

Commodity-Sensitive Canadian Dollar and  
Exchange Rate dynamics

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## CONTENTS

ABSTRACT.....	III
1 INTRODUCTION.....	1
2 RELATIVE THEORIES.....	3
2.1 Purchasing Power Parity.....	3
2.1.1 Absolute PPP.....	3
2.1.2 Relative PPP.....	4
2.1.3 Productivity.....	6
2.1.4 Terms of Trade.....	9
2.2 Monetary Models.....	10
2.2.1 Interest Rate Parity.....	10
2.2.2 The Flexible Price Monetary Model.....	12
2.2.3 The Sticky Price Monetary Model.....	14
3 MODEL AND DATA DESCRIPTION.....	15
4 UNITROOT AND COINTEGRATION RESULTS.....	23
4.1 The Econometric Rationale.....	23
4.2 Unit Root Test.....	24
4.3 Cointegration.....	27
4.3.1 Engle-Granger Test.....	27
4.3.2 Johansen Test.....	30
4.4 The Error Correction Model.....	32

5. CONCLUSION .....38

APPENDIX.....40

REFERENCES.....46

## **Abstract**

In this paper, I reviewed the relevant literature of the exchange rate determination and examined the long-run and short-run movements of the Canada-U.S exchange rate, using monthly data from 1994-2001. With the help of cointegration tests, I found significance evidence to prove the fact that the real non-energy commodity price and the purchasing power parity condition together can explain most movements of the Canada-U.S exchange rate in the long run. Thereafter, an error correction model was specified to link the long-term equilibrium with the short-term dynamics. In my paper, I used the interest rate spread differential between Canada and the United States to capture the short-term movement of the exchange rate. Since this model was based on the Canadian economic situation and the special trade relationship between Canada and the United States, it is unlikely to be generalized to other countries.

## 1. INTRODUCTION

The exchange rate is the most difficult macroeconomic variable to model in the post-Bretton Wood era. Historically, there are two lines of research on exchange rate fluctuations.

The first line links economic fundamentals and exchange rate movements. The view of this school is that financial markets determine the exchange rate in the short run, whereas in the long run the goods market plays a role as well. According to the purchasing-power-parity hypothesis, the real exchange rate should be expected to be mean reverting, but such reversion is over such long periods of time that we would expect gradual shifts in industrial structure, relative productivity and other factors to alter real equilibrium exchange rates. Hence, many economists tried to concentrate on the significant relationships between real exchange rates and fundamentals, and identified the relative importance of shocks in explaining real exchange rate volatility (MacDonald 1999). They found, in empirical research, that supply-factors are the key determinants of real exchange rates.

The second line of research is that of Meese and Rogoff(1983), who have shown that, for many time horizons, the random walk model is better than the structural model to forecast exchange rates. This branch has been extended by the microstructure approach which emphasizes institutional aspects and actual behavior of market participants. It examines aspects like volume of transactions, heterogeneity of traders, the bid-ask spread, and asymmetric information (Frankel 1996; Kirman 1995).

Recently, using a variety of statistical techniques and much broader data samples, researchers have begun to reject the real exchange rate random-walk hypothesis (Diebold et. al 1991; Lothian and Taylor 1996) and the consensus is that PPP is an anchor of the exchange rate in the long run (Rogoff 1996). Real shocks, tastes and technology, determine the long run movement of the real exchange rate.

In Canada, most economists believe that a few macroeconomic factors can explain most of the fluctuations of the exchange rate. The chief economist at the Royal Bank, Craig Wright (2002) notes:

While it is almost futile to attempt to guess where a currency is heading over a short-term horizon, there is some hope for forecasters over longer periods. Here, economic fundamentals do matter. For the Canadian dollar, a number of variables explain much of the movement in our currency. The key ones to watch are non-energy commodity prices, Canadian inflation compared to U.S. inflation, and the government's debt load compared to our major trading partners, particularly the United States

In this paper we explore the long run relationship of the bilateral Canada-U.S exchange rate fluctuation with two fundamental variables: the Canada-U.S. inflation differential and the relevant price of non-energy commodities, by a simple error-correction model. In addition, short-run dynamics are captured by changes of the Canada-U.S. interest rate differential. It is derived from a model which was first developed in the early 1990's, by two Bank of Canada economists, Amano and Norden (1993 a), except I find that the energy term of trade is rarely correlated with the exchange rate in the long run.

This model can not explain all of the movements of the exchange rate, however. The expectations of agents also affect the swings of the real exchange rate. The agents construct their expectations not only based on the interest rate differential and productivity, but also by checking the fiscal policy, political uncertainty, the intervention of the government and investor sentiments.

The second section of the paper reviews several related models of the exchange rate determination. In the third section, I introduce the exchange rate determination model which is used throughout the experiments, and I explain the data. The actual empirical study of the unit root test and cointegration test, as well as the error correction model, are described in the fourth section. The final section offers conclusions.

## 2. RELATIVE THEORIES

An exchange rate is the price of one currency measured by another currency. It is more volatile than any other economic factor and is notoriously difficult to forecast. There are many theories about the determination of the exchange rate, but none of them are satisfying. The core theories of the exchange rate are the purchasing power parity (in the goods market) and uncovered interest rate parity (in the money market).

### 2.1 Purchasing Power Parity (PPP)

#### 2.1.1 Absolute PPP

The purchasing power parity exchange rate model was put forth by Cassel in 1918. This theory suggests that the exchange rate between currencies of two countries should equilibrate the price levels of these two countries (Rogoff 1996).

The law of one price is the fundamental building block of the PPP condition. This law implies that in the absence of transaction costs and trade barriers, competitive arbitrage should force identical products to sell for the same price everywhere when the prices are measured in the same currency. That is, for any product  $i$ , the absolute PPP implies that

$$P_i^* = SP_i \quad (2.1.1)$$

Where  $P_i$  is the domestic-currency price of product  $i$ ,  $P_i^*$  is the foreign currency price and  $S$  is the nominal exchange rate, defined as the foreign currency price of the domestic currency. If it holds for every good, it must also apply to the whole price level in different countries. Let  $P = \sum \alpha P_i$  and  $P^* = \sum \alpha P_i^*$ , which  $\alpha$  is the weight of different goods in the national price levels. Hence, we can write equation (2.1.1) as:

$$P^* = SP \quad (2.1.2)$$

This means the nominal exchange rate will adjust to equalize the price levels of the different countries. If one country's price level rises relative to another's, its currency should depreciate and the other country's currency should appreciate.

### 2.1.2 Relative PPP

The weaker vision of PPP is relative PPP:

$$S_t/S_0 = (P_t^*/P_0^*) / (P_t/P_0) \quad (2.1.3)$$

The relative PPP implies that the normal exchange rate will adjust to offset inflation differentials between two countries over time. The monetary policies of countries with different inflation-rate objectives should lead to exchange rate movements. Therefore, relative PPP is useful in explaining exchange rate movements when countries are experiencing hyperinflation, such as Mexico, where relative high inflation explains 92% of the exchange rate movement (Lafrance and Schembri 2002).

However, empirical evidence shows that the PPP does not hold well for countries experiencing similar inflation rates. Theoretically, there are two reasons to explain this.

First, PPP is built on the assumption that there is frictionless arbitrage in the goods market but the international goods market is not as integrated as the intra-national market. The relative prices of similar goods across countries are more volatile than the relative prices of substitute goods within countries (Rogoff 1996). This is mainly due to the tariff and non-tariff trade barriers. In general, increasing a country's trade barriers causes this country's currency to appreciate in the long run. On the other hand, the transaction costs of some products or services are so high that some non-traded goods and services exist.

Second, in the comparison of the national price levels between two countries, consumer price indices (CPI) are usually used. The baskets of goods, from which are derived the consumer price indices, are different across countries. Besides, the same products may carry a different weight in the components of the CPI (Obstfeld and Rogoff 1996). Hence, identical goods are difficult to get.

The relative PPP also means that the real exchange rate between two countries, which is the ratio of the domestic price index to the foreign price index expressed in the same currency, is a constant. We also can express the relative PPP as:

$$E = SP / P^* = k \quad (2.1.4)$$

Where  $E$  is real exchange rate,  $k$  is a constant term, which can be expressed as some measure of the transaction cost. The theory of PPP predicts that the real exchange rate should be equal to a constant, or at least that it mean reverts quickly to the constant in the long-run. In fact, the real exchange rate deviates from PPP over time. Researchers have focused on establishing significant relationships between fundamentals and the real exchange rate, including supply factors (e.g. productivity) and demand-side variables, such as government spending and terms of trade (Chinn and Johnston 1997, Alexius and Nilsson 2000, and MacDonald 1998). If a real shock is permanent, the mean of the real exchange rate will be drifting.

### 2.1.3 Productivity

In general, if one country becomes more productive than other countries, its currency tends to appreciate. In the second half of the 1990s, U.S. productivity growth was faster than that of Japan and Euro-land (See table 1). Economists took productivity growth as the key variable that drove the U.S. dollar sharply higher versus most major currencies. (Rosenberg 2003)

Balassa (1964) and Samuelson (1964) separately gave the same explanation of this economic phenomenon. If a country has higher productivity in tradable goods industries compared with non-tradable goods industries, this country tends to have a

higher price level and consequently a higher real exchange rate. If the country were to experience an equal rise of productivity in both traded and non-traded sectors, there would be no relative price effect, therefore, no effect on the real exchange rate.

<b>Table 1</b>		
<b>Productivity Growth Rates</b>		
<b>(Percentage Changes in Multifactor Productivity)</b>		
	<b>1990-95</b>	<b>1996-99</b>
	(%)	(%)
U.S.	0.79	1.47
Canada	0.26	0.27
France	0.89	1.12
Germany	1.02	1.07
Italy	1.32	-0.14
Japan	1.31	0.85
U.K.	1.21	0.95
Australia	1.15	2.11
Denmark	2.37	0.31
Norway	2.48	1.13
Switzerland	-0.57	0.84

Source: Gust, C. and Marquee, J., "Productivity Developments Abroad,"  
*Federal Reserve Bulletin*, October 2000

Their conclusion is based on the model of two economies, home and foreign. There are two sectors in each economy; one produces traded goods and the other one produces non-traded goods. The factors of production are capital (K) and Labor (L). Capital is mobile between two sectors and between two countries, while labor is mobile between two sectors but not between two countries. The traded goods can

move between two countries without cost, while the non-traded goods can not. Two economies share the same CRS (constant returns to scale) production function. Two sectors make zero economic profits in the long run.

Due to the frictionless arbitrage in the traded product, the price of the domestic traded product should equal the price of the foreign product when they are expressed in the same currency. When the productivity of the home traded sector is higher than that of the foreign traded sector, the marginal product of labor increases so that the wage of labor should be higher in the domestic traded sector. Because labor is mobile between the domestic sectors, the wage of labor in the non-traded sector should be higher, too. Since the productivity growth of the non-traded sector is not as high as that of the traded sector, the price of the non-traded output should increase in order to keep zero profit.

According to the assumption that the traded product can move between two economies without cost, the price of traded good can be the numeraire in home and foreign countries. The national price index can be measured by the prices of non-traded goods in terms of tradable goods. As a result, the real exchange rate can be expressed as the ratio of two countries' relative prices of the non-traded product and the traded product.

In reality, the tradable sector is mainly manufacturing, while the non-tradable sector is mainly services. When a country is experiencing higher productivity growth on account of the improvement of technology in the manufacturing sectors, non-traded sectors tend to be more service intensive and there is thus less room for

establishing technological superiority. We would therefore expect high-growth countries to experience real appreciation over time (Rogoff 1996).

#### 2.1.4 Terms of Trade

Term of trade is defined as the relative price of domestic and foreign goods on the trade flows (Gandolfo 2001). A change in the relative price of goods brings about a change in the demand for the various goods by both domestic and foreign consumers, thus inducing changes in the flows of exports and imports which will adjust the balance of payments. Hence, a change of a country's terms of trade can influence the direction of its exchange rate. For instance, in Australia, New Zealand and Canada, where commodity exports make up a large part of GDP, one finds strong and positive relative trends between the relevant commodity-price indices and these dollars respectively.

This can be explained by the model of a small open economy (Visser 1994). There are three products – non-tradables, importables and exportables. Importables can be produced at home but also imported and exportables can be produced and consumed at home and can also be exported. The foreign-currency prices of importables and exportables are determined in world markets. Consider the case of a price increase of exportables in the world market on account of the increased foreign demand for exportables. Because of the substitution effect, domestic consumers will reduce expenditures on the exportables and raise their expenditures on importables and nontradables. In addition, the increasing foreign demand induces a considerable increase of the exportables production as well as exports receipts. The income effect also promotes the domestic consumer to spend more on importables and non-tradables. All of these call for a relative price increase of nontradables and consequently an appreciation of domestic currency.

## 2.2 Monetary Models

### 2.2.1 Interest Rate Parity

Being the price of an asset, the exchange rate is also affected by the financial market. In the open financial market, it is assumed that there is no impediment to capital mobility. That is, the domestic deposits and the foreign deposits are perfect substitutes. Market speculative forces tend to equilibrate the expected rate of return of similar risk and liquid assets in financial investments. This implies that the risk-neutral agents must equal the rate of return for holding the domestic asset to the rate of return for holding the foreign asset plus the appreciation of the domestic currency (Sarno and Taylor 2001). That is named uncovered interest parity (UIP). This idea dates back at least to an 1896 article by Irving Fisher (Levich 1978).

Suppose the existence in international financial markets of domestic and foreign securities, which are identical as to default risk and time to maturity, and hence are perfect substitutes. A dollar invested at the domestic interest rate  $i$  at time  $t$  will have grown after one period to  $(1+i)$ . If one transfers a domestic dollar to an amount of  $S$  foreign currency at time  $t$ , meanwhile, to buy the foreign securities at interest rate  $i^*$ , it will have grown after one period to  $(1+i^*)S_t$ . Under UIP, the expected exchange rate  $S_{t+1}$  should make this amount equal to  $(1+i)$ :

$$(1+i) = (1+i^*) S_t / S_{t+1}^e \quad (2.2.1)$$

$$\text{Or} \quad (S_{t+1}^e - S_t) / S_t = i^* - i \quad (2.2.2)$$

The superscript e denotes the expectation of the spot exchange rate at time t+1 based on all information at time t, and S is the spot exchange rate expressed as the foreign price of the domestic currency. Transfer equation (2.2.1) in logarithmic form:

$$s_{t+1}^e - s_t = i^* - i \quad (2.2.3)$$

where the lower case s is the logarithmic spot exchange rate. From equation (2.2.2), we can see that the spot exchange rate can be affected not only by the interest rate differential, but also by the expected future exchange rate. If agents expect the domestic currency to appreciate in the future, they will reduce their investments in foreign securities and buy more domestic securities right away. This speculation will push the spot exchange rate up.

In addition, because of the expectation of the future exchange rate movement, an increase of the domestic interest rate does not always push the domestic currency up (suppose the foreign interest rate is fixed). Based on the Fisher Effect, the nominal interest rate equals the real rate plus the expected rate of inflation:

$$i = r + E\Delta p \quad (2.2.4)$$

where r is the real interest rate and EΔp is the expected inflation rate. Only the real interest rate reflects the marginal efficiency of capital. If the domestic real interest rates rise without any change of inflation, the domestic currency appreciates. However, if the nominal interest rate rises in order to compensate for the potential loss of purchasing power, the result is completely different. If a country is experiencing higher inflation than other countries, agents will expect the domestic

currency to depreciate, as a result from the inflation increase, and the expected depreciation of the currency will result in immediate depreciation.

### 2.2.2 The Flexible Price Monetary Model

The flexible price monetary model of the exchange rate determination was developed by Frenkel (1976), Mussa (1976). This model combines UIP with PPP and the money demand and supply equilibrium function:

$$M = KPY^{\alpha}I^{\beta} \quad (2.2.5)$$

It is based on two assumptions. First, the domestic and foreign assets are perfect substitutes. Second, the goods prices swiftly respond to changes of the money supply.

In discrete time, monetary equilibria in the domestic and foreign country respectively are given in logarithms by:

$$m_t = k + p_t + \alpha y_t - \beta i_t \quad (2.2.6)$$

$$m_t^* = k + p_t^* + \alpha y_t^* - \beta i_t^* \quad (2.2.7)$$

For simplicity, assume that  $k$ ,  $\alpha$  and  $\beta$  have the same value abroad as at home. The lower case  $m$ ,  $p$ , and  $y$  represent the logarithmic form of the nominal money supply, the national price index and GDP respectively. The lower case  $i$  is the interest rate. The asterisk denotes the foreign variables and  $k = \ln K$  is a constant. PPP provides the link between the domestic and the foreign price levels. Because the money supply determines the price level, the exchange rate is determined by relative money supplies of the domestic country and the foreign country. The solution for the nominal exchange rate is:

$$s_t = (m_t^* - m_t) - \alpha(y_t^* - y_t) + \beta(i_t^* - i_t) \quad (2.2.8)$$

According to this model, an increase in the domestic money supply relative to the foreign money stock, for example, induces a depreciation of the domestic currency in terms of the foreign currency. A rise in domestic real income will induce domestic currency appreciation. Because real income increases require increases of real money balances, a constant nominal money supply will generate a falling domestic price level. Via purchasing power parity, the fall in domestic prices (with foreign prices constant) implies an appreciation of the domestic currency in terms of the foreign currency.

This model can show that both the present values of exogenous factors and their expected future values determine the present exchange rate. Substituting the UIP condition (2.2.3) for the nominal interest rate differential ( $i^*-i$ ) in equation (2.2.8), the resulting equation yields:

$$s_t = (m_t^* - m_t) - \alpha(y_t^* - y_t) + \beta (s_{t+1}^e - s_t) \quad (2.2.10)$$

reparameterizing equation (14) and iterating it forward, the rational expectations solution may be written:

$$s_t = (1+\beta)^{-1} \sum_{i=0}^{\infty} (\beta/(1+\beta))^i E_t [(m_{t+i}^* - m_{t+i}) - \alpha(y_{t+i}^* - y_{t+i})] \quad (2.2.11)$$

From equation (2.2.11) we can see that not only the present money supply but also the expectation of the future money supply shock can affect the current exchange rate. Agents can frequently change their expectation based on the available information. That is why the exchange rate is more volatile than other economic factors.

### 2.2.3 The sticky-price monetary model

The sticky-price monetary model, due originally to Dornbusch (1976), was the dominant exchange rate model in the 1970s. It explains short-term overshooting of the nominal and real exchange rates above their long run equilibrium level very well. Its basic assumption is that the price in the good market is not as flexible as the price in the capital market (exchange rate) or the price in the money market (interest rate), particularly, in the short term. Hence, changes in money supply will cause the exchange rate and interest rate to jump to compensate for the sluggish good price. Consider the effects of an expansionary monetary policy. Since goods prices are sticky in the short run, the real money supply will rise and interest rates will decrease in order to clear the money market. The decrease in domestic interest rates then leads to a capital outflow and a depreciation of the domestic currency. On the other hand, investors are aware that the higher money supply will lead to a higher price level in the long run and expect the depreciation of domestic currency so that the future exchange rate will be expected to be lower. Risk-neutral investors will continue to invest into foreign assets until the expected future rise of the exchange rate just offsets the higher interest rate. In the medium run, however, because of the basic proposition in monetary theories, monetary neutrality, the domestic prices begin to rise in response to the rise in the money supply. The real money supply decreases and the domestic interest rates start to increase back to the initial level. The exchange rate then appreciates to the long- run equilibrium level.

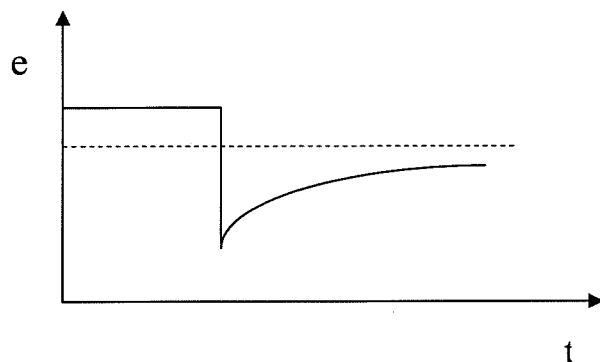


Figure 1: Overshooting of the Exchange Rate in the Stick Price Monetary Model

Although the overshooting of this model is always used to explain the fact that exchange rates are more variable than the ratio of price levels or money stocks, there is rarely empirical evidence to support it. The main reason is that the monetary factors, which involve the money and asset market shocks, can only explain the movement of the exchange rate in the short term, and this effect will disappear in the long run.

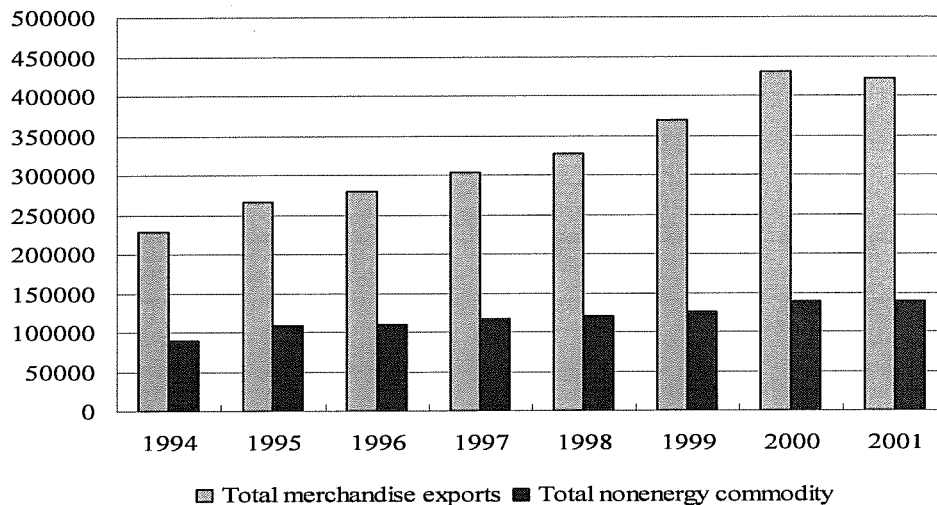
### 3. MODEL AND DATA DESCRIPTION

In this paper, I present evidence of a stable long-run relationship between the Canada – U.S. bilateral nominal exchange rate and the PPP price ratio as well as the real non-energy commodity prices by a cointegration test, and I use the Canada-U.S three months and one month corporate paper rate spread differential to capture the short run dynamics of the exchange rate. Then I set up an error correction model to explain the short term adjustment processes to its long run equilibrium. The data are observed monthly and cover the period 1994:1 to 2001:9. All variables are in logarithmic forms except for the interest rate spread differential.

Canada, like Australia and New Zealand, is a small open economy and a resource export country. Commodity exports make up a relatively large part of GDP. From Figure 2, it can be seen that the weight of the commodity exports in the total merchandise exports is about 36.76% within the sample period. The demand shocks originating from Canada's major trade partners can affect the evolution of the domestic economy (Hunt 1995). With a floating exchange rate regime, the exchange

**Figure 2**

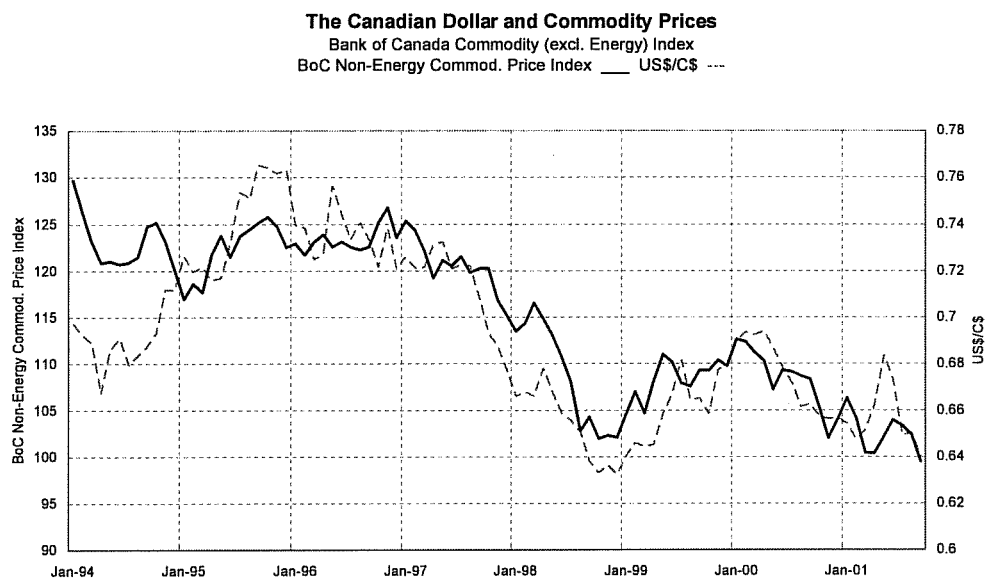
**The Weight of the Non-energy Commodity Exports in the Total Merchandise Exports (millions)**



Source : from CANSIM

rate fluctuations are a channel to absorb foreign shocks to the domestic economy. It can be expected that a change in world commodity prices, which comes from a foreign demand shock, can affect the Canadian exchange rate and domestic price level through the terms of trade. From Figure 3, it can be shown that the Canada - U.S. exchange rate and the non-energy commodity prices move together.

**Figure 3**



Source : from CANSIM

Generally, world commodity prices shocks should be expected to affect the effective exchange rate. However, the United States are, overwhelmingly, the largest market for Canadian commodity exports (see Table 2). Trades between Canada and

**Table 2**

**Canada Major Export Market Shares**

	percentage of total exports to	
	1994-99 (%)	2000-2001 (%)
United States	83.97	87.69
Japan	3.47	2.05
European Union	5.31	4.66
Developing Countries	6.74	5.23
Australia	0.51	0.37

Source: Direction of trade Statistics Yearbook 2001, IMF

the United States are of a predominant weight in Canadian imports and exports. It is reasonable to expect that a change in world commodity prices can affect the Canada - U.S. bilateral exchange rate. Here, the Canada-U.S. nominal exchange rate is defined as the U.S. dollar price per Canadian dollar (U.S.\$/CAD\$).

In studies of the real bilateral Canada - U.S. exchange rate, Clarida and Gali (1994) note that real supply (productivity) shocks and demand (terms of trade) shocks can affect the level of the real exchange rate, but they conclude that variations in the exchange rate are dominated by real demand shocks. In addition, Amano and Norden (1995 b) think that the movements in relative productivity are sufficiently small and gradual, so that relative productivity growth can be omitted to explain the behavior of real exchange rates. There nevertheless is a risk that some of the explanatory power of relative productivity shocks might be attributed to terms of trade shocks. In order to reduce the effect of relative non-tradable goods and services prices in terms of tradables, I use the industrial production index (IPI) to measure prices rather than the consumer price index (CPI) or the GDP deflator. The manufacturing industry is mostly comprised of traded goods. Hence, IPI is an ideal index to test the validity of PPP. The price ratio was constructed by the nominal IPI for the U.S. over the nominal IPI for Canada. Both IPIs are taken from CANSIM. Additionally, the real exchange rate is measured by the nominal exchange rate (in U.S\$ per CAD\$) multiplied by the ratio of the Canadian IPI to the American IPI.

From the literature, It can be seen that many economists are interchanging the real commodity price and the terms of trade, But they are distinct concepts, exhibiting

significantly different behaviors (Clinton 2001). Terms of trade is measured as the ratio of unit export prices over unit import prices, while the real world commodity price is the commodity price in U.S. dollars over the U.S. price index. I approximately use the real commodity price instead of the terms of trade in the Canadian case because of the structure of Canadian import and export products. Canada still exports a large amount of resource-based commodities, such as agriculture products, forest products, crude mineral products and energy products (see Figure 2 above). The main imported goods are manufactured goods, for instance, raw materials for construction and industries, machinery and equipment and other consumer goods. In this paper, the real commodity price was constructed by dividing a nominal commodity price index in U.S. dollar by the IPI of the United States. The commodity price index coincides with the unit value of exports, while the Industrial Production Index is comparable with the unit value of the imports. Hence, the real commodity price is approximately consistent with the terms of trade in this situation.

In addition, I use non-energy commodity prices rather than an all-inclusive commodity price index with energy components. From Table 3, we can see the result of the correlation between the nominal exchange rate and other various variables. The correlation between the nominal exchange rate and real non-energy commodity prices is higher than the correlation between nominal exchange rate and real commodity prices, which include energy components. The absolute value of the correlation coefficient, above 0.8, indicates a high correlation between variables.

Hence, the real non-energy commodity price is more powerful in the explanation of the exchange rate movement than real commodity prices.

Furthermore, from the result of Table 3, I can conclude that the real energy price does not correlate with the nominal exchange rate at all. Hence, I rule out the real energy price variable. This conclusion is different from the result of the study by Amano and Norden (1995a,c). Amano & Norden showed that energy prices did have a negative effect on the nominal exchange rate, even though its explanatory power was rather small.

Table 3:

**Correlations between the Nominal Exchange Rate and Various Variables**

1994:1-2001:9

Explanatory variables	r
Ratio of the U.S. IPPI and CAD IPPI	-0.79
Real non-energy commodity prices	0.92
Real commodity prices	0.58
Real energy prices	-0.03

All variables are in logarithmic form

Table 3 also shows that the correlation between nominal exchange rates and the industrial price ratio is high but negative. Moazzami and Anderson (2003) explained this negative sign with the following statement:

After 1986, however, the correlation becomes negative signifying the fact that the Bank of Canada followed contractionary monetary policy to reduce inflation during the early part of that period. High interest rates resulted in appreciation of the Canadian dollar. This was accompanied by a fall in the general level of prices in Canada.

Canada is small relative to world markets, For instance, the share of Canada in world trade is 4% from 1994 to 2000 (Direction of Trade Statistics Yearbook 2001, IMF). Hence, commodity prices are independently set by demand shocks in the rest of the world rather than by Canadian domestic changes in demand. Hence, the non-energy commodity price is supposed to be an exogenous variable, and any relationship between the exchange rate and the non-energy commodity price can be interpreted as a causal link (Amano and Norden 1995).

Finally, Canada and the United States both have long-standing policies of flexible exchange rates and open capital markets. It is reasonable to expect that the difference in the monetary policy of the two countries will affect the movement of the exchange rate. In order to capture the influence of monetary policy, I include a variable of the Canada-U.S. interest rate spread differential INTD.

$$\text{INTD} = (i_{\text{ca\_long}} - i_{\text{ca\_short}}) - (i_{\text{us\_long}} - i_{\text{us\_short}}) \quad (3.1)$$

Where  $i_{\text{ca\_long}}$  and  $i_{\text{ca\_short}}$  are the Canadian long term and short term interest rates respectively; and  $i_{\text{us\_long}}$  and  $i_{\text{us\_short}}$  are the long term and short term interest rates of the United States, respectively. Let IS to represent the long term interest rate and short term interest rate's spread. Then INTD can be rewritten as:

$$\text{INTD} = \text{IS}_{\text{ca}} - \text{IS}_{\text{us}} \quad (3.2)$$

I use 3 months corporate paper rate to represent the long term rate while one month corporate rates represent the short term rate. The data come from the Bank of Canada's data base posted on the website.

Based on the expectation theory of the term structure (Mishkin et al. 2003), the three months interest rate should be equal to the average of the one month interest rate plus the summation of the expectation of the second one month interest rate and the expectation of the third one month interest rate. That is:

$$i_{t,3} = (i_{t,1} + E_t i_{t+1,1} + E_t i_{t+2,1}) / 3 \quad (3.3)$$

where  $i_{t,3}$  represents the three month interest rate at time  $t$ ;  $i_{t,1}$  represents the one month interest rate;  $E_t i_{t+1,1}$  and  $E_t i_{t+2,1}$  represents the expectation of the future one month interest rate at time  $t$ . Suppose that  $E_t i_{t+1,1} = E_t i_{t+2,1}$ , the interest rate spread (IS) can be written as:

$$IS = i_{t,3} - i_{t,1} = 2/3 (E_t i_{t+1,1} - i_{t,1}) \quad (3.4)$$

The equation (3.2) can be written as:

$$INTD = 2/3 (E_t i_{t+1,1} - i_{t,1})_{ca} - 2/3 (E_t i_{t+1,1} - i_{t,1})_{us} \quad (3.5)$$

The interest rate  $i_{t,1}$  is an instrument of the monetary policy controlled by government, while  $E_t i_{t+1,1}$  is the expectation of the government's monetary policy for the next period. From the above analysis, I can see that the forward-looking nature of the long – term interest rate can be used to capture expectations of future monetary policy. Hence, the INTD should be able to capture the usual short-run dynamics implied by standard monetary models of the exchange rate. All of these variables are assumed to be exogenous variables. So, INTD is an exogenous variable.

There is another reason to use INTD as a measure of the Canada – U.S. monetary policies differential. Based on the classical exchange rate theories, the interest rate differential should be a stationary variable. However, in the sample period, from

1994:1 to 2001:9, I can not reject the null hypothesis, that there is a unit root in the Canada – U.S interest rate differential, for three different interest rates: the overnight rate, the one month corporate paper rate, and the three months corporate paper rate. It may be the problem of the test power. It is known that, when dealing with finite samples, the unit roots tests are biased towards accepting the null hypothesis of non stationary when the series is in fact stationary but close to having a unit root (Harris 1995). Because the span of my sample period is just over seven years, it may be short for the long run analysis so that I can believe that there is bias in my test. Hence, I use INTD, which shows a good stationary characteristic, to capture the short term dynamic effect of the interest rate differential on the nominal exchange rate.

#### 4. UNIT ROOT AND COINTEGRATION RESULTS

##### 4.1 The Econometric Rationale

In time series data, there are important differences between stationary and non-stationary series. Shocks to a stationary time series are temporary; over time, the effects of the shocks will dissipate and the series will revert to its long-run mean level. On the other hand, a non-stationary series has permanent components. The mean and variance of a non-stationary series are time dependent (Enders 1995). Non-stationary series require non standard distributional theory to perform valid statistical inference.

We can not use the classical regression model to estimate and infer the non-stationary variables, because the non-stationary variables violate the basic

classical assumptions and the customary tests of statistical inference do not hold. Otherwise, the trends of non-stationary data can result in spurious regression problems (Granger and Newbold 1974).

Instead of the classical regression model, econometricians look for evidence of co-integration to capture the long run relationship of the non-stationary variables. If variables are integrated of the same order, greater than or equal to one, while their linear combination can reduce the order of integration, then it could be the case that these variables are co-integrated (see Engle and Granger 1987). That is, if there is a long run relationship between two (or more) non-stationary variables, the idea is that deviations from this long run path are stationary.

This long equilibrium relationship between two or more non-stationary variables will be incorporated in an error correction model, which is used to link the long run and short run effects. Because the variables in the error correction model are stationary, there is no spurious regression problem with this approach. (Harris 1995)

#### 4.2 Unit Root Test

First, I need to examine the time-series properties of each variable. In order to find out a series' order of integration, I begin by testing for the unit root of each variable. I use the Augmented Dickey and Fuller (1979) test (ADF) and Phillips and Perron (1988) test (PP) to test the null hypothesis that an autoregressive variable has a unit root versus the alternative hypothesis that the variable is stationary. In the test, I follow Enders (1995) method to select the lag length.

One approach is to start with a relatively long lag length and pare down the model by the usual

t-test and F-tests. For example, one could estimate equation using a lag length of  $n^*$ . If the t-statistic on lag  $n^*$  is insignificant at some specified critical value, re-estimate the regression using a lag length of  $n^*-1$ . Repeat the process until the lag is significantly different from zero.

Monte Carlo evidence by Schwert (1987) indicates that these standard unit-root tests often have weak power against persistent alternatives, so we also use the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test (1992) for the null hypothesis that the variable is stationary versus the alternative hypothesis that the variable is non-stationary.

A critical first step in any econometric analysis is to visually inspect the data. Plots of variables are shown in Appendix 1. From the figures, we can see that, except for INTD, all variables contain trends and the mean of these variables are not equal to zero. Hence, when I test the unit roots of these variables, I used the model with intercept and trend. There is little visual evidence of a trend in the interest rate spread differential (INTD), but its mean is not equal to zero. As a result, I use the model with intercept but no trend to test the unit root of the interest rate spread differentials. The test results are shown in Table 4.

From Table 4, I get the following conclusions. With the ADF and PP tests, I can not reject the null hypothesis that there is a unit root in the series at a 1% significance level for four variables - the nominal Canada - U.S. exchange rate, the price ratio, the real non-energy commodity price and the real exchange rate. In KPSS test, I can reject the null hypothesis that the variable is stationary at a 1% degree of significance for these four variables. These three tests get the same result that the above four variables are non-stationary.

**Table 4:****Test for Unit Root**

Variables	lag	ADF	PP	KPSS
Nominal CAD-U.S exchange rate	1	-2.549	-2.414	2.969**
Price ratio	2	0.563	0.604	39.52**
Real non-energy commodity price	1	-2.208	-2.2612	8.742**
Real exchange rate	0	-0.608	-0.608	18.37**
INTD	2	-4.887**	-7.983**	0.341

1. The 1% and 5% significant critical value for Augmented Dick Fuller and Phillips and Perron tests with intercept and trend are -4.061 and -3.459 respectively. The 1% and 5% significant critical values for ADF and PP with intercept but without trend are -3.50 and -2.89 respectively.
2. Reject the null hypothesis at \*\* 1% significant level and \* 5% significant level respectively.
3. The result is not sensitive to the intercept and/or trend.

One needs to notice that the non-stationary real exchange rate shows evidence against long-run PPP. If the relative purchasing power parity PPP holds, the real exchange rate should be stationary, that is, it should have a stable mean and revert to its mean in the long run. However, in the study period, I can not get this conclusion. This implies that the real exchange rate should be determined by other integrated variables.

**Table 5:****Unit Root Test for The First Difference of Variables**

Variables	ADF	PP
First difference of nominal CAD-U.S exchange rate	-8.27**	-8.263**
First difference of price ratio	-4.012**	-7.105**
First difference of real non-energy commodity prices	-5.43**	-9.117**

In this paper, I examine the long-term equilibrium relationship between the nominal exchange rate and the price ratio and the non-energy commodity prices. Then, I test the unit root in the first difference of these three variables. These turn out to be stationary. It implies that the nominal exchange rate has a unit root as well as the price ratio and the non-energy commodity prices. All these three variables are integrated of the same order, so it is possible to find the cointegration relation between these variables in the next step.

In addition, I can conclude that at least at the 1% significance level, the Canada-U.S. interest rate spread differential variable is stationary. This means that the effect of the two countries' monetary policies differential is temporary and will disappear over time. Hence, INTD will be included only in the error correction model.

#### 4.3 Cointegration

##### 4.3.1 Engle-Granger Test

If there is a stable long run equilibrium relationship of the non-stationary variables, these variables must be cointegrated (Engle and Granger 1987). Here, I tested the cointegration of the nominal exchange rate with the price ratio and the non-energy commodity price. If the long-run real exchange rate is determined by non-stationary factors other than the non-energy commodity prices, then their omission should prevent us from finding significant evidence of cointegration. Evidence of cointegration, on the other hand, suggests that asymptotically, the non-energy commodity price can adequately capture all the permanent innovations in the real exchange rate over my sample period (Amano & Norden 1995 a).

First, I tested for cointegration using the two-step single equation approach developed by Engle and Granger (1987). Following the definition of cointegration: if, first, three time series  $y_t$ ,  $z_t$  and  $w_t$  are integrated of order  $d$ , defined as  $I(d)$ ; second, no two of them are cointegrated; and third, there exists a vector  $\beta$  such that the linear combination of three variables is stationary, (Hence, the disturbance term from the regression is of a lower order of integration  $I(d-b)$ , where  $b > 0$ .) then these three variables are defined as cointegrated of order  $(d, b)$ . Therefore, because the nominal exchange rate, the price ratio and the non-energy price all are  $I(1)$ , and if the residual  $\varepsilon_t$  is  $I(0)$ , then these three series would be cointegrated of order  $CI(1,1)$ . This implies that if we wish to estimate the stable long-run relationship of the nominal exchange rate with the price ratio and the non-energy commodity price, it is only necessary to estimate the static model:

$$NEX_t = c + \beta_1 PPP_t + \beta_2 COM_t + \varepsilon_t \quad (4.3.1)$$

by the ordinary least square (OLS) method. Then, I tested the stationary propriety of the residual. Here,  $NEX$  represents the log of the nominal Canada-U.S. exchange rate,  $PPP$  represents the log of the U.S-Canada industrial production prices ratio, and  $COM$  represents the log of the non-energy commodity price.

If the variables are cointegrated, an OLS regression yields a “super-consistent” estimator of the cointegrating parameters. Stock (1987) proves that the OLS estimation of parameters converge faster than in OLS models using stationary variables. Hence, I can use OLS to achieve a consistent estimate of the long-run steady-state relationship between the variables in the model. In addition, all dynamics

and endogeneity issues can be ignored asymptotically (Harris 1995).

I specify the nominal exchange rate simply as a function of the price ratio and the non-energy commodity price. The OLS estimate is

$$\text{NEX}_t = -0.1445 + 0.542 \text{PPP}_t + 0.476 \text{COM}_t + \varepsilon_t \quad (4.3.2)$$

(0.001)
(0.062)
(0.027)

(-132.57)
(8.749)
(17.81)
 $R^2=0.917$ 
DW=0.818

The results of the residual test are presented in Table 6. The null hypothesis is that there is no cointegration between variables, that is, the residual is non-stationary. The alternative hypothesis is that there is cointegration between variables, that is, the residual is stationary. From Table 6, it can be seen that the augmented Dickey and Fuller (1979) and Phillips and Perron (1990) tests reject the null hypothesis of no co-integration at the 1 percent significance level. Consequently, the disturbance term from the regression does not have a unit root, so it becomes a stationary variable. Hence, the results yield strong evidence of co-integration of the nominal exchange rate with the price ratio and the non-energy commodity prices.

**Table 6**

**Engle - Granger Approach to Test the Cointegration**

	ADF test	PP test
Residual	-4.55**	-5.021**

1. It is not appropriate to use the critical values reported in Dickey and Fuller Table, because the residuals are not the actual error terms. Rather, the residuals are estimated error terms that are obtained from the estimate of the equilibrium regression.
2. The critical values for the Engle-Granger cointegration test are given by Enders (2004). The critical values of three variables with lags and a constant for the null hypothesis of no cointegration are -4.441 for the 1 percent significance level and -3.828 for the 5 percent significance level.

The result confirm what should be expected: an increase in commodity prices

lead to an appreciation of the Canadian dollar (in terms of the U.S dollar); and rising prices in the U.S (relative to Canadian prices) also lead to an appreciation of the Canadian dollar.

#### 4.3.2 Johansen Test

Although the Engle-Granger approach is simple to test for cointegration, it is less powerful. I used an efficient and therefore more powerful co-integration test developed by Johansen (1988). The Johansen approach examines the total number of cointegrating vectors in the system and it gives additional information about the dynamics of the system.

The Johansen approach is based on analyzing a VAR model for the  $n \times 1$  vector of  $I(1)$  variables, namely:

$$X_t = \mu + A_1 X_{t-1} + \dots + A_k X_{t-k} + u_t \quad (4.3.3)$$

where  $X_t$  includes all endogenous variables of the system, and  $u_t$  is assumed to be identical white noise error term vector. Then rewrite this equation as

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + u_t \quad (4.3.4)$$

where  $\Gamma_i = -(I - A_1 - \dots - A_i)$   $i=1 \dots k-1$

$$\Pi = -(I - A_1 - \dots - A_k)$$

By rewriting equation (4.3.3) into equation (4.3.4), the long-run information in  $X_t$  will be included in the long-run impact matrix,  $\Pi$ , and the rank ( $r$ ) of this matrix can determine the number of cointegrating vectors. That is, if there are  $r$  cointegrating vectors, only these  $r$  linear combinations of the variables are stationary. All other linear combinations are non-stationary.

Johansen proposes two tests of the cointegration with differing assumptions about the alternative hypothesis: (i) the trace statistic tests the null hypothesis  $r \leq q$  ( $q < n$ ) against the completely unrestricted model  $q < r \leq n$ ; and (ii) the  $\lambda_{\max}$  statistic makes the alternative hypothesis more precise by specifying that only one additional cointegrating vector exists ( $r = q + 1$ ).

In my model, X is comprised of three endogenous variables, such as, the nominal exchange rate, the price ratio and the real non-energy commodity price. The results of these two Johansen tests for the cointegration of the variables are reported in Table 7.

In the trace statistic tests, 91.498 exceeds the 1% critical value. Therefore, it is possible to reject the null hypothesis of a non-cointegrating vector and accept the alternative hypothesis of one or more cointegrating vectors. Next we can use the  $\lambda_{\text{Trace}}(1)$  statistic to test the null of  $r \leq 1$  against the alternative of two or more cointegrating vectors. The statistic value 14.770 is less than the 1% critical value and the 5% critical value. Even at the 5% critical value I cannot reject the null hypothesis that there is at most one cointegration vector. As a result, it implies that the  $\lambda_{\text{Trace}}$  statistic indicates at most one cointegrating vector at the 1% significance level.

In the  $\lambda_{\max}$  statistic test, the statistic value (76.728) for the null hypothesis of a non-cointegrating vector ( $r = 0$ ) against the specific alternative hypothesis  $r = 1$  is more than the 1% and 5% critical value. I can reject the null hypothesis of a non-cointegrating vector at the 1% significance level. For the next test of null hypothesis that there is no more than one cointegrating vector, I cannot reject the null

hypothesis even at the 5% critical value. Hence, the  $\lambda_{\max}$  statistic also indicates one cointegrating vector at the 1% significance level.

From the above analysis, the Johansen tests find significant evidence of co-integration at the 1% significance level, which suggests that the real non-energy commodity price and the price ratio together capture the permanent innovations of the nominal exchange rate in the Canadian and American bilateral case.

**Table 7**

**Johansen Cointegration Test (19 lags)**

Null hypothesis	Alternative Hypothesis		5% critical value	1% critical value
$\lambda_{\text{Trace}}$ Test		$\lambda_{\text{Trace}}$ statistic		
$r=0$	$r>0$	91.498**	29.68	35.65
$r\leq 1$	$r>1$	14.770	15.41	20.04
$r\leq 2$	$r>2$	2.326	3.76	6.65
$\lambda_{\max}$ Test		$\lambda_{\max}$ Statistic		
$r=0$	$r=1$	76.728**	20.97	25.52
$r\leq 1$	$r=2$	12.444	14.07	18.63
$r\leq 2$	$r=3$	2.326	3.76	6.65

1. \*\* represent significance at the 1 percent levels.
2. I test the model that allow the linear deterministic trend in the data and intercept (no trend) in the CE
3. The lag lengths are determined by the  $\chi^2$  test with AIC criterion. Please refer the Appendix 3.

**4.4 The Error Correction Model**

The fact that variables are cointegrated implies that there is some adjustment process which prevents the errors in the long run relationship from becoming larger

and larger. Engle and Granger(1987) have shown that any cointegrated series has an error correction representation. The error correction model (ECM) represents the most common approach to incorporate both the economic theory relating to the long run relationship between variables and the short run disequilibrium behavior.

In equation (4.3.4), under the null hypothesis of  $r$  ( $0 < r < n$ ) cointegrating vectors,  $\Pi$  can be decomposed as the product of two matrices, i.e.  $\Pi = \alpha\beta^T$  where  $\alpha$  and  $\beta$  are  $n \times r$  matrices. Therefore, under the null hypothesis, equation (4.3.4) can be written as

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \dots + \Gamma_{k-1} \Delta X_{t-k+1} + \alpha\beta^T X_{t-k} + u_t \quad (4.4.1)$$

where  $\beta X_{t-1}$  represents the error-correction mechanism and  $\alpha$  gives the speed of adjustment towards the system's long run equilibrium;  $\beta$  is a matrix of long-run coefficients such that the term  $\beta X_{t-1}$  represents  $r$  cointegration relationships in the multivariate model which ensure that the  $X_t$  converge to their long run steady-state solutions (Harris 1995). After including the short term exogenous variables into the model, Johansen full system Error Correction Model (ECM) is written as:

$$\Delta X_t = \alpha \cdot \beta X_{t-k} + \sum^k \gamma_i Z_{t-i} + u_t \quad (4.4.2)$$

$Z$  represents a matrix of stationary variables, including lagged differences of  $X$  and other transitory factors which can capture the short term dynamics of the dependent variables;  $\beta$  and  $\gamma$  are vectors of parameters; and  $u$  is an error term vector.

The speed of the adjustment coefficient vector is important for the dynamics of the system. A large value of  $\alpha$  is associated with a large change of the dependent variable in response to the previous period disequilibrium. If one element of  $\alpha$  is equal to zero, the change of the associated dependent variable does not respond at all

to this deviation. If all elements in  $\alpha$  are equal to zero, there is no error correction and the equation (4.4.2) is nothing more than a VAR in first differences. If the endogenous variables are cointegrated, at least one element in vector  $\alpha$  should be significantly different from zero. Additionally, the dependent variable associated with a zero speed of adjustment is defined as weak exogeneity (Enders 2004).

In my model, X includes the nominal exchange rate (NEX), the price ratio (PPP) and the real non-energy commodity price (COM). By the likelihood ratio test for lag lengths, I set the lag length for ECM as zero (refer to the Appendix 3, LR criteria). Hence, I define Z to just include a Canada - U.S interest rate spreads differential. The equation for the nominal exchange rate is reported as:

$$\Delta NEX_t = \alpha_1 (NEX_{t-1} + C + \beta_1 PPP_{t-1} + \beta_2 COM_{t-1}) + \gamma_1 INTD_t + u_{1t} \quad (4.4.3)$$

Here, C is the constant term. The equations for the price ratio and the non-energy commodity price are respectively reported as:

$$\Delta PPP_t = \alpha_2 (NEX_{t-1} + C + \beta_1 PPP_{t-1} + \beta_2 COM_{t-1}) + \gamma_2 INTD_t + u_{2t} \quad (4.4.4)$$

$$\Delta COM_t = \alpha_3 (NEX_{t-1} + C + \beta_1 PPP_{t-1} + \beta_2 COM_{t-1}) + \gamma_3 INTD_t + u_{3t} \quad (4.4.5)$$

First, according to the weak exogeneity condition, I tested whether  $\alpha_1$ ,  $\alpha_2$  and  $\alpha_3$  are significantly different from zero by the likelihood ratio test. The test results are presented in Table 8. From the results shown in Table 8, the speed of adjustment  $\alpha_1$  is significantly different from zero at the 5% significance level, while  $\alpha_2$  and  $\alpha_3$  are insignificantly different from zero. I then tested the joint null hypothesis of  $\alpha_2 = 0$  and  $\alpha_3 = 0$ , and I obtained the marginal significance level which is 15.4 percent. This also proves that the speed of adjustment coefficients for the price ratio and for the real

non-energy commodity price are weakly exogenous. This implies that the weak exogeneity assumption for the real non-energy commodity price is valid.

**Table 8**

**Weak Exogeneity Test**

Null Hypothesis	Chi-square statistic	significance level
$\alpha_1 = 0$	4.956	0.026
$\alpha_2 = 0$	1.284	0.257
$\alpha_3 = 0$	3.358	0.067
$\alpha_2 = 0, \alpha_3 = 0$	3.744	0.154

I have proved that the price ratio change and the real non-energy prices change do not respond to the previous period's deviation from the long run equilibrium. Now I only need to estimate equation (4.4.3). The results are presented in Table 9.

In order to assess the adequacy of the model and to ensure that the standard errors presented in Table 9 are valid, I did a variety of residual diagnostic tests (the results are presented in Appendix B). First, I tested the autocorrelation of the residual by the Lagrange multiplier (LM) test. If the residuals are serially correlated, the lag length may be too short. The LM tests up to order 12 are unable to find significant evidence of autocorrelation in the residual terms. Hence, the LM test tells me that the selected lag length is reasonable. Second, I tested the heteroskedastic property of the residual by the White heteroskedasticity test (White, 1980). If there is evidence of heteroskedasticity, the standard errors for estimated coefficients are no longer valid. Fortunately, the White heteroskedasticity test gives a 46.87 percent marginal

significance level; I cannot reject the null hypothesis that there is no heteroskedasticity in the residual. Hence, the standard errors are valid. Finally, the Jarque and Bera (1980) test cannot reject the null hypothesis of normal distribution in the error term.

**Table 9**

**Error Correction Model Estimates (0 lag)**  
Adjusted sample 1994:3-2001:9 and 91 Observations

Variable	Parameter Estimate	Standard Error	t-statistic	Significance Level
Cointegrating Equation				
constant	0.1439	0.002	62.808	0.000
PPP	-0.673	0.125	-5.378	0.000
COM	-0.546	0.055	-9.941	0.000
Error Correction Equation				
speed of adjustment	-0.238	0.075	-3.165	— <sup>1</sup>
INTD	-0.011	0.003	-3.582	0.000

1. the t-statistic for this parameter does not have the standard distribution under the null, so the conventional significance levels do not apply.

The above analysis shows that the estimate of the error correction model equation (4.4.3) is valid within the standard errors. This equation implies that the change of the nominal Canada – U.S exchange rate responds to the previous period’s deviation from the long run equilibrium, the change of the Canada-U.S interest rate spread differential and a stochastic shock.

The estimated long run effects are included in the previous error term. That is:

$$\varepsilon_t = \text{NEX}_t + 0.1439 - 0.673\text{PPP}_t - 0.546\text{COM}_t \quad (4.4.6)$$

Rewrite this equation into the following form:

$$\text{NEX}_t = -0.1439 + 0.673\text{PPP}_t + 0.546\text{COM}_t + \varepsilon_t \quad (4.4.7)$$

Compared equation (4.4.7) with equation (4.3.2), I can conclude that the estimated parameters signs of the long run relationship between NEX and PPP and COM from the ECM test are the same as those of the Engle - Granger approach, which are shown in equation (4.3.2). And, the measures of parameter estimates in both test approaches are similar to each other within two standard errors. This equation suggests that a 1 percent improvement in the worldwide real non-energy commodity prices leads to a 0.546 percent appreciation of the Canada - U.S nominal exchange rate, while a 1 percent improvement in the U.S-Canada industrial price index ratio results a 0.673 percent appreciation of the Canada-U.S nominal exchange rate. It can be seen that from 1994 to 2001, the world wide commodity price suffered an ongoing decrease. From this model, it is easy to understand that the Canadian currency is undervalued compared to the purchasing power parity exchange rate (Lafrance and Schembri 2002). The price ratio effect implies that, if the American inflation growth is higher than the Canadian inflation growth, the Canada currency will appreciate. Hence, the sign of this variable is expected.

The complete ECM equation is:

$$\Delta\text{NEX}_t = -0.238(\text{NEX}_{t-1} + 0.1439 - 0.673\text{PPP}_{t-1} - 0.546\text{COM}_{t-1}) - 0.011\text{INTD}_t + u_{1t} \quad (4.4.8)$$

The speed of adjustment  $\alpha$  is -0.238 implying that 96.17 percent of the adjustment is completed within one year. This can explain why the exchange rates are more volatile than other economic factors. Finally, as the effects of monetary policies predict,

increases in Canadian short term interest rates lead to an appreciation of the Canadian dollar. However, this effect is transitory.

## 5. CONCLUSION

This paper tries to prove that the price ratio and the real non-energy commodity prices can capture the long run movement of the Canada U.S nominal exchange rate and that the dynamic effect of the short term interest rate differential is temporary. In the study, I have uncovered several findings. First, there is a cointegrating relationship between the nominal exchange rate and the price ratio and the real non-energy commodity prices that appears to be stable over the sample period. Secondly, tests of weak exogeneity in this relationship have shown that while the exchange rate has a significant response to previous deviations from the long run equilibrium, the price ratio and the real non-energy commodity prices don't. This is consistent with the assumptions that Canada is a small open economy and that the real non-energy commodity prices are exogenous variables. Thirdly, not all of the interest rate differentials are stationary in my tests. Only the interest rate spread differential can capture the dynamic effect of monetary policies on the nominal exchange rate.

Although this model is successful in explaining the movement of the Canada-U.S bilateral nominal exchange rate, it can not be generalized to other countries. This is due to the special situation between Canada and the United States. (1) Canada is a small open economy; conversely, the United States is a large open economy. While demand shocks in the United States have significant effects on the Canadian economy,

the reverse effect does not exist. (2) Canada and the United States share the largest bilateral trade in the world. The trade between Canada and the United States dominates the overall Canadian imports and exports. (3) As an industrial country, Canada is still overwhelmingly dependent on resource exports, while the United States are striving on manufacturing and technology. (4) Canada and the United States both have open capital markets. Although they have their own monetary targets, their monetary policies are similar.

**Appendix 1**  
**Graphs of the series**

**Variables of the model**

**Log of real non-energy commodity price**



**Log of real CAN-U.S. exchange rate**



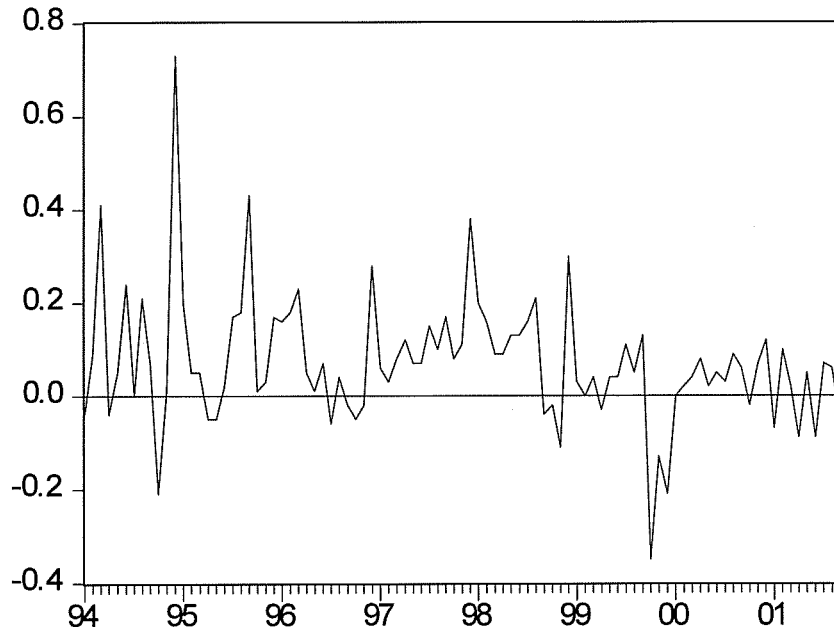
Log of price ratio (U.S.\$/CAD\$)



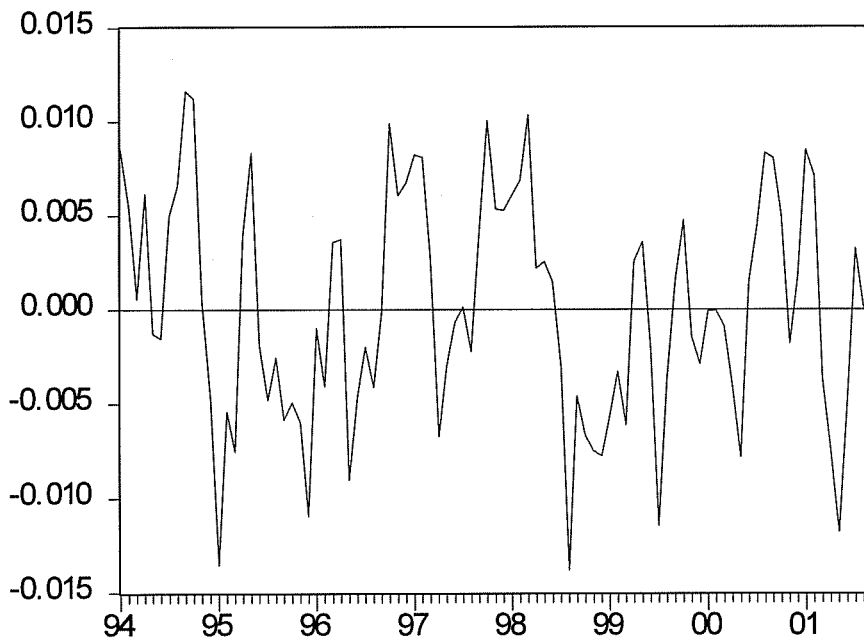
Log of nominal Can-U.S. exchange rate



The Canada-U.S Interest Rate Spread Differential of 3 months Commercial Paper and Overnight Rate



Residual in the Engle and Ganger Test of Cointegration



Appendix 2

Residual Diagnostic

	Null Hypothesis	test	Statistic	Significance level
Autocorrelation	No serial correlation at lag order 1	LM(1)	13.952	0.2887
	No serial correlation at lag order 4	LM(4)	12.931	0.7477
	No serial Correlation at lag order 8	LM(8)	10.768	0.2332
	No serial Correlation at lag order 12	LM(12)	4.285	0.8705
White heteroskedasticity	There is no heteroskedasticity (30df)	Chi_square	29.94	0.4687
Normal distribution	Residual are multivariate normal (25df)	Jarque-Bera	29.889	0.2285

## Appendix 3

VAR Lag Order Selection Criteria  
 Endogenous variables: NEX PPP COM  
 Exogenous variables: C  
 Date: 04/08/04 Time: 12:22  
 Sample: 1994:01 2001:09  
 Included observations: 73

Lag	LogL	LR	FPE	AIC	SC	HQ
0	599.4427	NA	1.61E-11	-16.34090	-16.24677	-16.30339
1	873.5271	518.1321*	1.13E-14*	-23.60348	-23.22697*	-23.45343*
2	877.4065	7.014781	1.30E-14	-23.46319	-22.80429	-23.20061
3	879.9246	4.346419	1.56E-14	-23.28561	-22.34432	-22.91049
4	884.3795	7.322986	1.77E-14	-23.16108	-21.93741	-22.67343
5	892.9275	13.34898	1.81E-14	-23.14870	-21.64264	-22.54851
6	899.3432	9.491770	1.98E-14	-23.07790	-21.28946	-22.36517
7	901.3250	2.769014	2.45E-14	-22.88562	-20.81479	-22.06036
8	907.6878	8.367629	2.71E-14	-22.81337	-20.46015	-21.87557
9	914.1065	7.913441	3.02E-14	-22.74264	-20.10705	-21.69231
10	922.4604	9.612662	3.22E-14	-22.72494	-19.80696	-21.56208
11	934.0161	12.34722	3.19E-14	-22.79496	-19.59459	-21.51956
12	945.8462	11.66800	3.19E-14	-22.87250	-19.38974	-21.48456
13	950.3929	4.110716	3.96E-14	-22.75049	-18.98535	-21.25002
14	959.6722	7.626804	4.43E-14	-22.75814	-18.71062	-21.14513
15	961.9016	1.649143	6.17E-14	-22.57265	-18.24274	-20.84710
16	984.6233	14.94035	5.08E-14	-22.94858	-18.33629	-21.11051
17	992.6003	4.589507	6.55E-14	-22.92056	-18.02588	-20.96994
18	1025.222	16.08718	4.57E-14	-23.56771	-18.39065	-21.50456
19	1055.400	12.40221	3.70E-14	-24.14795	-18.68850	-21.97227
20	1080.209	8.156211	3.92E-14	-24.58106*	-18.83922	-22.29284

\* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

## Appendix 4

Vector Error Correction Estimates  
 Date: 04/08/04 Time: 12:30  
 Sample(adjusted): 1994:02 2001:09  
 Included observations: 92 after adjusting endpoints  
 Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		
NEX(-1)	1.000000		
PPP(-1)	-0.672705 (0.12508) [-5.37836]		
COM(-1)	-0.545981 (0.05492) [-9.94152]		
C	0.143885 (0.00229) [ 62.8081]		
Error Correction:	D(NEX)	D(PPP)	D(COM)
CointEq1	-0.238086 (0.07523) [-3.16464]	-0.094009 (0.05015) [-1.87444]	0.464035 (0.16069) [ 2.88770]
IDS	-0.010951 (0.00306) [-3.58276]	0.002354 (0.00204) [ 1.15516]	-0.009794 (0.00653) [-1.50006]
R-squared	0.164217	0.034976	0.078486
Adj. R-squared	0.154930	0.024253	0.068247
Sum sq. resids	0.001875	0.000833	0.008553
S.E. equation	0.004564	0.003043	0.009748
F-statistic	17.68342	3.261883	7.665346
Log likelihood	366.3074	403.6145	296.4879
Akaike AIC	-7.919727	-8.730751	-6.401911
Schwarz SC	-7.864905	-8.675929	-6.347089
Mean dependent	-0.000818	0.000462	-0.002032
S.D. dependent	0.004965	0.003080	0.010099
Determinant Residual Covariance	1.14E-14		
Log Likelihood	1088.082		
Log Likelihood (d.f. adjusted)	1085.049		
Akaike Information Criteria	-23.37064		
Schwarz Criteria	-23.09653		

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