\Delta lnRex_t = \alpha(lnRex_{t-1} - \beta_0 - \theta_t - \beta_c lnCom_{t-1} - \beta_e lnEner_{t-1}) + \gamma Intdiff_{t-1} + \phi \Delta lnRex_{t-1} + \varepsilon_t \,. \qquad (2)$$

The only change made in specification (2) is adding a trend *t* to the long-term dynamics along with the terms of trade. The estimation results are provided in tables 8 and 9.

Basically, the estimation results in table 8 are close to those of table 6, which is based on specification (1). Even the values of R-squared for the two specifications are almost identical, which implies that for sample A1 and A2, adding a trend variable would not improve the model and better explain the data. Additionally, the coefficients of the trend variable are all positive and statistically significant, except when the CPI is used as deflator in sample A1.

Once again considering the variation in the coefficients when the sample size is increased gradually after 1992Q1, table 9 shows that the general findings do not deviate much from those for specification (1). Specifically, the estimated coefficient of the commodity terms of trade is positive for all the five subsamples, which supports the hypothesis that the Canadian dollar is a

[13] Even though that is not a theoretical justification for including a trend in the long-run relationship, it provides a possible way to modify the standard estimation equation.

commodity currency. However, the coefficients are larger in magnitude in the last two subsamples when the time trend is added; in particular, in column (v), where the whole sample is used, the results indicate that the Canadian dollar would appreciate by 0.446 percent when there is a one percent increase in the commodity price index, as compared to 0.288 percent when specification (1) is estimated. In contrast, only a 0.038 percent appreciation is associated with a one percent improvement in the energy price index, which is about half of the corresponding coefficient for the full sample in specification (1). Thus, adding a time trend variable to the cointegrating equation tends to strengthen the effect of the non-energy commodity terms of trade, but weaken that of the energy commodity terms of trade, especially when the whole sample period is considered. Furthermore, for the second subsample in column (ii) of table 9, the coefficient of 0.036 for the non-energy price index is quite small and statistically insignificant. Recall that the corresponding coefficient equals 0.245 in specification (1), and is statistically significant.

Moreover, the estimated speed of adjustment is negative in all the subsamples, but its statistical significances declines as sample size increases. The adjustment coefficient is also statistically insignificant for the whole sample in column (v). As for the time trend, its coefficients do not exhibit a monotonic trend, which is reasonable because the change in the real exchange rate fluctuates over different sample periods. Additionally, comparing the value of R-squared for any subsample to that in column (v), one can see that specification (2) is less convincing when more recent data are included because it only can explain 8 percent of fluctuations in the real exchange rate. Finally, including a deterministic trend does not significantly change the estimation results with respect to the coefficient of the interest rate differential and the lagged change in the real exchange rate.

Overall, including a deterministic trend in the cointegrating equation does not much help to explain the data, given the similarity between the results with and without it.

5.2 Adding a constant term

Recall that my estimation results based on the specification (1) over the period 1972Q2-1994Q3, are different from the findings of Lafrance and Van Norden (1995). A constant term is added to the original model as a potential solution to minimize the differences between my coefficient estimates and theirs in all my samples. I name this new model specification (3). Adding a constant to the error correction model would be appropriate if there is a linear deterministic trend in the real exchange rate. Graph 1 shows the nominal and real exchange rates from 1972Q1 to 2017Q1. After observing their fluctuations over time, I believe that there might exist a deterministic trend in both exchange rates and therefore include a constant term, with which is expected to lead to better results. The form of the econometric model is as follows:

$$\Delta lnRex_t = \mu + \alpha(lnRex_{t-1} - \beta_0 - \beta_c lnCom_{t-1} - \beta_e lnEner_{t-1}) + \gamma Intdiff_{t-1} + \phi \Delta lnRex_{t-1} + \varepsilon_t \,. \quad (3)$$

Table 10 demonstrates that the speed of adjustment coefficient for sample A1 is still smaller by a difference of 2.4 percent when the GDP deflator is used; the estimated speed of adjustment is -0.127 in table 10 as compared to -0.089 in specification (1) in table 6. The magnitude of

-0.127 is indeed an improvement. The coefficient also increases in magnitude when the CPI is used as the deflator. Since the error correction term is not affected by the inclusion of a constant (due to the use of a two-step estimation method), the coefficients for the non-energy commodity price and the energy price index remain the same. However, the coefficient of the interest rate differential is affected quite a bit by this adjustment. The new results in sample A1 imply a 41.3 percent appreciation in the real exchange rate as a result of a one percent increase in the interest rate differential using the CPI as the deflator; similarly, an appreciation of 38.1 percent is associated with an increase in the interest rate differential of one percent using the GDP deflator. Furthermore, both coefficients are statistically significant at the one percent level. Compared with the coefficients of the same variable in specification (1), which are 0.077 and 0.098 respectively, the results are greatly improved not only in terms of the smaller differential in the magnitudes of the interest rate differential coefficients between Lafrance and van Norden (1995) and sample A1, but also in that the coefficients turn from being statistically insignificant to being significant.

In sample A2, the speed of adjustment coefficients are barely changed and remain statistically insignificant. Also, the interest differential coefficient of 0.006 for specification (1) changes to -0.006 in specification (3) under the CPI as a deflator and is still statistically insignificant, different from a significant improvement in sample A1. Furthermore, the coefficient of the lagged change in the real exchange rate is not substantially changed by adding a constant term. The estimated constant term itself, the major change introduced in specification (3), shows that, in sample A1, the real exchange rate tends to depreciate as time increases; this is also reflected in graph 1 in that one Canadian dollar can be exchanged for fewer U.S. dollars from 1972 to 1994. When it comes to sample A2, however, there does not exist a distinct trend from 1995 to 2017; the estimated constants are therefore statistically insignificant as expected. Lastly, in sample A1, comparing the explanatory power of specification (1) to that of specification (3), the adjusted R-squared in specification (3) demonstrate that the data fit the model better when a constant term is included. In contrast, the opposite conclusion is found in sample A2.[14]

Table 11 shows the estimation results for specification (3) for five subsamples using the CPI as the deflator. First, the estimated speed of adjustment still shows an increasing trend as the sample period lengthens, with negative signs in five time periods. However, the magnitudes for first three periods are much larger -- -0.124, -0.099, and -0.070 for (i) to (iii) respectively, as compared to -0.089, -0.050, and -0.049 in specification (1). This implies that the ability to adjust to a deviation from long-run equilibrium within one quarter is stronger in specification (3). Second, the coefficients of the real interest rate in columns (i) to (iii) for specification (3) change dramatically; the magnitudes of 0.392, 0.466, and 0.345 are all statistically significant at the one percent level and are much larger than the corresponding values of 0.112, 0.166, and 0.158 obtained for specification (1) in table 6; however, in table 11, the coefficients of the real interest rate in columns (iv) and (v) are still insignificant. This implies that the interest rate differential

[14] Using the CPI as the deflator, the adjusted R-squared in specification (3) equals 0.234 in sample A1 and 0.023 in sample A, as compared to 0.15 in sample A1 and 0.034 in sample A2 when specification (1) is estimated. This finding does not change when the GDP deflator is used. Also, as mentioned before, specifications (1) and (2) yield similar R-squared and adjusted R-squared values.

performs better in capturing the short-run effect in first three subsamples. Third, the magnitudes of the coefficients of the lagged change in the real exchange rate decrease slightly in specification (3); they are all statistically significant at the one percent level and affect the change in the real exchange rate in a positive way.

Next, the constant term plays an essential role in specification (3) in the first three subsamples, as the coefficient estimates are all statistically significant at least at the five percent level; they ascend from -0.008 to -0.005. Additionally, in columns (iv) and (v), the coefficients are statistically insignificant, which implies that when more recent observations are included in the sample, there is less evidence that change in the real exchange rate has an obvious downward tendency. Note that as compared to the values of 0.205, 0.118, and 0.129 obtained for specification (1) for subsamples (i) to (iii) respectively, the corresponding values of R-squared in specification (3) -- 0.282, 0.240, and 0.162 -- are improved as expected.

6. Conclusions

First of all, consistent with Amano and van Norden (1993), my estimation results show that the conclusions are not essentially changed by the choice of deflator. Second, after estimating the Lafrance and van Norden (1995) equation using two mutually exclusive sample periods -- before and after 1994Q3[15] -- poorer performance is obvious when the up-to-date data are considered. This implies that this equation lacks the ability to explain recent fluctuations in the real exchange

[15] In order to replicate the study of Lafrance and van Norden (1995), the same sample period (1972Q2 – 1994Q3) was used; the second sample period is from 1994Q4 to 2017Q1.

rate, corresponding to the reality that led to many new models being constructed. Third, the model is re-estimated for five subsamples of my complete sample period (1972Q1 to 2017Q1), all of which start in 1972Q1 but differ in length. The estimation results demonstrate that the Canadian dollar, as always, is a commodity currency, which means that the non-energy commodity terms of trade place upward pressure on the value of the Canadian dollar. For the whole sample period, a one percent increase in the non-energy commodity price index causes the Canadian dollar to significantly appreciate by 0.288 percent. Also, the impact of the energy commodity terms of trade shifts from depreciation to appreciation as expected. Specifically, for the whole sample period, a one percent increase in the energy price index would lead to a 0.074 percent rise in the value of the Canadian dollar, an effect that is statistically significant at the one percent level.

In addition, I consider two variables that capture the short-run effect. In all subsamples the coefficient of the lagged real exchange rate is always statistically significant, and with an estimated value that ranges from 0.283 to 0.352. Unfortunately, the interest rate differential, in general, plays a statistically insignificant role in explaining movements in the value of the Canadian dollar, which is inconsistent with the results of Lafrance and van Norden (1995), even when the same sample period is used.

Therefore, in an attempt to improve my estimation results, two modifications of the original model were considered: adding a deterministic trend to the cointegrating equation and adding a constant term to the error correction model. In the main, adding a trend variable does not trigger a huge difference in the estimation results; also, the coefficients of the trend variable in different sample periods are very close to zero, but most of them are statistically significant. However, once a constant term is included instead, the estimation results are very close to those of Lafrance and van Norden (1995) for their sample period. In particular, a one percentage point increase in the interest rate differential would significantly appreciate the Canadian dollar by 38.1 percent,[16] compared to 53.3 percent in the study of Lafrance and van Norden (1995). However, for the latest period (1994Q4 - 2017Q1) and the whole sample period (1972Q1 - 2017Q1), the corresponding coefficient of the interest rate differential is no longer significant.

To conclude, this paper answers the question of how the first difference of the real exchange rate reacts to changes in the non-energy commodity price index, the energy price index, and the interest rate differential during the latest time period up to 2017Q1. However, a potential limitation of my study is that the estimated results are not exactly the same as those of Lafrance and van Norden (1995), even using the same sample period (1972Q2 - 1994Q3), and equation. In particular, the coefficient of the interest rate differential is not statistically significant. As discussed in the literature, different model specifications, econometric techniques, and even data formats can produce different results. Since the analysis and forecasting of the exchange rate are enormous issues in macroeconomics, its dynamic behaviour and uncertainty will always need to be reconsidered as time goes by. Moreover, the current cointegrating relationship among the real exchange rate and commodity terms of trade becomes much weaker than before. This unstable relationship seriously affects the ECM's viability and effectiveness; therefore, based on more

[16] The coefficient is 0.381 when the GDP deflator is used. When the CPI deflator is chosen, the estimated value is 0.413. Both coefficients are statistically significant at the 1 percent level.

cointegration analysis, modifying this long-run relationship could be a further research topic as well.

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Table 1.

Amano and van Norden (AvN) equation estimation results
(Sample: 1973M1 to 1992M2)

Variable	*Coefficient*	*Standard error*
Constant – (β_0)	0.552	0.097
Adjustment – (α)	-0.038	0.011
TOTCOMOD – (β_c)	-0.811	0.296
TOTENRGY – (β_e)	0.223	0.060
RDIFF – (γ)	-0.187	0.043
R-squared	0.123	

Lafrance and van Norden’s equation estimation results
(Sample: 1972Q2 to 1994Q3)

Variable	*Coefficient*	*Standard error*
Constant – (ξ_0)	-0.030	0.070
Adjustment – (α)	-0.151	0.031
COM – (ξ_1)	0.474	0.075
ENE – (ξ_2)	-0.080	0.023
INT– (ϕ_2)	0.533	0.112
ΔRFX – (ϕ_1)	0.328	0.091
R-squared	0.351	

Notes: In the AvN equation, the real exchange rate is defined as CAD/USD. In contract, the real exchange rate in Lafrance and van Norden’s Equation refers to USD/CAD.

Table 2. Summary statistics (1972Q1 to 2017Q1)

Explanatory Variable	*Means*
Exchange rate [a]	
Nominal	0.834(0.113)
Real	0.885 (0.106)
Consumer price index [b]	
Canada	81.090(31.898)
U.S.	146.004(60.521)
3-month Commercial Paper rates [c]	
Canada	6.387(4.313)
U.S.	5.309(3.802)
Differentials	1.078(1.469)
Nominal commodities price index [d]	
Non-energy Commodities	244.506 (75.732)
Energy Commodities	740.415 (497.718)
Observations	181

Notes: Standard deviations are in parentheses.

a. The exchange rate represents the amount of U.S. dollars required to buy a unit of Canadian dollar.

b. The base year of Canadian and the U.S. CPI is 1982-84 and 2002 (=100) separately.

c. The unit of interest rate is percentage.

d. The base year of commodity price index is 1972 (=100).

Table 3. Tests for unit roots

	Sample A1 1972Q2 to 1994Q3 (Obs: 90)					Sample A2 1994Q4 to 2017Q1 (Obs: 90)				
Variable	*ADF* [a,b]	*ADF Lag*	*PP* [a]	*KPSS* [c]	*Model with*	*ADF* [a,b]	*ADF Lag*	*PP* [a]	*KPSS* [c]	*Model with*
At Level										
lnRex	-1.951 [0.619]	4	-1.614 [0.780]	0.181[ii]	*I & T* [d]	-1.225 [0.899]	2	-1.123 [0.919]	0.152[ii]	*I & T*
lnCom	-2.604 [0.280]	0	-3.083 [0.117]	0.198[ii]	*I & T*	-1.648 [0.766]	2	-1.729 [0.730]	0.137[iii]	*I & T*
lnEner	-1.964 [0.613]	2	-1.734 [0.728]	0.264[i]	*I & T*	-1.038 [0.933]	5	-1.797 [0.698]	0.244[i]	*I & T*
Intdiff	-2.669 [0.252]	2	-3.496 [0.046]	0.052	*I & T*	-2.544 [0.011]	7	-2.610 [0.009]	0.338	*NONE* [d]
First Difference										
lnRex	-3.011 [0.038]	2	-6.712 [0.000]	0.112	*I* [d]	-2.066 [0.259]	11	-7.293 [0.000]	0.236	*I*
lnCom	-2.986 [0.040]	3	-7.537[0.000]	0.096	*I*	-3.928 [0.003]	3	-7.044 [0.000]	0.103	*I*
lnEner	-2.120 [0.237]	6	-7.556 [0.000]	0.094	*I*	-7.269 [0.000]	0	-7.034 [0.000]	0.115	*I*

a. For ADF and PP the p-values are provided in square brackets.

b. The lag length of ADF test is automatically selected by the modified AIC.

c. [i] Reject stationarity at 1%. [ii] Reject stationarity at 5%. [iii] Reject stationarity at 10%.

d. *I & T* means the testing model includes the intercept and trend; *NONE* means the testing model excludes the intercept and trend; .*I* means the testing model includes the intercept only

Table 4. Tests for unit roots (***whole sample:*** 1972Q1 to 2017Q1) (Obs: 181)

Variable	*ADF* [a,b]	*ADF Lag Length*	*PP* [a]	*KPSS* [c]	*Model with*
			At Level		
lnRex	-2.03 [0.582]	1	-1.871 [0.665]	0.181[ii]	*Intercept & Trend*
lnCom	-2.394 [0.381]	6	-2.254 [0.456]	0.299[i]	*Intercept & Trend*
lnEner	-2.048 [0.571]	5	-2.088 [0.548]	0.179[ii]	*Intercept & Trend*
Intdiff	-2.491 [0.119]	7	-3.386 [0.013]	0.379[iii]	*Intercept*
i_Canada	-3.830 [0.017]	2	-3.497 [0.043]	0.162[ii]	*Intercept*
i_US	-3.256 [0.077]	2	-3.698 [0.025]	0.113	*Intercept*
			First Difference		
lnRex	-3.611 [0.007]	7	-10.121 [0.000]	0.079	*Intercept*
lnCom	-5.009 [0.000]	3	-10.279 [0.000]	0.054	*Intercept*
lnEner	-10.431 [0.000]	0	-10.324 [0.000]	0.104	*Intercept*

a. For ADF and PP the p-values are provided in square brackets.

b. The lag length of ADF test is automatically selected by the modified AIC.

c. [i] Reject stationarity at 1%. [ii] Reject stationarity at 5%. [iii] Reject stationarity at 10%.

Table 5. Tests for cointegration

Hansen Cointegration Test [a]			
Sample Period	*Lag selection by*	*Lc Statistic*	*Prob.*
Sample A1	AIC [b]	0.1930	>0.2
1972Q2-1994Q3	BIC	0.1047	>0.2
Sample A2	AIC	0.4866	0.0481
1994Q4-2017Q1	BIC	0.4866	0.0481
Whole sample	AIC	0.4195	0.0734
1972Q1-2017Q1	BIC	0.1587	>0.2

a. The null hypothesis of Hansen cointegration test is that series are cointegrated.

b. In E-views, there is no option to choose the modified AIC or BIC for this test.

Table 6. Estimation results, specification (1)

Variable	***Sample A1*** *1972Q2-1994Q3*			***Sample A2*** *1994Q4 – 2017Q1*	
	Lafrance and van Norden	*Specification (1)* [a]		*Specification (1)* [a]	
		CPI	*GDP*	*CPI*	*GDP*
Adjustment – (α)	-0.151*** (0.031)	-0.072** (0.031)	-0.089*** (0.030)	0.0141 (0.083)	0.039 (0.080)
lnCom – (β_c)	0.474*** (0.075)	0.186*** (0.026)	0.124*** (0.033)	0.510*** (0.038)	0.569*** (0.044)
lnEner – (β_e)	-0.080*** (0.023)	-0.087*** (0.017)	-0.040** (0.018)	0.165*** (0.012)	0.202*** (0.014)
Intdiff – (γ)	0.533*** (0.112)	0.077 (0.076)	0.098 (0.078)	-0.006 (0.363)	-0.077 (0.399)
$\Delta lnRex_{-1}$ – (ϕ)	0.328*** (0.091)	0.400*** (0.098)	0.454*** (0.093)	0.233** (0.108)	0.318*** (0.103)
Constant – (β_0)	-0.030 (0.070)	-0.458*** (0.136)	-0.320* (0.180)	-3.156*** (0.138)	-3.558*** (0.161)
R-squared	0.351	0.170	0.264	0.056	0.107
Adj. R-squared	…	0.150	0.247	0.034	0.086
Durbin-Watson	1.99	2.090	2.042	1.936	1.900
Obs.	90			90	

Notes: Standard deviations are in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level (All tests are two-tailed).

a. Specification (1): $\Delta lnRex_t = \alpha(lnRex_{t-1} - \beta_0 - \beta_c\, lnCom_{t-1} - \beta_e\, lnEner_{t-1}) + \gamma\, Intdiff_{t-1} + \phi\, \Delta lnRex_{t-1} + \varepsilon_t$. The real exchange rate is defined as how many U.S. dollars can be exchanged for one Canadian dollar.

Table 7. Results from estimating specification (1) for different subsamples [a]

Variable	*(i)* 1972Q1-1992Q1	*(ii)* 1972Q1-1998Q1	*(iii)* 1972Q1-2006Q1	*(iv)* 1972Q1-2010Q1	*(v)* 1972Q1-2017Q1
Adjustment – (α)	-0.089*** (0.031)	-0.050* (0.025)	-0.049** (0.023)	-0.044* (0.025)	-0.040* (0.024)
lnCom – (β_c)	0.160*** (0.027)	0.245*** (0.029)	0.328*** (0.023)	0.299*** (0.024)	0.288*** (0.023)
lnEner – (β_e)	-0.105*** (0.017)	-0.039** (0.019)	-0.005 (0.018)	0.039** (0.017)	0.074*** (0.015)
Intdiff – (γ)	0.112 (0.074)	0.116 (0.079)	0.158* (0.089)	0.106 (0.105)	0.062 （0.109）
$\Delta lnRex_{-1}$ – (ϕ)	0.338*** (0.107)	0.348*** (0.093)	0.326*** (0.082)	0.352*** (0.078)	0.283*** (0.073)
Constant – (β_0)	-0.238 (0.154)	-0.989*** (0.141)	-1.549*** (0.121)	-1.635*** (0.125)	-1.759*** (0.119)
R-squared	0.205	0.118	0.129	0.127	0.082
Adj. R-squared	0.184	0.101	0.116	0.116	0.072
Durbin-Watson	1.938	2.052	1.964	1.902	1.961
Obs.	81	105	137	153	181

Notes: Standard deviations are in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level (All tests are two-tailed). CPI is used as price deflator.

a. Specification (1): $\Delta lnRex_t = \alpha(lnRex_{t-1} - \beta_0 - \beta_c\, lnCom_{t-1} - \beta_e\, lnEner_{t-1}) + \gamma\, Intdiff_{t-1} + \phi\, \Delta lnRex_{t-1} + \varepsilon_t$. The real exchange rate is defined as how many U.S. dollars can be exchanged for one Canadian dollar.

Table 8. Estimation results, specification (2)

Variable	***Sample A1*** *1972Q2-1994Q3*			***Sample A2*** *1994Q4 – 2017Q1*	
	Lafrance and van Norden	*Specification (2)* [a]		*Specification (2)* [a]	
		CPI	*GDP*	*CPI*	*GDP*
Adjustment – (α)	-0.151*** (0.031)	-0.073** (0.031)	-0.099*** (0.031)	0.014 (0.083)	0.056 (0.114)
lnCom – (β_c)	0.474*** (0.075)	0.180*** (0.062)	0.282*** (0.062)	0.542*** (0.032)	0.589*** (0.032)
lnEner – (β_e)	-0.080*** (0.023)	-0.087*** (0.018)	-0.035** (0.017)	0.119*** (0.012)	0.142*** (0.012)
Intdiff – (γ)	0.533*** (0.112)	0.077 (0.076)	0.098 (0.077)	-0.006 (0.363)	-0.046 (0.388)
$\Delta lnrex_{-1}$ – (ϕ)	0.328*** (0.091)	0.400*** (0.098)	0.449*** (0.092)	0.233** (0.108)	0.305*** (0.109)
Constant – (β_0)	-0.030 (0.070)	-0.424 (0.334)	-1.139*** (0.326)	-3.209*** (0.115)	-3.540*** (0.118)
Trend – (θ)	…	-0.686E-06 (0.0006)	0.001*** (0.0005)	0.001*** (0.0002)	0.002*** (0.0002)
R-squared	0.351	0.170	0.272	0.056	0.107
Adj. R-squared	…	0.150	0.255	0.034	0.086
Durbin-Watson	1.99	2.089	2.053	1.936	1.900
Obs.	90			90	

Notes: Standard deviations are in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level (All tests are two-tailed).

a. Specification (2): $\Delta lnRex_t = \alpha\ (lnRex_{t-1} - \beta_0 - \theta t - \beta_c\ lnCom_{t-1} - \beta_e\ lnEner_{t-1}) + \gamma\ Intdiff_{t-1} + \phi\ \Delta lnRex_{t-1} + \varepsilon_t$. The real exchange rate is defined as how many U.S. dollars can be exchanged for one Canadian dollar.

Table 9. Results from estimating specification (2) for different subsamples [a]

Variable	*(i)*	*(ii)*	*(iii)*	*(iv)*	*(v)*
	1972Q1-1992Q1	*1972Q1-1998Q1*	*1972Q1-2006Q1*	*1972Q1-2010Q1*	*1972Q1-2017Q1*
Adjustment – (α)	-0.092***	-0.060**	-0.046*	-0.052*	-0.042
	(0.031)	(0.027)	(0.023)	(0.027)	(0.027)
lnCom – (β_c)	0.223***	0.036	0.257***	0.418***	0.446***
	(0.056)	(0.060)	(0.058)	(0.047)	(0.037)
lnEner – (β_e)	-0.104***	-0.064***	-0.005	0.022	0.038**
	(0.017)	(0.019)	(0.018)	(0.017)	(0.016)
Intdiff – (γ)	0.109	0.122	0.148*	0.132	0.083
	(0.073)	(0.078)	(0.088)	(0.108)	（0.114）
$\Delta lnrex_{-1}$ – (ϕ)	0.333***	0.351***	0.327***	0.352***	0.287***
	(0.107)	(0.093)	(0.082)	(0.078)	(0.073)
Constant – (β_0)	-0.560*	0.177	-1.193***	-2.128***	-2.347***
	(0.293)	(0.327)	(0.288)	(0.209)	(0.155)
Trend – (θ)	0.0007	-0.002***	-0.0006	0.0009***	0.001***
	(0.0006)	(0.0005)	(0.0004)	(0.0003)	(0.0002)
R-squared	0.209	0.127	0.126	0.132	0.080
Adj. R-squared	0.189	0.110	0.113	0.120	0.070
Durbin-Watson	1.943	2.045	1.966	1.900	1.958
Obs.	81	105	137	153	181

Notes: Standard deviations are in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level (All tests are two-tailed). CPI is used as price deflator.

a. Specification (2): $\Delta lnRex_t = \alpha\ (lnRex_{t-1} - \beta_0 - \theta t - \beta_c\ lnCom_{t-1} - \beta_e\ lnEner_{t-1}) + \gamma\ Intdiff_{t-1} + \phi\ \Delta lnRex_{t-1} + \varepsilon_t$. The real exchange rate is defined as how many U.S. dollars can be exchanged for one Canadian dollar.

Table 10. Estimation results, specification (3)

Variable	***Sample A1*** *1972Q2-1994Q3*			***Sample A2*** *1994Q4 – 2017Q1*	
	Lafrance and van Norden	*Specification (3)* [a]		*Specification (3)* [a]	
		CPI	*GDP*	*CPI*	*GDP*
Adjustment – (α)	-0.151*** (0.031)	-0.112*** (0.032)	-0.127*** (0.033)	0.0135 (0.084)	0.040 (0.081)
lnCom – (β_c)	0.474*** (0.075)	0.186*** (0.026)	0.124*** (0.033)	0.510*** (0.038)	0.569*** (0.044)
lnEner – (β_e)	-0.080*** (0.023)	-0.087*** (0.017)	-0.040** (0.018)	0.165*** (0.012)	0.202*** (0.014)
Intdiff – (γ)	0.533*** (0.112)	0.413*** (0.127)	0.381*** (0.139)	0.006 (0.383)	-0.100 (0.422)
$\Delta lnRex_{-1}$ – (ϕ)	0.328*** (0.091)	0.351*** (0.094)	0.451*** (0.090)	0.233** (0.108)	0.317*** (0.103)
Constant – (β_0)	-0.030 (0.070)	-0.458*** (0.136)	-0.320* (0.180)	-3.156*** (0.138)	-3.558*** (0.161)
Constant – (μ)	…	-0.009*** (0.003)	-0.007** (0.003)	-0.0004 (0.004)	0.001 (0.004)
R-squared	0.351	0.260	0.311	0.056	0.107
Adj. R-squared	…	0.234	0.287	0.023	0.076
Durbin-Watson	1.99	2.007	1.987	1.936	1.901
Obs.		90		90	

Notes: Standard deviations are in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level (All tests are two-tailed).

a. Specification (3): $\Delta lnRex_t = \mu + \alpha\ (lnRex_{t-1} - \beta_0 - \beta_c\ lnCom_{t-1} - \beta_e\ lnEner_{t-1}) + \gamma\ Intdiff_{t-1} + \phi\ \Delta lnRex_{t-1} + \varepsilon_t$. The real exchange rate is defined as how many U.S. dollars can be exchanged for one Canadian dollar.

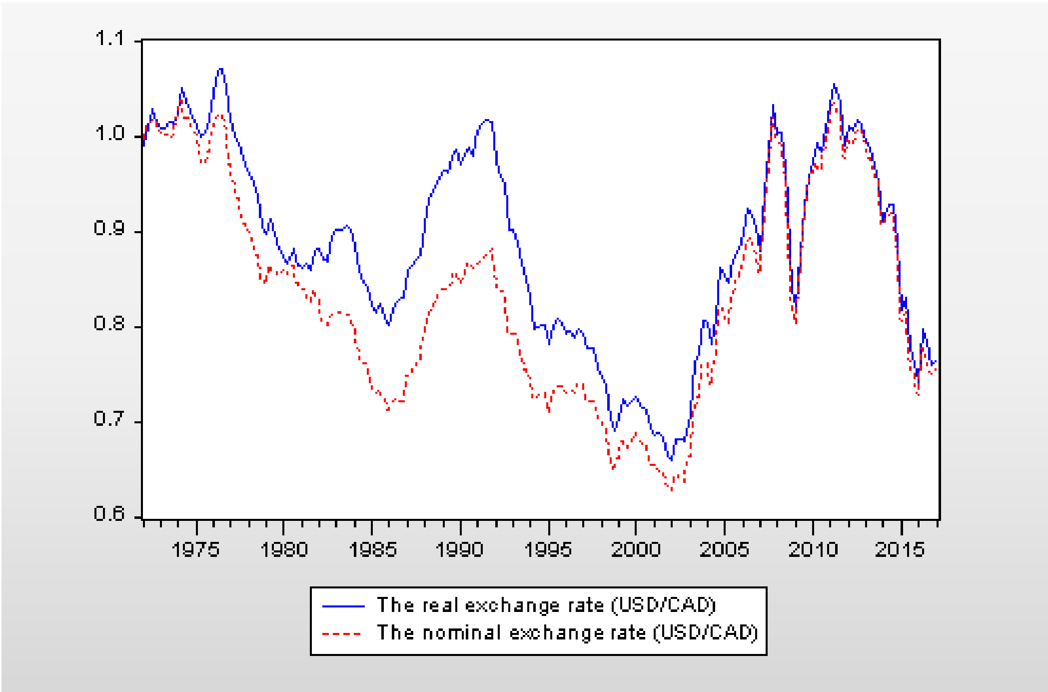
Table 11. Results from estimating specification (3) for different subsamples [a]

Variable	*(i)*	*(ii)*	*(iii)*	*(iv)*	*(v)*
	1972Q1-1992Q1	*1972Q1-1998Q1*	*1972Q1-2006Q1*	*1972Q1-2010Q1*	*1972Q1-2017Q1*
Adjustment – (α)	-0.124*** (0.032)	-0.099*** (0.027)	-0.070*** (0.025)	-0.050* (0.026)	-0.045* (0.024)
lnCom – (β_c)	0.160*** (0.027)	0.245*** (0.029)	0.328*** (0.023)	0.299*** (0.024)	0.288*** (0.023)
lnEner – (β_e)	-0.105*** (0.017)	-0.039** (0.019)	-0.005 (0.018)	0.039** (0.017)	0.074*** (0.015)
Intdiff – (γ)	0.392*** (0.121)	0.466*** (0.115)	0.345*** (0.121)	0.181 (0.134)	0.162 （0.138）
$\Delta lnRex_{-1}$ – (ϕ)	0.284*** (0.104)	0.288*** (0.088)	0.314*** (0.081)	0.354*** (0.078)	0.280*** (0.073)
Constant – (β_0)	-0.238 (0.154)	-0.989*** (0.141)	-1.549*** (0.121)	-1.635*** (0.125)	-1.759*** (0.119)
Constant – (μ)	-0.008*** (0.003)	-0.009*** (0.002)	-0.005** (0.002)	-0.002 (0.002)	-0.003 (0.002)
R-squared	0.282	0.240	0.162	0.132	0.090
Adj. R-squared	0.253	0.216	0.142	0.115	0.074
Durbin-Watson	1.904	1.962	1.936	1.895	1.953
Obs.	81	105	137	153	181

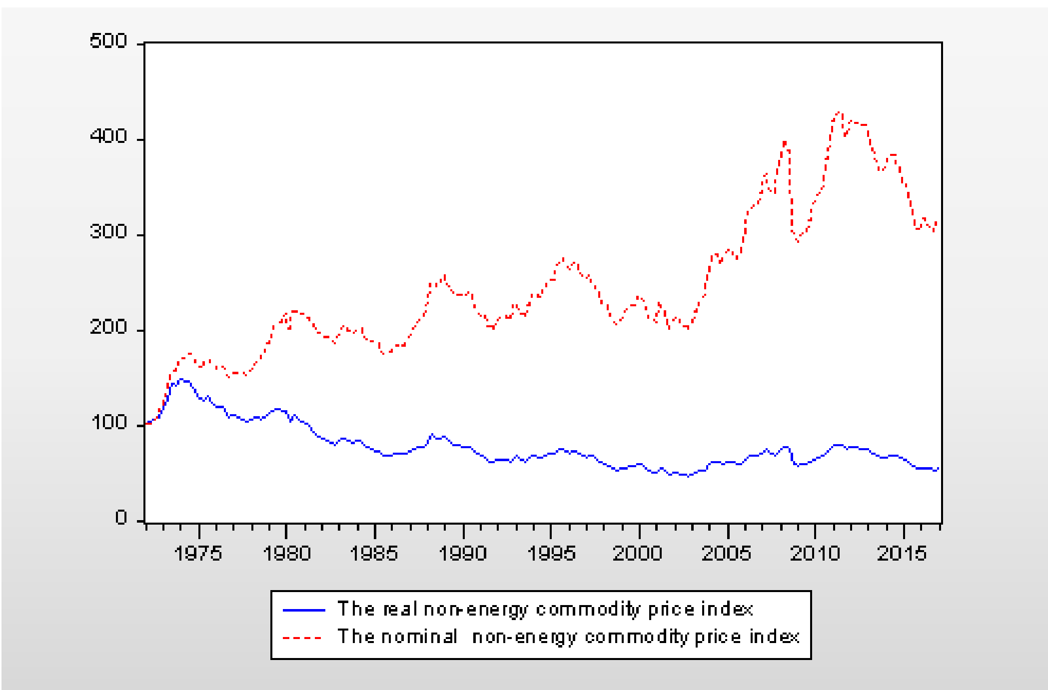
Notes: Standard deviations are in parentheses. * significant at 10% level, ** significant at 5% level, *** significant at 1% level (All tests are two-tailed). CPI is used as price deflator.

a. Specification (3): $\Delta lnRex_t = \mu + \alpha\ (lnRex_{t-1} - \beta_0 - \beta_c\ lnCom_{t-1} - \beta_e\ lnEner_{t-1}) + \gamma\ Intdiff_{t-1} + \phi\ \Delta lnRex_{t-1} + \varepsilon_t$. The real exchange rate is defined as how many U.S. dollars can be exchanged for one Canadian dollar.

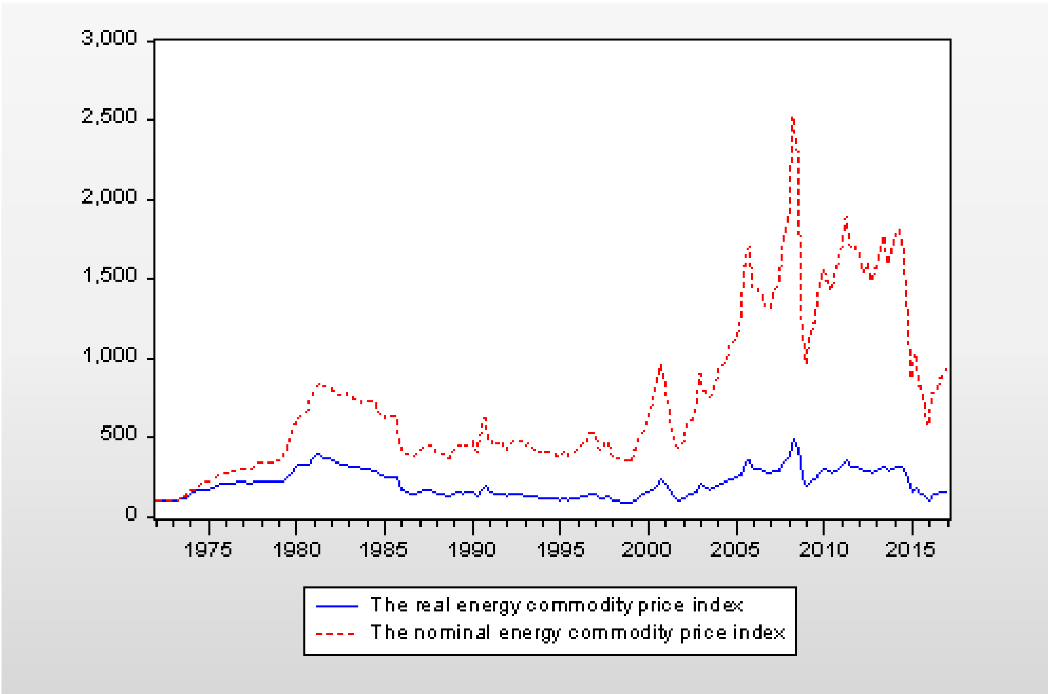
Graph 1.



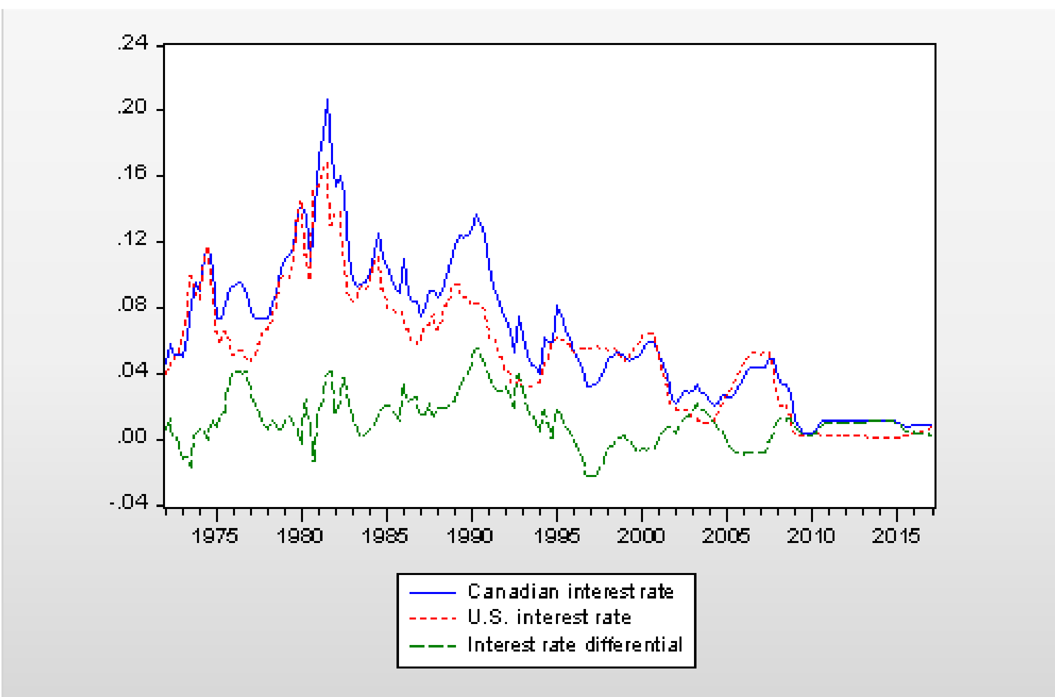
Graph 2.



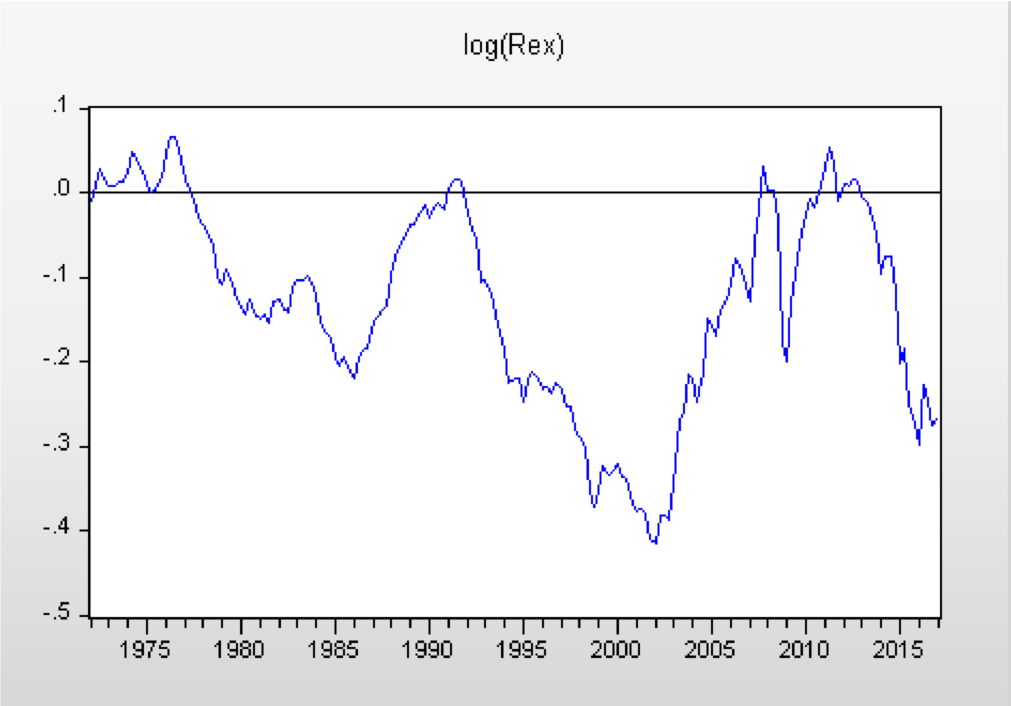
Graph 3.



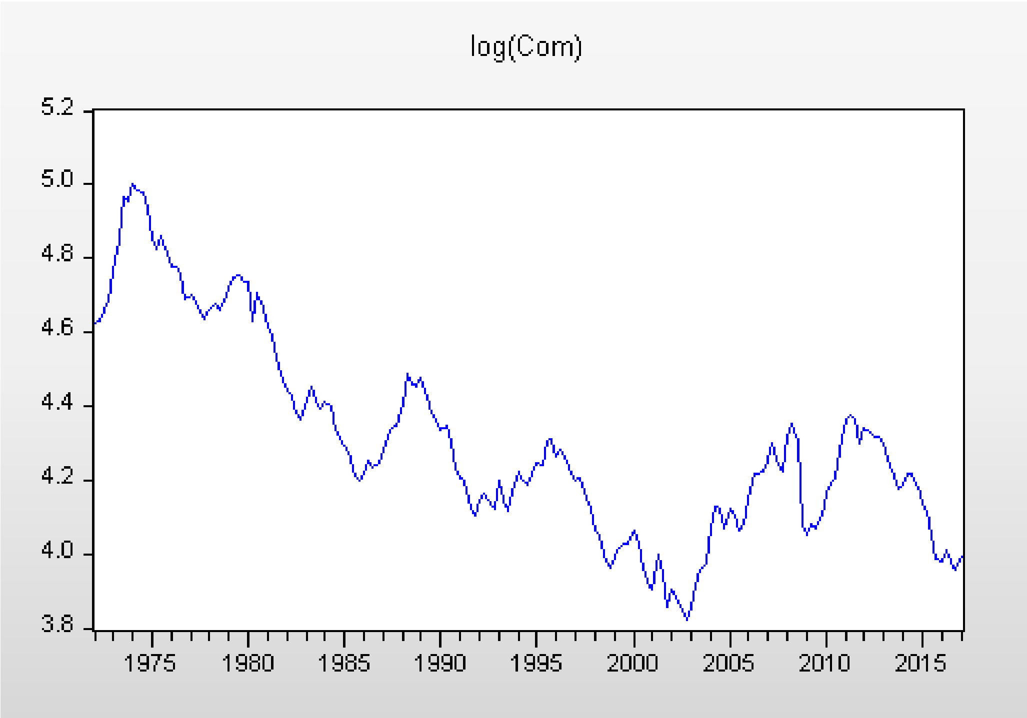
Graph 4.



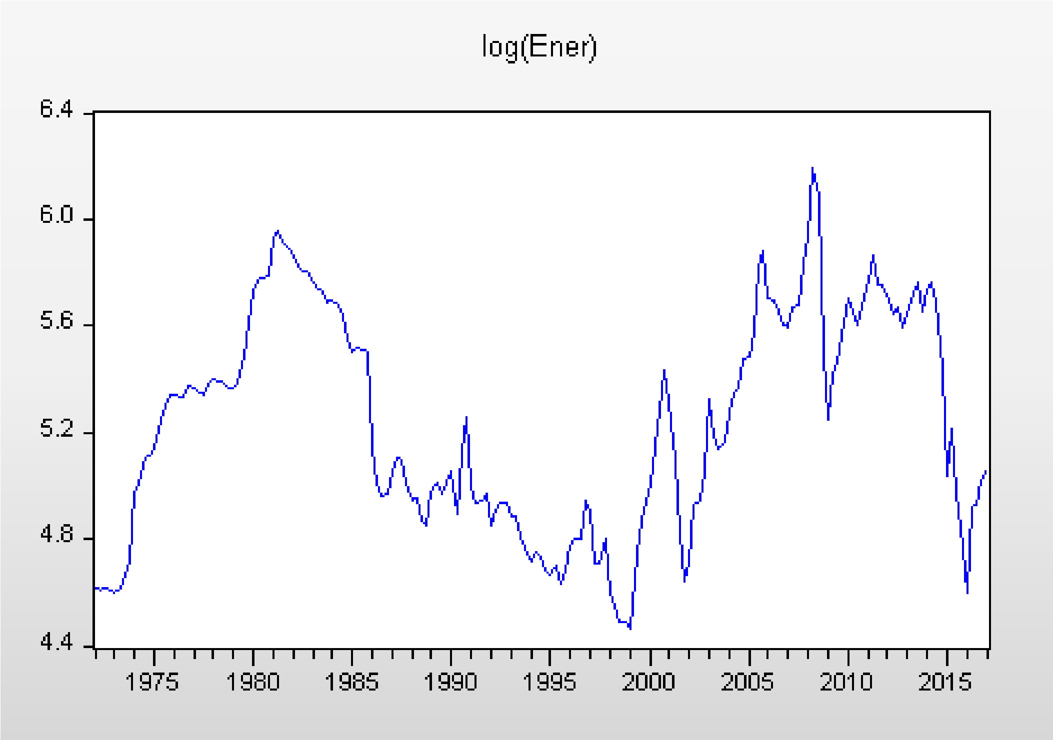
Graph 5.



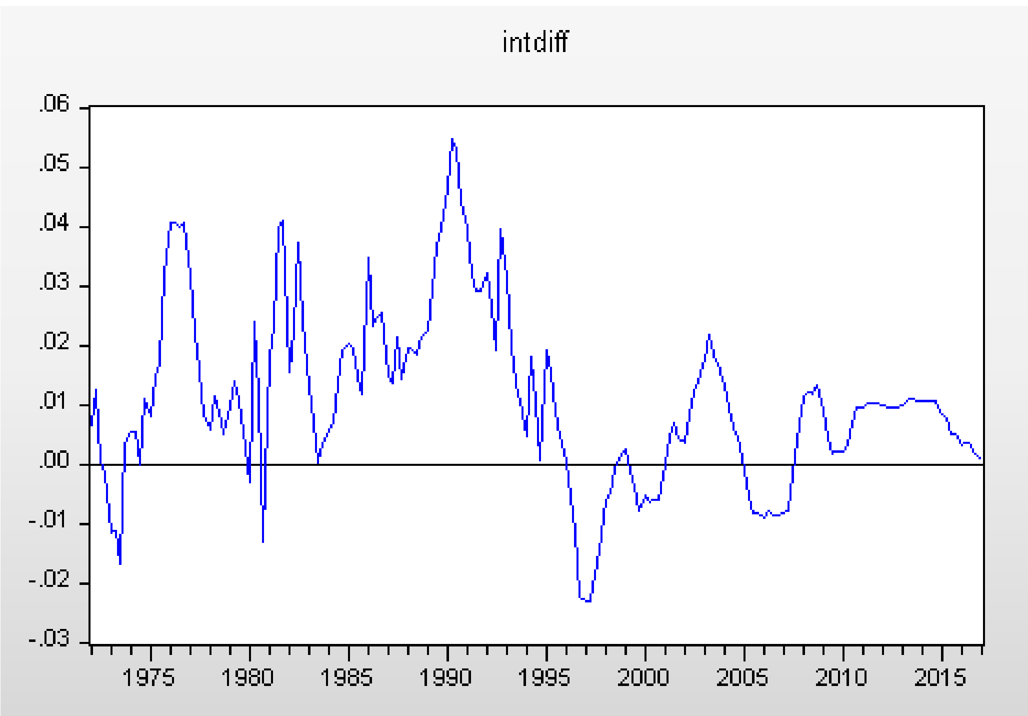
Graph 6.



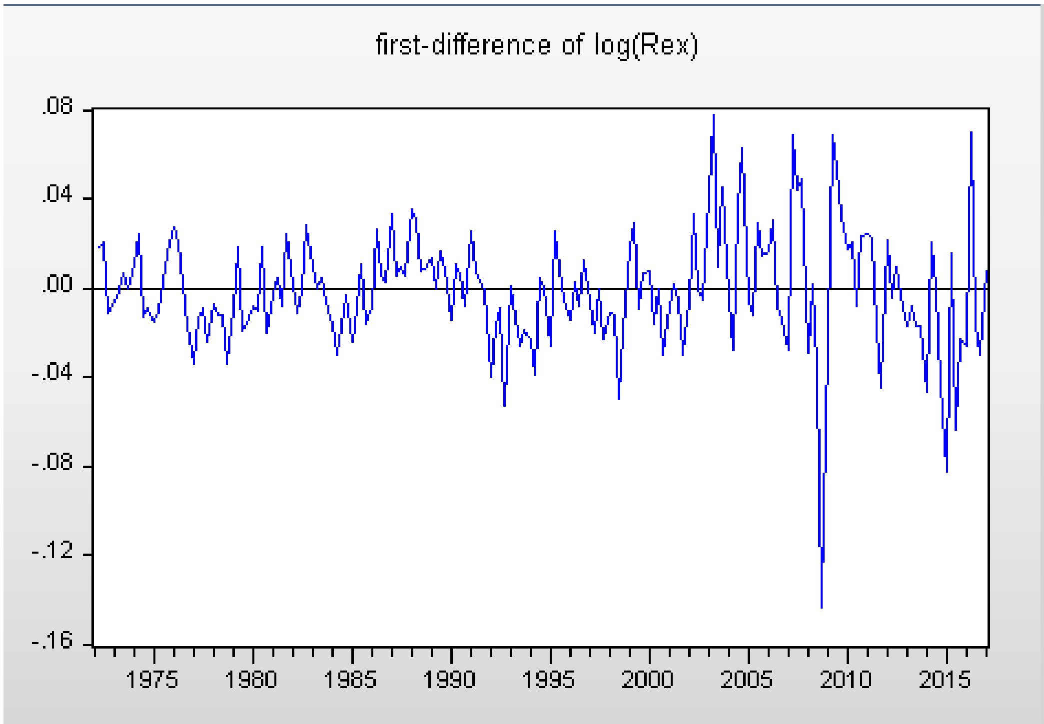
Graph 7.



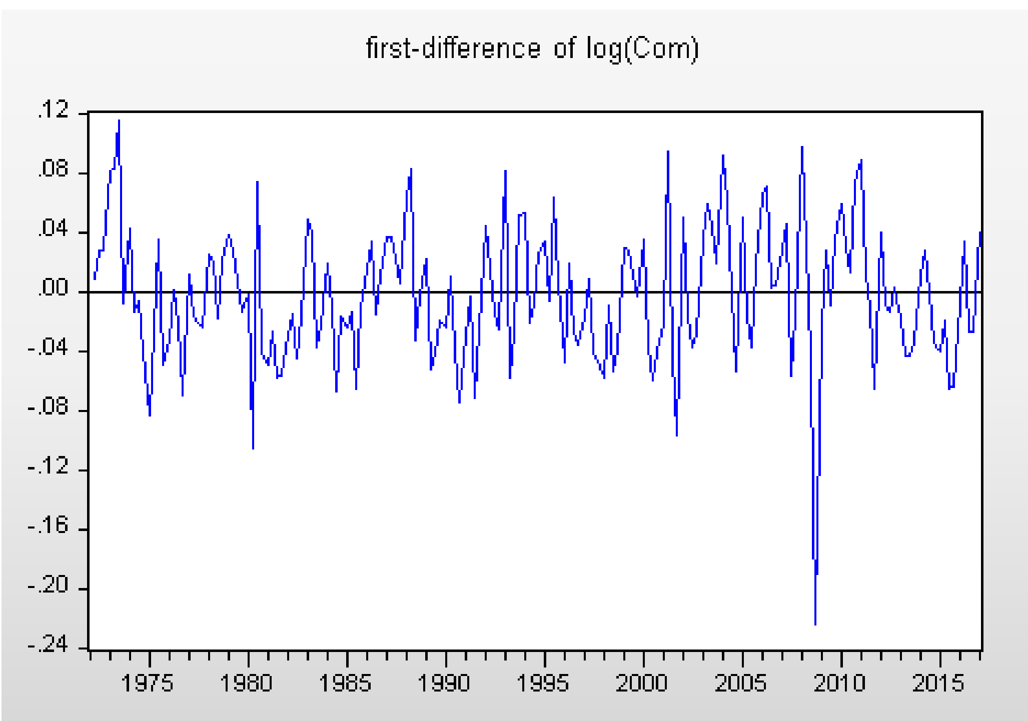
Graph 8.



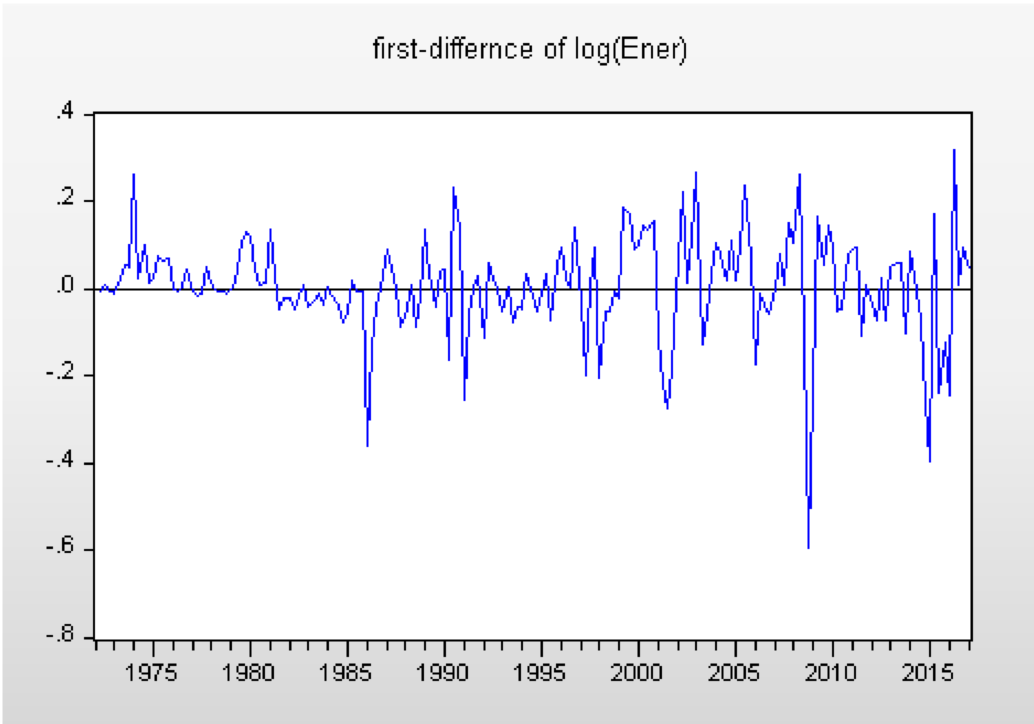
Graph 9.



Graph 10.



Graph 11.


first-differnce of log(Ener)
.4
.2
.0
-.2
-.4
-.6
-.8
1975
1980
1985
1990
1995
2000
2005
2010
2015