

The Predictability of Exchange Rates

By

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Oguz Tunturk

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Chairperson Mohamed El-Hodiri

John Keating

Elizabeth Asiedu

Jianbo Zhang

Ferhat Akbas

Date Defended: April 7, 2016

The Dissertation Committee for Oguz Tunturk
certifies that this is the approved version of the following dissertation:

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Chairperson Mohamed El-Hodiri

Date approved: April 7, 2016

Abstract

This study investigates the predictability of exchange rates by using the long horizon regression approach (or sometimes called the Error Correction Model (ECM)) derived from the Vector Error Correction Model (VECM) for Canada, Japan and Switzerland for the period between 1973:Q2 and 2013:Q4. The predictive ability of the exchange rate models were evaluated according to in-sample analysis and out-of sample analysis. The in-sample analysis results suggest that the fundamentals are useful to explain the long horizon changes in the logarithm of the exchange rates under the assumption of country specific income elasticities for Canada and Japan but not Switzerland. On the other hand, the out-of sample analysis presents the evidence that whether the ECM or the random walk (RW) explains the nature of exchange rates is time varying. During recessions, the RW explains the exchange rate changes better while, the ECM works better in expansions.

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I. Introduction

One of the important debates centers on the international economics is the difficulty of predicting exchange rates by using market fundamentals such as money supplies, outputs, and interest rates. The theories in the economics literature state that the exchange rate is determined by such fundamental variables. However, since Meese and Rogoff (1983), it has been well known that exchange rates are very difficult to predict using economic models; in particular, a simple a-theoretical model, such as the random walk without drift (RW), is found to generate better exchange rate forecasts than fundamental-based exchange rate models. In other words, fundamental variables do not help predict future changes in exchange rates. According to the RW, the best predictor of exchange rates tomorrow is the exchange rate today. Thus, exchange rate changes are completely unpredictable.

Meese and Rogoff's (1983) finding was a shock for economists since market fundamentals have long been considered key determinants of exchange rates. If their finding is true then all exchange rate models based on the fundamentals are misleading, and exchange rates are unpredictable. Therefore, large numbers of studies have attempted to refute Meese and Rogoff's findings and find positive results in favor of fundamentals-based models. One of the most well-known rebuttals to Meese and Rogoff's work is Mark's (1995) study.

Mark's (1995) study states that monetary fundamentals contain predictive power for exchange rates, at least in the long horizon. In his study, Mark used the long horizon regression approach (or sometimes called the Error Correction Model (ECM)) derived from the Vector Error Correction Model (VECM). According to the ECM, if the spot exchange rates (s_t) are not equal to the fundamental value or long run equilibrium value of exchange rates (f_t), the spot exchange rates will adjust themselves and converge to its fundamental value under the assumption of no

government intervention. As a result, current deviations from the fundamental value of the exchange rate are expected to be useful for predicting future changes of the exchange rate. Since the work by Mark, the ECM have been widely used. Therefore, Mark's and Meese and Rogoff's (1983) studies are claiming opposite results.

However, these studies are not the only ones testing the predictive ability of exchange rate models. Several models have been used in the literature in the attempt to predict exchange rates. These are, in general, the single equation linear models, single-equation ECM, non-linear models, multi-equation VECM models, and panel models. Even though most of the authors are unable to document short-run exchange rate predictability, some of them find evidence of long horizon predictability. However, the literature has remained pessimistic about the link between exchange rates and fundamentals.

The predictive ability of the exchange rate models can be evaluated according to in-sample fit and out-of sample forecast performance. In-sample evidence focuses on both the statistical significance of the estimated coefficients, and the R^2 's of the regressions at various horizons. On the other hand, out-of sample evidence includes the forecast errors provided by the forecasts from the estimated model versus those from the RW model. The same out-of sample benchmark is commonly used in literature, as Meese and Rogoff (1983) and Mark (1995) used.

The main purpose of the study is to investigate the exchange rate predictability by using the market fundamentals in the ECM. This study shows the in-sample fit of the ECM and compares the out-of sample forecast performance of the ECM against the RW model. It is basically based on the critiques regarding in-sample and out-of sample analysis followed by the literature. The first result of the study presents evidence that market fundamentals are useful to explain the long

horizon changes in the logarithm of the exchange rates. The second result of the study states that whether it is the ECM or the RW that explains the nature of exchange rates is time varying.

The first critique is based on the in-sample analysis followed by the literature. Since the long horizon regression approach is derived from the VECM, the error correction term (ECT) must be stationary in order for the long run regression to make sense. The long-horizon approach is based on the assumption that nominal exchange rates and fundamentals are cointegrated with the cointegration vector $[1 \ -1]^T$. If the $[1 \ -1]^T$ cointegration vector does not make ECT stationary, then the regression between fundamentals and exchange rates is meaningless, and the coefficients are misleading. That is, we cannot pretend that exchange rates move dependently of fundamentals over the long time horizon with the assumed cointegration vector $[1 \ -1]^T$. However, in the ECM literature, the studies do not consider this fact, and the results are interpreted as if there is a long run relationship between fundamentals and exchange rates with the assumed cointegration vector. To avoid this problem, I will use the VECM and estimate the true cointegration vector that makes ECT stationary. When I guarantee the stationarity of ECT and the long run relationship between fundamentals and nominal exchange rates, I will run the long horizon regressions and estimate the regression coefficients for different horizons.

The second critique is based on the out-of sample analysis followed by the literature. In order to evaluate the model out-of sample forecasting ability, for example, the mean absolute forecast error of the model ($MAFE_m$) is compared with the mean absolute forecast error of the random walk model ($MAFE_{rw}$) as the benchmark model. If $MAFE_m < MAFE_{rw}$, then it is concluded that the model forecasts outperform the RW forecasts for the whole forecast period, and the result is never time varying. However, even though it might be true that the exchange rate model outperforms the RW model for the whole forecast period, we also might have some

subperiods that the RW outperforms the exchange rate model. In other words, instead of taking the average of absolute forecast errors for the whole forecasting period, we might need to focus on the subperiods of the whole forecasting period. More importantly, these different subperiods might have different expansion and recession periods, and the dynamics are not the same in these periods. Therefore, I will discuss that whether or not the exchange rate models or the RW explain the nature of exchange rates is time varying. In other words, I will argue that the RW should explain the exchange rates in recessions, since recession periods are characterized by uncertainty in the economy, while exchange rate models should work better in expansions.

In this study, I will start with a discussion of theories behind the determination of the exchange rate. The market fundamentals used for exchange rate predictions are obtained from these theories. I will also discuss the econometric models which are commonly used in the literature for prediction purposes.

After discussing the literature, I will present two studies based on the critiques regarding in-sample and out-of sample analysis. In the first chapter, I revise in-sample analysis results in literature by guarantying ECT is stationary. In the second chapter, I argue that whether the ECM or the RW explains the nature of exchange rates is time varying. The fundamentals used in the ECM are derived from the monetary model of exchange rate determination which will be discussed in the following section.

Finally, the structural differences between countries was not taken into consideration in these studies. When exchange rate is determined, the structural differences and the bargaining power of the countries are not considered. For example, when the US Dollar/Euro exchange rate is determined, military, economic, and technological power differences of the two countries might be a crucial factor. However, in exchange rate literature, it is assumed that all countries have the

same index of power. It should be noted that if the countries have different power, then it might be more realistic to consider bargaining equilibrium for exchange rate determination instead of Walrasian equilibrium. Under this assumption, different results might be obtained, but as stated earlier, I do not consider this assumption here.

II. Exchange Rate Determination

Exchange rates are prices that are determined by supply and demand. If we want to understand why some currencies depreciate and others appreciate, we must investigate the factors that cause the change in supply and demand of currencies. Carbaugh (2008) states that these factors include market fundamentals such as real income, inflation rates, real interest rates, consumer preferences, and government trade policy. Market fundamentals also include market expectations such as news about future market fundamentals and traders' opinions about future exchange rates. Now, I will briefly discuss the theories behind the determination of the exchange rate.

A) Purchasing Power Parity (PPP) Theory

The oldest theory of exchange rate determination is the purchasing power parity theory, commonly attributed to Cassel (1918). Two versions of the PPP are distinguished, the absolute and the relative one. The simplest concept of purchasing power parity is the law of one price. It states that an identical good should be sold at identical prices in all nations.

According to the absolute version of the theory, exchange rates are equal to the relative price of comparable commodity baskets containing the same amounts of the same commodities in two countries. It says that currency prices adjust to make goods and services cost the same everywhere.

There is also the relative version. It is the same model but applied to differences: the change in the exchange rate will compensate inflation differentials. That is, a country's currency will depreciate by an amount equal to the excess of domestic inflation over foreign inflation. In other words, a three percent inflation rate in the United States and a one percent inflation rate in Japan should imply a depreciation of the Dollar versus the Yen by two percent. Briefly, PPP states that price and inflation differentials change the exchange rates.

B) Traditional Flow Approach

This approach is also called the balance-of-payments view or the exchange rate market approach. According to Gandolfo (2002), "The traditional flow approach starts from the observation that the exchange rate is actually determined in the foreign exchange market by the demand and supply of foreign exchange, and it moves (if free to do so) to bring these demands and supplies into equality and hence (if no intervention is assumed) to restore equilibrium in the balance of payments" (p. 226). That is, exchange rate will move on in order to keep the balance of payments in equilibrium.

C) Uncovered Interest Parity (UIP)

UIP states that if funds flow freely across countries, the exchange rate between two countries is expected to change such that the dollar return on dollar deposits is equal to the dollar return on foreign deposit. If this parity does not exist, there is an opportunity to make a profit. In other words, the expected change in the exchange rate (s_t) equals the current interest rate differential, $i_t - i_t^*$,

$$E_t(s_{t+h}) - s_t = i_t - i_t^*$$

According to UIP, under the assumption floating exchange rates, a nation that has relatively high real interest rates finds its currency appreciating. Briefly, UIP states that the interest rate differentials affect the exchange rates.

D) Monetary Model of Exchange Rate Determination

According to the monetary model of exchange rate determination, nominal exchange rate fluctuations should reflect movements in a country's relative money, output, interest rates and prices. The monetary model of exchange rate determination is based on money demand functions, uncovered interest parity, and purchasing-power parity.

i) Money Market Equations:

$$m_t - p_t = \beta y_t - \lambda i_t \quad (1)$$

$$m_t^* - p_t^* = \beta y_t^* - \lambda i_t^* \quad (2)$$

β is the income elasticity of money demand, and λ is the interest rate semi-elasticity of money demand in a home country. m_t , p_t , y_t and i_t denote the log-levels of the money supply, the price level, income, and the level of the interest rate, respectively, at time t . Money demand parameters are identical across countries, and asterisks denote foreign country variables.

ii) Uncovered Interest Parity (UIP):

$$i_t - i_t^* = E_t[s_{t+1}] - s_t \quad (3)$$

iii) Purchasing Power Parity (PPP):

Price levels and the exchange rate are related through purchasing-power parity.

$$s_t = p_t - p_t^* \quad (4)$$

When we solve money market equations with respect to p_t and p_t^* and plug into the equation (4), we get the flexible price version of the monetary model which is also known as the **Frenkel-Bilson model**.

$$s_t = (m_t - m_t^*) - \beta(y_t - y_t^*) + \lambda(i_t - i_t^*) \quad (5)$$

There are more general monetary models that include additional predictors. In the presence of sticky price adjustment, inflation differentials ($\pi_t - \pi_t^*$) are included to the Frenkel-Bilson model to obtain the "sticky price version of the monetary model", that is also known as the **Dornbusch-Frankel model**. On the other hand, trade balance differentials ($TB - TB^*$) are included to Dornbusch-Frankel model to obtain the **Hooper-Norton model**.

E) Monetary Approach to the Balance of Payments

The monetary approach to the balance of payments was developed in the 1950s and 1960s by Jacques J. Polak, Harry G. Johnson, and Robert A. Mundell. Gandolfo (2002) states that the main point of the monetary approach was to stress that the balance of payments is essentially a monetary phenomenon and therefore must be analyzed in terms of adjustment of money stocks. The balance of payments disequilibria are in fact monetary symptoms of money-stock disequilibria which correct themselves in time, if the money stock is allowed to adjust itself automatically.

Under the flexible exchange rate system, suppose an increase in domestic credit raises money supply relative to money demand. Then, the balance of payments must go into deficit. A deficit in the balance of payments resulting from an excess money supply leads to an automatic depreciation of the nation's currency; this causes prices and therefore the demand for money to rise sufficiently to absorb the excess supply of money. Therefore, balance of payment deficits will be automatically eliminated.

Now, suppose money demand increases relative to money supply. Then, the balance of payments must go into surplus. A surplus in the balance of payments resulting from an excess money demand leads to an automatic appreciation of the nation's currency, which tends to reduce domestic prices. This will eliminate the excess demand for money and the balance of payments surplus. As a result, balance of payments problems result directly from imbalances in the money market, and these imbalances change exchange rates.

F) Asset-Pricing Approach

The increasing amount of trading of financial assets has required a reconsider of its impact on exchange rates. Several economists started to consider that the economic variables such as economic growth, prices, money supply, and interest rates are not the only factors of currency changes. Instead, economists started to think of currencies as any other assets.

Engel and West (2005) showed that existing exchange rate models can be written in a present value asset-pricing format. In these models, exchange rates are determined not only by current fundamentals but also by expectations of what the fundamentals will be in the future.

Engel and West (2005) examine asset-pricing models of the form:

$$p_t = (1-b)\sum_{j=0}^{\infty} b^j E_t (a_1^T x_{t+j}) + b\sum_{j=0}^{\infty} b^j E_t (a_2^T x_{t+j}) \quad (6)$$

Where x_t is the $n \times 1$ vector of fundamentals, b is a discount factor, and a_1 and a_2 are $n \times 1$ vectors. In this form asset price, p_t , can be expressed as a discounted sum of current and expected future fundamentals. The general form of the asset price model relate the exchange rate to economic fundamentals and to the expected future exchange rate. We write this relationship as:

$$s_t = (1-b)(f_{1t} + z_{1t}) + b(f_{2t} + z_{2t}) + bE_t(s_{t+1}) \quad (7)$$

f_{it} denotes observable fundamentals such as price and income differences, and z_{it} stands for unobservable fundamentals (shocks) such as money demand shocks, productivity shocks, etc. By following Engel and West (2005), iterating forward and imposing no-bubbles condition that $b^j E_t(s_{t+j})$ goes to zero as j goes to infinity, we have the following present-value relationship:

$$s_t = (1-b) \sum_{j=0}^{\infty} b^j E_t (f_{1t+j} + z_{1t+j}) + b \sum_{j=0}^{\infty} b^j E_t (f_{2t+j} + z_{2t+j}) \quad (8)$$

This equation has the form of the equation (6), where we have $a_1^T x_{t+j} = f_{1t+j} + z_{1t+j}$ and $a_2^T x_{t+j} = f_{2t+j} + z_{2t+j}$.

III) Statistical Approach to Evaluate Exchange Rate Models

Several models have been used in the literature in an attempt to predict exchange rates. Before reviewing the detail of models, I will briefly explain how models are evaluated in the literature in terms of predictive ability. First, I will explain in-sample and out-of sample analysis used in exchange rate literature, since the predictive ability of the exchange rate models can be evaluated according to in-sample fit or out-of sample forecast performance.

In-sample analysis means to estimate the model using all available data. In-sample fit is typically evaluated by estimating a model's parameters and R^2 's over the full sample and calculating t-test. If the test rejects, it states that the fundamental contains useful information for explaining exchange rate fluctuations over the full sample.

To evaluate a model's out-of sample forecasting ability, the sample is split into two parts: the **in-sample portion** for estimation (model fitting) and the **out-of sample portion** for evaluating forecasting performance. Then, the model parameters are re-estimated progressively over time based on the in-sample portions under the rolling window forecast scheme, and these windows include all previous data. Since the window width increases by one observation for each

regression, we sometimes call these windows as increasing windows. New forecasts are generated based on these in-sample fits.

The models' performance is typically evaluated relative to the RW as the benchmark model since Meese and Rogoff (1983). The forecasting ability of the model is measured by a loss function; for example, common choices are the Mean Absolute Forecast Error (MAFE), Root Mean Squared Forecast Error (RMSFE) and Mean Squared Forecast Error (MSFE). If the value of chosen loss function for the model is less than the one obtained from the RW, then the model forecasts outperform the RW forecasts.

IV) Literature Review

Researchers generally use price, interest rate, income, and money supply differentials, future exchange rates and future market fundamentals as predictors in the exchange rate literature. These fundamentals come from the exchange rate determination part as discussed earlier. Based on these predictors, there are many studies testing exchange rate predictability. The objective of this part is to review the models and literature on predicting exchange rates.

The monetary approach to exchange rate determination emerged as the main exchange rate model in the early 1970s and remained an important exchange rate model. However, Meese and Rogoff's (1983) finding that monetary models' forecasts could not outperform simple random walk forecasts was a devastating critique of standard models and created a crisis in exchange rate economics. What Meese and Rogoff did in their study was to examine the out-of sample predictive performance of the models where exchange rate fluctuations are explained by the **simple single-equation linear models**. They used three version of the monetary models which have already been discussed in the monetary model of the exchange rate determination previously.

Contrary to Meese and Rogoff (1983), Mark (1995) reported that monetary fundamentals may contain predictive power for exchange rates, at least in the long horizon, by using **single-equation ECM**. Since Mark's work, the ECM has been widely used. Essentially, Mark used the Frenkel-Bilson model assuming that $\beta=1$ and the interest differential is equal to zero, so that the fundamental term is $f_t = (m_t - m_t^*) - (y_t - y_t^*)$. In this model, error correction term $z_t = f_t - s_t$ shows the difference between the current fundamentals (f_t) and the current exchange rate (s_t). These are cointegrated with the cointegration vector $[1 \ -1]^T$. Error correction term determines the k-period-ahead change in the exchange rate:

$$s_{t+k} - s_t = \alpha_k + \gamma_k z_t + v_{t+k,t} \quad k=1,2,\dots,K$$

$z_t = f_t - s_t$: deviation of the spot exchange rate from its fundamental value (or long run equilibrium exchange rate).

$f_t = (m_t - m_t^*) - (y_t - y_t^*)$: fundamental value of log exchange rate where m_t and y_t denote the log of money supply and of real GDP, respectively, and asterisks represent the United States quantities.

According to Berkowitz and Giorgianni (2001), this error-correction representation is motivated by the assumption that exchange rates cannot move independently of macroeconomic fundamentals over the long run.

On the other hand, Chinn and Meese (1995) confirm that fundamental exchange rate models forecast no better than a RW model for short-term prediction horizons. For longer horizons, these models significantly outperform the RW model. The model that they used in their study is the same model used by Mark (1995). Their fundamental values comes from the monetary model of the exchange rate determination. Moreover, using exactly the same ECM specification used by Mark, Kilian (1999) and Groen (1999) does not find predictive ability for the monetary model at

long horizons, whereas Rossi (2005) does. In literature, there is a common consensus that single equation ECM works at longer horizons. However, most of the studies are unable to document short-run exchange rate predictability.

Even though most of the literature focuses on linear models, there are also some researchers pursuing the **nonlinear modeling of exchange rates**. One of the most common nonlinear models used in the exchange rate literature is **Markov Switching models**. The Markov Switching models relax the assumption that all the observations on a particular time series are drawn from a normal distribution with constant mean and variances over the sample period. According to the Markov Switching models, a series is separated into finite sequences of distinct regimes, and all estimated parameters are allowed to vary over the number of regimes considered.

Engel (1994) showed that a Markov Switching fits well in-sample for many exchange rates for exchange rates at quarterly frequencies. By the mean squared error criterion, the Markov model does not generate superior forecasts to a random walk.

Frömmel et al. (2005) use the real interest differential (RID) model which is an extended version of the Frankel-Bilson model by introducing Markov regime switches for three exchange rates, over the years 1973–2000. He finds the evidence of a non-linear relationship between exchange rates and the fundamentals. Also, Mahavan and Wagner (1999), Marsh (2000), Taylor and Peel (2000), and De Grauwe and Vansteenkiste (2007) study to analyze the monetary model in a nonlinear model for a set of main bilateral exchange rates, and they provide support in favor of a fundamental model.

In literature, traditional **multi-equation vector error correction model (VECM)** is also used. The single-equation ECM model is a simplification of the traditional multi-equation VECM

model. The empirical evidence on VECMs is mixed. MacDonald and Taylor (1993) finds positive evidence while Rapach and Wohar (2002), and Diebold, Gardeazabal and Yilmaz (1994) find more negative results. Moreover, Sarantis (1994) uses the Johansen multivariate cointegration framework to examine the three variants of the monetary approach to the long-run exchange rate model by using four bilateral sterling exchange rates. He does not find cointegration relation between exchange rates and monetary fundamentals.

Several **panel models** also have been estimated in the literature. The empirical studies in the literature suggest that the panel ECMs are quite successful for the monetary model. With panel techniques, the models generally produce better forecast than the random walk model.

Mark and Sul (2001) showed dominance of fundamentals over the random walk out-of sample forecasts. Their panel cointegration test suggests that the nominal exchange rate is cointegrated with fundamentals, and that fundamentals contain significant predictive power for future exchange rate movements.

Cerra and Saxena (2010) tested for cointegration and out-of sample fit of monetary models for the nominal exchange rate for a large panel of industrial, emerging market, and developing countries. For the in-sample analysis, they find strong evidence of cointegration between nominal exchange rates, relative money supplies, and relative output levels. For the out-of sample analysis, they find that the fundamentals based models beat a random walk and random walk with drift in terms of RMSFE. Also, Groen (2005) and Engel, Mark and West (2007) suggest that panel ECMs are quite successful for the monetary model.

Chapter 1: In-sample Analysis of Exchange Rate Predictability

1.1) Introduction

This study is based on the critique related with in-sample analysis followed by literature. The model used in this study is the long horizon regression approach (or ECM) used by Mark (1995). Since the long horizon regression approach derived from the VECM, the error correction term (ECT) must be stationary in order for the long run regression to make sense. According to the long-horizon regression approach in the exchange rate literature, it is assumed that nominal exchange rates and fundamentals are cointegrated with the cointegration vector $[1 \ -1]^T$. However, if $[1 \ -1]^T$ cointegration vector does not make ECT stationary, then the regression results between fundamentals and exchange rate changes would be meaningless. However, ECM literature overlooks the fact that the assumed cointegration vector $[1 \ -1]^T$ might not be able to give us stationary ECT. Also, the results are interpreted as if there is a long run relationship between fundamentals and exchange rates with the assumed cointegration vector, even if this long run relationship does not in fact exist. The VECM will be used to estimate the true cointegration vector in order to remove this problem. When I guarantee that ECT is stationary, then I will plug into the long horizon regression and estimate the regression coefficients for different horizons. In doing so, country specific income elasticities of money demand will be used for different countries.

1.2) Model

The model used in this study is long horizon regression approach used by Mark (1995). Essentially, Mark used the Frenkel-Bilson model assuming that $\beta=1$ and the interest differential is equal to zero, so that the fundamentals term is $f_t = (m_t - m_t^*) - (y_t - y_t^*)$. The long-horizon regression approach entails estimating K individual equations,

$$s_{t+k} - s_t = \alpha_k + \gamma_k z_t + v_{t+k,t} \quad k=1,2,\dots,K \quad (9)$$

According to the model, if the spot exchange rate (s_t) is not equal to the fundamental value or long run value of exchange rates (f_t), the spot exchange rate will adjust itself and converge to its fundamental value under the assumption of no government intervention. As a result, current deviations from the fundamental value of the exchange rate are expected to be useful for predicting future changes of the exchange rate. For example, suppose $f_t > s_t$. Then, s_t will adjust itself and increase. That is, national currency will depreciate since being s_t lower than f_t creates foreign trade deficits for the home country.

In this model, if the γ_k 's, the associated t-statistics, and the regression R_k^2 are found to increase with k , it is generally concluded that error correction term $z_t = f_t - s_t$ can explain long-run movements in s_t better than short-run changes.

As it is said earlier, exchange rates and fundamentals are expected to be cointegrated in this model. If we are unable to reject the null hypothesis that $(f_t - s_t)$ is nonstationary for any of the exchange rates considered, then the regression results are worthless. However, neither Mark (1995) nor Chinn and Meese (1995) are unable to reject the null hypothesis that $(f_t - s_t)$ is nonstationary for any of the exchange rates considered in their studies.

1.3) Data

The data are quarterly observations for the United States, Canada, Japan and Switzerland. The United States is the numeraire country. The sample consists of 163 observations extending from 1973:Q2 to 2013:Q4.

The exchange rates are United States dollar prices of the foreign currency and were obtained from OECD Main Economic Indicators. The currency values are United States dollar prices of the Canadian dollar, the Swiss franc, and the Japanese yen from 1973 to 2013, and the

evidence is based on estimated projections of 1, 4, 8, 12, and 16 quarter changes in the log exchange rate on the deviation of the current log exchange rate from its "fundamental value".

The monetary variable used to construct the fundamental value in the Swiss franc, Japanese yen, and Canadian dollar regressions is M1. M1 data were obtained from International Monetary Statistics (IFS) and Federal Reserve Economic Data (FRED). These monetary variables are seasonally adjusted.

Nominal income is measured by quarterly nominal GDP and were obtained from IFS. These nominal income data are seasonally adjusted and are deflated by GDP deflator.

1.4) Relationship to the Vector Error-Correction Model

The long horizon regression approach is derived from VECM by following Berkowitz and Giorgianni (2001). The long-horizon approach is based on the assumption that nominal exchange rates and fundamentals cointegrated with cointegration vector $[1 \ -1]^T$. We assume that both f_t and s_t are integrated of order one, $I(1)$. Then, there exists a valid VECM representation based on the Granger representation theorem:

$$\Delta s_{t+1} = \lambda_1(f_t - s_t) + \omega_{1,t+1} \quad (10)$$

$$\Delta f_{t+1} = \lambda_2(f_t - s_t) + \omega_{2,t+1} \quad (11)$$

The drift components are omitted from the VECM for simplicity. The two terms represented by $\omega_{1,t+1}$ and $\omega_{2,t+1}$ are white noise disturbance terms, and long run equilibrium is attained when $f_t = s_t$. Given that $\omega_{1,t+1}$ and $\omega_{2,t+1}$ are stationary, it follows that the linear combination of f_t and s_t must also be stationary; hence, f_t and s_t must be cointegrated with cointegration vector $[1 \ -1]^T$. The essential point is that the error correction representation necessitates the two variables be cointegrated.

By following Berkowitz and Giorgianni (2001), since $z_{t+1} = f_{t+1} - s_{t+1}$,

$$\Delta z_{t+1} = \Delta f_{t+1} - \Delta s_{t+1}$$

$$\Delta z_{t+1} = \lambda_2 z_t + \omega_{2,t+1} - \lambda_1 z_t - \omega_{1,t+1}$$

$$z_{t+1} = (1 + \lambda_2 - \lambda_1) z_t + \omega_{2,t+1} - \omega_{1,t+1}$$

$$z_t = \phi z_{t-1} + \omega_t \text{ where } \omega_t = \omega_{2,t} - \omega_{1,t} \text{ and } \phi = 1 + \lambda_2 - \lambda_1 \quad (12)$$

Stationarity of the error correction term, $z_t = f_t - s_t$, requires $|\phi| < 1$. Exploiting the autoregressive structure of the z -process, we can write

$$z_{t+k} = \phi^k z_t + \xi_{t+k}, \quad \text{with} \quad \xi_{t+k} = \sum_{j=0}^{k-1} \phi^j \omega_{t+k-j} \quad (13)$$

By following Berkowitz and Giorgianni (2001), using some mathematical manipulation, the k -period change in the log spot rate can be written as

$$s_{t+k} - s_t = \left[\lambda_1 \left(\frac{1-\phi^k}{1-\phi} \right) \right] (f_t - s_t) + \sum_{j=0}^{k-1} \lambda_1 \phi^j \xi_{t+j} + \omega_{1,t+k} \quad k=1, \dots, K \quad (14)$$

Now, we can compare the equation (14) with long horizon regression (9) such that

$$s_{t+k} - s_t = \gamma_k (f_t - s_t) + v_{t+k,t}, \text{ where } \gamma_k = \left[\lambda_1 \left(\frac{1-\phi^k}{1-\phi} \right) \right] \quad (15)$$

Therefore, we conclude that the error correction term, z_t , must be stationary in order for the long run regression to make sense. In Table 1, we conduct a formal assessment of stationarity, using the Augmented Dickey-Fuller (ADF) (1979). The Akaike (1973) Information Criterion (AIC) is used to determine the optimal lag length.

Table 1: ADF Test for Error Correction Term, $z_t = (m_t - m_t^*) - (y_t - y_t^*) - s_t = f_t - s_t$

Countries	Test statistic for an ADF test on z_t	Number of lag selected by AIC
Canada	1.264*	1
Japan	1.228*	4
Switzerland	1.797*	1

Note: * denotes that we were unable to reject the null of a unit root on z_t for any countries at the 5 percent level.

Sometimes it is convenient to have stationarity as the null hypothesis. Therefore, the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) (1992) test of stationarity will be employed, since unit roots tests have poor power characteristics when the process is stationary but with a root it is close to the nonstationary boundary. The ADF unit root tests are for the null hypothesis that a time series is $I(1)$. Stationarity tests, on the other hand, are for the null that the time series is $I(0)$, and the most commonly used stationarity test is the KPSS test. In order to conduct this test, serial correlation lag length should be selected to calculate a robust estimate of the variance for the error.

Table 2: KPSS Test for Error Correction Term, $z_t = (m_t - m_t^*) - (y_t - y_t^*) - s_t = f_t - s_t$

Countries	Critical Values at %5 percent level	Test statistic for KPSS test on z_t	Selected Number of Lags
Canada	0.146	.665	1
		.282	4
		.172	8
Japan	0.146	1.48	1
		.603	4
		.346	8
Switzerland	0.146	.778	1
		.334	4
		.204	8

The ADF test result shows that we are unable to reject the null hypothesis that $z_t = f_t - s_t$ is nonstationary for any of the three exchange rates considered. Also, the KPSS test confirms these results for different lag lengths. Therefore, when the stationarity of z_t is tested for the sample period 1973-2013, it is seen that z_t is not stationary with the assumed cointegration vector $[1 \ -1]^T$. In other words, assumed cointegration vector $[1 \ -1]^T$ does not make z_t stationary for any of the countries. This violates the fact that error correction terms must be stationary for each individual country, and the estimation of the following long-horizon regression

$$s_{t+k} - s_t = \gamma_k + \gamma_k z_t + v_{t+k,t} \quad k=1,2,\dots,K$$

will be meaningless.

In order to avoid meaningless results, I use the VECM model for each country and estimate the cointegration vector among the variables between fundamentals and exchange rate, if the cointegration vector exists. When I estimate the true cointegration vector, I will assume country specific income elasticities of money demands for two reasons. First, the assumption that the distinct countries have identical income elasticities of money demand is indeed not a realistic assumption. Second, cointegration relation is not found for any of the three exchange rates under the assumption of identical income elasticities of money demands for different countries. Therefore, this assumption will be relaxed and use different income elasticities for different countries. Under the assumption of country specific elasticities, the definition of z_t will change and it can be rewritten as:

$$z_t = \beta_0(m_t - m_t^*) - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t$$

$$z_t = \beta_0 m_s t - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t, \text{ where } m_s t = m_t - m_t^*$$

As a result, this study follows a different path from the literature and the true cointegration vector $[\beta_0 \ \beta_1 \ \beta_2 \ \beta_3]^T$ will be estimated by assuming different income elasticities for home and foreign countries, if the cointegration vector exists. Then z_t , which is derived by the estimated cointegration vector, is plugged into the long horizon regression, and γ_k is estimated for various $k=1, 4, 8, 12, 16$.

1.5) Vector Error Correction (VECM) Representation

Consider a VAR with p lags

$$X_t = v + A_1 X_{t-1} + A_2 X_{t-2} + \dots + A_p X_{t-p} + \varepsilon_t \quad (16)$$

where X_t is a $N \times 1$ vector of variables, v is a $N \times 1$ vector of parameters, $A_i \ i=1,2,\dots,p$ are $N \times N$ matrices of parameters, and ε_t is a $N \times 1$ vector of disturbances s.t ε_t is iid(0, Σ). Using some algebra, we can write (16) as a VECM form:

$$\Delta X_t = v + \Pi X_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-i} + \varepsilon_t \quad (17)$$

where $\Pi = \sum_{j=1}^p A_j - I_n$ and Π has a rank $0 \leq r \leq N$, $\Gamma_i = -\sum_{j=i+1}^p A_j$.

Suppose that the vector X_{t-1} contains integrated of order one, $I(1)$, variables. Everything except the vector ΠX_{t-1} in the VECM is integrated of order zero, $I(0)$. This implies that the vector ΠX_{t-1} must also be $I(0)$. This is only possible that multiplying X_{t-1} by Π produces the linear combinations of X_{t-1} that are $I(0)$.

When Π has reduced rank $0 < r < N$ then it can be expressed as $\Pi = ac^T$, and both a and c are $N \times r$ matrices. c is a matrix containing the cointegration vectors. Hence, ΠX_{t-1} can be regarded as the **error correction term**. a is then called **speed of adjustment vector**.

1.6) Monetary Model in VECM Representation

The following VECM will be used

$$\Delta X_{t+1} = v + \Pi X_t + \sum_{i=0}^{p-1} \Gamma_i \Delta X_{t-i} + u_{t+1}$$

Where $X_t = \begin{bmatrix} ms_t \\ y_t \\ y_t^* \\ s_t \end{bmatrix}$ is a 4x1 vector of variables.

To test for cointegration or fit cointegrating VECMs, we must specify how many lags (p) to include. Based on the number of lags, the number of the cointegrated vector(s) will be determined. Before determining the number of cointegrated vector(s), we conduct a formal assessment of stationarity, using the Augmented Dickey-Fuller (ADF) test for the variables in X_t .

Table 3: ADF Test for the Variables ms_t , y_t , y_t^* , s_t

Canada	DF Test Statistic	Number of lags	5% Critical Value
ms_t	-1.412	1	-2.960
y_t	-1.285	4	-2.928
y_t^*	-1.577	12	-2.811
s_t	-0.927	4	-2.928
Japan			
ms_t	-1.627	1	-2.960
y_t	1.461	8	-2.874
s_t	-2.850	3	-2.939
Switzerland			
ms_t	-2.376	1	-2.960
y_t	-2.429	1	-2.960
s_t	-2.284	1	-2.960

Using Dickey-Fuller tests, we were unable to reject the null of a unit root in any of the four variables for any countries, and all variables are I(1).

1.7) Number of Cointegration Equations

The order of lag in VAR model with I(1) variables is found one for Japan and Canada, and two for Switzerland. The body of the Tables 4, 5, and 6 present test statistics and their critical values of the null hypotheses of no cointegration and one or more cointegration equations for Canada, Japan, and Switzerland, respectively.

Johansen's (1991) testing procedure starts with the test for zero cointegration equations (a maximum rank of zero) and then accepts the first null hypothesis that is not rejected. Tables 4 and 5 shows that we strongly reject the null hypothesis of no cointegration and fail to reject the null hypothesis of at most one cointegration equation for Canada and Japan. Thus, we accept the null hypothesis that there is one cointegration equation in the model for those countries. As can be seen from (17), the order of the corresponding VECM is always one less than the VAR. Therefore, there will not be any lagged variables in VECM for Japan and Canada.

However, Table 6 shows that there is not a cointegration equation for Switzerland and a linear combination of the I(1) variables, which is stationary, does not exist.

Table 4: The Number of Cointegration Equation(s) for Canada

Maximum Rank	Trace Statistic	5% Critical Value
0	160.38	53.12
1	32.22*	34.91
2	15.59	19.96
3	3.95	9.42
4		

Table 5: The Number of Cointegration Equation(s) for Japan

Maximum Rank	Trace Statistic	5% Critical Value
0	118.61	53.12
1	28.62*	34.91
2	6.45	19.96
3	0.62	9.42
4		

Table 6: The Number of Cointegration Equation(s) for Switzerland

Maximum Rank	Trace Statistic	5% Critical Value
0	44.60*	47.21
1	22.32	29.68
2	11.87	15.41
3	4.20	3.76
4		

The VECM with $r=1$ is written for Canada and Japan as:

$$\Delta ms_{t+1} = a_0 [(\beta_0 ms_t - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t)] + u_{1,t+1} \quad (18)$$

$$\Delta y_{t+1} = a_1 [(\beta_0 ms_t - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t)] + u_{2,t+1} \quad (19)$$

$$\Delta y_{t+1}^* = a_2 [(\beta_0 ms_t - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t)] + u_{3,t+1} \quad (20)$$

$$\Delta s_{t+1} = a_3 [(\beta_0 ms_t - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t)] + u_{4,t+1} \quad (21)$$

Then, since $z_{t+1} = \beta_0 ms_{t+1} - \beta_1 y_{t+1} + \beta_2 y_{t+1}^* - \beta_3 s_{t+1}$

$$\Delta z_{t+1} = \Delta ms_{t+1} - \beta_1 \Delta y_{t+1} + \beta_2 \Delta y_{t+1}^* - \beta_3 \Delta s_{t+1} \quad (22)$$

Note that the Johansen normalization restriction on the coefficient of ms_t , β_0 , is 1, in the cointegration equation for each country.

By following Berkowitz and Georgianni (2001) insert equations (18), (19), (20) and (21) into equation (22) and solve for z_t :

$$z_{t+1} = (1 + a_0 - \beta_1 a_1 + \beta_2 a_2 - \beta_3 a_3) z_t + u_{t+1} \text{ where } u_{t+1} = u_{1,t+1} - \beta_1 u_{2,t+1} + \beta_2 u_{3,t+1} - \beta_3 u_{4,t+1}$$

$$z_t = \phi z_{t-1} + u_t \text{ where } \phi = 1 + a_0 - \beta_1 a_1 + \beta_2 a_2 - \beta_3 a_3 \quad (23)$$

Stationarity of the error correction term, $z_t = m_t - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t$, requires $|\phi| < 1$.

Exploiting the autoregressive structure of z -process, we can write:

$$z_{t+k} = \phi^k z_t + \varepsilon_{t+k}, \quad \text{with} \quad \varepsilon_{t+k} = \sum_{j=0}^{k-1} \phi^j u_{t+k-j} \quad (24)$$

By using the same mathematical manipulation before, the k -period change in the log spot rate can be written as:

$$s_{t+k} - s_t = \left[a_3 \left(\frac{1-\phi^k}{1-\phi} \right) \right] (ms_t - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t) + \sum_{j=0}^{k-1} (a_3 \varepsilon_{t+j} + u_{4,t+j}) + u_{4,t+k}, \quad k=1, \dots, K$$

$$s_{t+k} - s_t = \gamma_k (ms_t - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t) + v_{t+k,t} \quad (25)$$

$$\text{where } \gamma_k = a_3 \left(\frac{1-\phi^k}{1-\phi} \right)$$

1.8) VECM Results

So far, one cointegration vector had been found Canada and Japan while zero cointegration vectors were found for Switzerland. Table 7 gives the summary of the VECM results for Canada and Japan.

Table 7: Estimation Results of Cointegration Vector

Cointegration Vector	Canada	Japan
β_0	1	1
β_1	10.78*	4.08*
β_2	8.52*	3.52*
β_3	9.42*	-5.44*

Note: Johansen normalization restriction on the coefficient of ms_t , β_0 , is one. * shows that estimated cointegration coefficients are statistically significant at the 5 percent level.

Now, new z_t can be defined for each country based on the VECM estimation results. Table 8 shows the estimated z_t .

Table 8: Estimated $z_t = (m_t - m_t^*) - \beta_1 y_t + \beta_2 y_t^* - \beta_3 s_t$

Countries	z_t
Canada	$z_t = (m_t - m_t^*) - 10.78y_t + 8.52y_t^* - 9.42s_t$
Japan	$z_t = (m_t - m_t^*) - 4.08 y_t + 3.52y_t^* + 5.44s_t$

After plugging in the estimated z_t , which is stationary, we can estimate regression

$$s_{t+k} - s_t = \alpha_k + \gamma_k z_t + v_{t+k,t} \quad k=1,2,\dots,K$$

for different $k = 1, 4, 8, 12, 16$ from short run to long run¹.

¹ The main issue when we include the estimated cointegration vector to form z_t in regression, is that we might have a generated regressors problem. Basically, we are using an estimate of z_t in the regression. The implication of generated regressors is biased standard errors, which impede proper inference making. However, the generated regressor problem here will not prevent us to obtain proper inference making. Pagan (1984) states that if one only tests the hypothesis $\gamma_k = 0$, the regression of $s_{t+k} - s_t$ against z_t yields all the information necessary and the estimator is perfectly efficient. The OLS estimator of the variance of γ_k is consistent, and the “asymptotic t-statistics” are valid. Since the hypothesis that I use is $\gamma_k = 0$ for different k , asymptotic t-statistics are valid in this study.

The methodology to compute heteroskedasticity and autocorrelation consistent (HAC) standard errors was developed by Newey and West (1987); thus, they are referred to as Newey-West standard errors. The Newey–West standard errors are used to adjust the covariance matrix of the parameters and produces consistent estimates when there is autocorrelation in addition to possible heteroskedasticity. The Newey-West standard errors are calculated conditionally on a choice of maximum lag. Normally, a lag length (L) exceeding the periodicity of the data will be sufficient; e.g. at least 4 for quarterly data. I follow Stock and Watson (2007) and determine the number of lags by $L = 0.75T^{1/3}$, where T is the sample length. Since $T=163$, lag length used in this study is 4.

Table 9: Regression Results for Canada

k	γ_k	R²	MSL
1	.001	0.01	0.296
4	.0055	0.05	0.096
8	.0116	0.11	0.025
12	.0202	0.18	0.005
16	.0315	0.30	0.000

Table 10: Regression Results for Japan

k	γ_k	R²	MSL
1	.0038	0.01	0.310
4	.0194	0.04	0.180
8	.0362	0.06	0.126
12	.0517	0.09	0.084
16	.0648	0.11	0.049

Table 9 and 10 contain the estimated slope coefficients, R^2 's, and marginal significance levels (MSL). The slope coefficients and R^2 's are getting slightly higher in magnitude for Japan and Canada when the horizon is extended. On the other hand, slope coefficients are only significant at $k=16$ for Japan, while they are significant at $k>4$ for Canada at 5 percent level. These results suggest that the fundamentals are useful to explain the changes in the logarithm of the exchange rates at least in the long horizon².

1.9) Conclusion

This study shows the in-sample fit of the ECM by using the data between 1973:Q2 and 2013:Q4. The fundamental value of exchange rate used in the ECM come from Frenkel-Bilson monetary model with country specific income elasticities and zero interest rate differentials.

When the fundamentals are tested in in-sample analysis, the exchange rates and fundamentals in the ECM should be cointegrated. In other words, their linear combinations should be stationary. If not, then the regression results would be meaningless. Therefore, instead of assuming the nominal exchange rates and fundamentals are cointegrated with cointegration vector

² As you recall, cointegration relationship was not found between Frenkel-Bilson version of fundamentals and exchange rates for Switzerland under the assumption of country specific income elasticities. Therefore, I also used different fundamental value, Dornbusch-Frankel version of fundamental value, for Switzerland. Dornbusch-Frankel model additionally adds inflation differentials on Frankel-Bilson model as discussed earlier in the monetary model of exchange rate determination part. By assuming country specific coefficients and nonzero interest rate differentials, I used the same Johansen VECM framework used above. Even though cointegration relationship is found between the new fundamentals and exchange rates, the new fundamentals are also not useful (statistically insignificant), even in the long horizon, to explain the changes in exchange rates for Switzerland.

$[1 \ -1]^T$, the cointegration vector that makes the error correction term, z_t , stationary is estimated by using the VECM.

This study has presented evidence that the fundamentals are useful to explain the long horizon changes in the logarithm of the exchange rates under the assumption of country specific income elasticities. Lengthening the forecast horizon results in rising values of γ_k and R_k^2 's, and makes γ_k values significant for Canada and Japan. However, for example, Mark (1995) does not find significant evidence in favor of the fundamentals for these countries with the assumed cointegration vector $[1 \ -1]^T$ even in the long run.

On the other hand, the fundamentals are not useful to explain the changes in the logarithm of the exchange rates for Switzerland, since the fundamentals and exchange rates are not cointegrated. This implies that running regression (9) for different k , as if the fundamentals and exchange rates are cointegrated with the assumed (not estimated) cointegration vector will give us meaningless results for Switzerland. However, several studies in the literature find evidence that fundamentals are useful at least in the long horizon to explain the changes in exchange rates for Switzerland, since these studies use the assumed cointegration vector $[1 \ -1]^T$. These results might not be reliable if there is not indeed a cointegration relationship for Switzerland. Therefore, using the cointegrated fundamentals and exchange rates (if cointegration exists) in the regression will give us more accurate results.

Chapter 2: Out-of Sample Analysis of Exchange Rate Predictability

2.1) Introduction

For many years, out-of sample analysis has been widely used for evaluating exchange rate models. The in-sample analysis briefly states that the model fits the data reasonably well by using all available data. For forecasting, a model that has the best results in the in-sample analysis does not have to give us best forecast values. Thus, many researchers use the out-of sample analysis in addition to the in-sample analysis to choose the best statistical model.

By out-of sample, we should understand that the data used in model fitting are different from those used in the forecasting evaluation. To evaluate the models' out-of sample forecasting performance, the sample is separated into two parts: the **in-sample portion** (or estimation sample) for estimation (model fitting) and the **out-of sample portion** (or forecasting sample) for evaluating forecasting performance. In this way, the out-of sample portion is reserved by not including it in the estimation sample, and reserved data is used in order to evaluate forecasting performance. Then, the model parameters are re-estimated progressively over time based on the in-sample portions under the rolling windows forecast scheme. Based on these in-sample fits, new forecast values are generated.

The majority of studies compare the out-of sample forecasting performance of the predictors with those of a random walk without drift (RW), as it has been shown to be the best predictor of exchange rates since Meese and Rogoff (1983). According to the RW, exchange rates are completely unpredictable.

In literature, the forecast evaluation process requires a loss function to be chosen to evaluate the forecasts. The forecasting ability of the model is measured by a loss function; for example, common choices are the Mean Absolute Forecast Errors (MAFE), Root Mean Squared

Forecast Errors (RMSFE) and Mean Squared Forecast Errors (MSFE). The loss function of the model is compared with the one obtained from the RW model as the benchmark model. Suppose we choose MAFE as the loss function. If the mean absolute forecast errors of the model ($MAFE_m$) are less than the mean absolute forecast errors of RW model ($MAFE_{rw}$), then it is concluded that the model forecasts beat the RW model. To judge whether or not the model forecasts are significantly better, one typically tests whether $MAFE_m - MAFE_{rw}$ is equal to zero against the alternative that the difference is negative using a t-test.

This study is based on criticizing the out-of sample procedure followed by literature. The out-of sample procedure used in the literature has two main problems:

- 1) The model parameters are re-estimated using all previous observations under the increasing rolling windows forecast scheme. However, this is not the reasonable way to produce forecast values.

In literature, the researchers generally use rolling regressions to produce forecasts of the models, but these rolling regressions use increasing windows which include all previous observations. According to the increasing windows practice, the sample is again split into two parts: the in-sample portion and the out-of sample portion. The parameter is estimated over time using the in-sample portion. In the next step, the new data is included in the in-sample portion. Then, model parameters are re-estimated progressively over time based on the in-sample portions (or all previous observations) under the rolling windows forecast scheme. In other words, for each window, the in-sample portion, including all previous observations, increases one by one, and the parameters are re-estimated. That is, in-sample portions or windows are expanding at each step.

Therefore, the economic agents use all previous observations to perform forecasting when increasing windows are used. However, economic agents have the tendency to use the new observations rather than the old observations when they are forecasting. Rolling regressions with fixed window widths will be used in order to overcome this problem. With this approach, I will add one new observation into my in-sample portion and leave out the oldest one for each regression under the rolling regression scheme. Therefore, my forecast values will be derived from the most recent observations, and each in-sample portion will have the same sample size for each regression.

There is an additional problem in using increasing windows under the rolling regressions forecast scheme. The researchers use different sample periods for out-of sample forecast evaluations in their studies. Based on the different samples, they use different choices of the window widths for estimation purposes. They also consider different initial in-sample portions for the selected window width. Specifically, if increasing windows are used, then the performance of the model might be sensitive to the choice of in-sample portions and window widths used for forecast evaluations. In other words, the results might not be robust to the choice of in-sample portions and window widths. For example, Kilian (1999) and Groen (1999) find that the long horizon predictability of the monetary model is sensitive to Mark's (1995) initial in-sample portion. On the other hand, Chinn and Meese (1995) state that their results are not sensitive to different initial in-sample portions. However, we should note that neither Mark nor Meese and Chinn used fixed windows when they ran rolling regressions.

On the other hand, when we use fixed window widths, then the sensitivity of results will be weakened, and the results will not be sensitive to choice of the initial in-sample portions. If we fix the window size, we will have the same forecast values no matter what in-sample portion you choose. Therefore, the potential robustness problem of choosing different initial in-sample portions

will be eliminated by using fixed windows contrary to the increasing windows practice. However, we still need to check robustness of results based on different window widths when using fixed windows.

2) As we recall, the forecasting ability of the models are measured by loss functions in the literature and these are MAFE, RMSFE, and MSFE etc. as stated earlier. Also, the RW is used as the benchmark to make a comparison between the performances of the models. Finally, loss functions are compared for the whole forecasting period to conclude whether the model beats RW or not.

In order to explain the problem at this stage, assume we take the average of absolute forecast errors for the whole forecast period and conclude that the RW beats exchange rate model. It might be true that the RW model outperforms the exchange rate model for the whole forecast period; however, we also might have some subperiods that the exchange rate model outperform the RW model. Thus, we might lose this valuable information by taking the average of absolute forecast errors for the whole forecasting period. More importantly, these different subperiods might have some common economic characteristics that we want to know. To put it more clearly: economies have expansion and recessions, and the dynamics are not the same in these periods. Recession periods are characterized by short termism and elevated information uncertainty in the markets. Knight (1921) defined uncertainty as peoples' inability to forecast the likelihood of events happening. Bloom (2014) states that uncertainty appears to increase during recessions since lower economic growth causes greater micro and macro uncertainty. For example, the volatility of stock markets, bond markets, exchange rates, and GDP growth all rise sharply in recessions and the macro uncertainty increases. According to Bloom, we can also examine micro uncertainty at different levels: industry, firm, plant or even individual product level. Thus, uncertainty appears

to rise during recessions at every level. Since uncertainty increases during recessions, the RW model is associated with recession periods. In recession periods, the elevated information uncertainty and short termism suggest that, a model that gives more weight to current information should work better. On the other hand, exchange rate models explain the exchange rate behavior when the future growth prospects of the economy are known with more certainty. Therefore, exchange rate models are expected to work better in expansion periods.

Therefore, I argue that whether or not the exchange rate models or the RW explains the nature of exchange rates is time varying. By using rolling regressions with fixed window widths, I will discuss that

- i) In recessions, RW should explain the exchange rate changes.
- ii) In expansions, exchange rate models should work better.

First, I determine the recession and expansion periods of each economy. Then, I derive forecast values by using rolling regressions with fixed window widths and calculate loss functions of the model and RW. Finally, I compare them for different recession and expansion periods.

Before finishing this section, I will give definitions of recession and expansion since these definitions are very important to determine the expansion and recession periods in the economies. In literature, the main indicator of a recession is two or more consecutive quarters of negative growth, and there is a very common consensus on this definition. O'Sullivan and Sheffrin (2007) states that "if real GDP falls for two consecutive quarters, then the economy is said to be in recession" (p. 311). On the other hand, O'Sullivan and Sheffrin define economic expansion as: "it is a period of economic growth measured by a rise in real GDP" (p. 310). In other words, it is an increase in the economic activity, and of the goods and services.

2.2) Model

I use the same long horizon regression approach (or ECM) as it is used in in-sample analysis. The only difference is that I will assume fundamentals and exchange rates are cointegrated with cointegration vector $[1 \ -1]^T$. In other words, home and foreign countries have the same income elasticity of money demand, which is equal to one, as it is suggested in the literature. Under this assumption, the model is again

$$s_{t+k} - s_t = \alpha_k + \gamma_k z_t + v_{t+k,t} \quad k=1,2,\dots,K$$

with $z_t = f_t - s_t = (m_t - m_t^*) - (y_t + y_t^*) - s_t$

2.3) Data and Procedure

The data are quarterly observations for the United States, Canada, Switzerland and Japan. Japan and Canada are large economies, and they are the main trade partners of the United States. Therefore, their economies are closely linked with the United States. On the other hand, Switzerland is not a main trade partner of the United States. The United States is again the numeraire country. The sample consists of 163 observations extending from 1973:Q2 to 2013:Q4.

I will use the rolling windows forecasting scheme with fixed window widths to measure the α_k and γ_k . Since the ECM is a long run model and gives the best results for the longest term, the result will be given only by $k=16$.

To evaluate the ECM model's out-of sample forecasting ability, the sample is split into two parts: the in-sample portion and out-of sample portion. My initial in-sample portion is 1973:Q2-1989:Q4. The ECM model is initially estimated for each exchange rate using data up to but not including the first forecasting period, 1990:Q1, and the forecast value for 1990:Q1 is generated. Then, the data for 1990:Q1 are added to the sample, and the data for 1973:Q2 are left out from the

sample. The ECM is re-estimated for the new sample 1973:Q3-1990:Q1 using rolling regressions, and the forecast value for 1990:Q2 is generated, etc. In this way, I refresh my in-sample portion by adding the newest data and removing the oldest data. It should be noted that the window width is fixed at 67 quarters for each regression. This procedure will end when the in-sample portion includes the 1993:Q2-2009:Q4 period since $k=16$. In this way, we produce the forecasts by using the most recent observations. Therefore, we have a more realistic assumption that the economic agent uses the most recent observations, rather than the old observations to make forecasts.

On the other hand, I will use absolute forecast errors (AFE) and mean absolute forecast errors (MAFE) to evaluate the forecast values. Also, the ECM have been considered successful or unsuccessful based on their ability to produce better forecasts than the RW as the benchmark model. According to the RW, the best predictor of exchange rates tomorrow is the exchange rate today. Thus, exchange rate changes are completely unpredictable:

$$E_t s_{t+k} - s_t = 0$$

The reason for generating forecast values starting from 1990:Q1 is to follow Tsay's (2008) suggestion regarding choosing the size of the in-sample portion. He suggests that a reasonable choice is $T/2$ for large T . Therefore, the reasonable in-sample size is about 74 (from 1973:Q2 to 1991:Q3). However, I narrowed the in-sample size down to 67 observations to include the more recent United States recessions into my forecast period. Therefore, I can see the effect of the economic recessions which occurred in the United States on Japan, Canada, and Switzerland. In this way, I have a chance to include the recession which occurred in the United States in 1990. Since Canada and Japan are main trade partners of the United States, and they are closely linked, it is reasonable to expect these recessions will also affect Canada and Japan seriously. However, since Switzerland is not a main trade partner of the United States, it is expected that the economic

recessions which occurred in the United States will not be as deeply effective as they were on Japan and Canada.

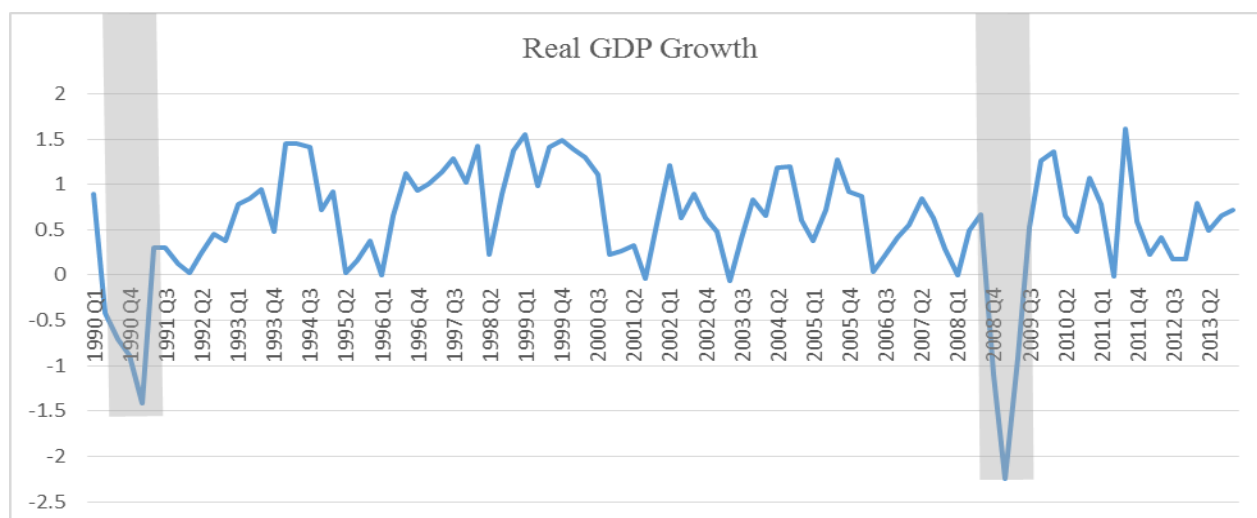
In closing, two quarters are added to the starting and ending points of the recessions when calculating the forecast errors after the recession periods are determined, since the effect of the recessions might still be seen just before and after the recession.

2.4) Results

2.4.1) Canada

As shown in Figure 1, Canada has two recessions for the period between 1990 and 2013. The first one is between 1990:Q2-1991:Q1, and the second is between 2008:Q4 and 2009:Q2. Therefore, except for the periods stated above, Canada has an expansion period and positive growth rates between 1990 and 2013. We should notice that Canada has similar recession periods to those which occurred in the United States. The recession in the United States beginning in 2000 hit the Toronto Stock Exchange, but Canada was affected only slightly. Even though the growth rates slightly slowed down during 2001, there is no recession for those periods in Canada. It is one of the rare times that Canada has escaped following the United States into a recession. Figure 1 is added in order to see the recession and expansion periods of Canada.

Figure 1: Real GDP Growth (Quarterly), Canada

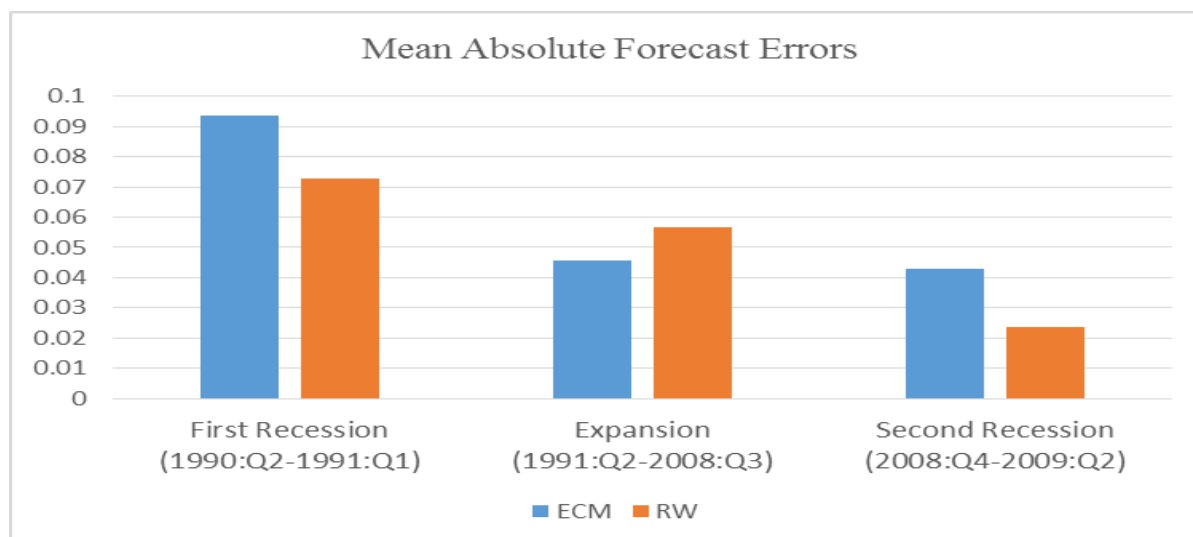


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Therefore, we can separate Canada's expansion and recession periods as follows:

- 1) 1990:Q2-1991:Q1.....First recession period
- 2) 1991:Q2-2008:Q3.....First expansion period
- 3) 2008:Q4-2009:Q2.....Second recession period

Figure 2: Mean Absolute Forecast Errors for Canada



The first blue and orange bars show the MAFE's for the first recession period, 1990:Q2-1991:Q1. This shows that the RW model beats the ECM for the first recession period, as expected. The second blue and orange bars show the MAFE's for the expansion period, and the ECM beats the RW model. Finally, the third blue and orange bar show the MAFE's for the second recession period, 2008:Q4 - 2009:Q2, and the RW model beats the ECM.

Table 11: Canada, t-test

Canada	1990:Q2-1991:Q1	1991:Q2-2008:Q3	2008:Q4-2009:Q2
MAFE _{ECM} /MAFE _{RW}	1.28*	0.80*	1.82*

Note: The coefficients show the MAFE_{ECM}/MAFE_{RW} for the corresponding period. * denotes MAFE_{ECM} - MAFE_{RW} is significant at the 5 percent level

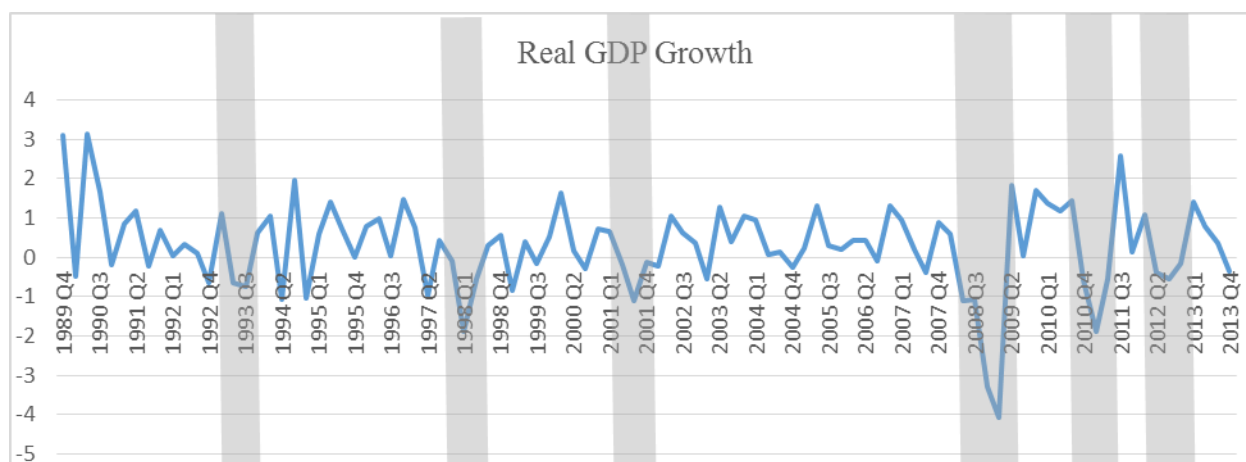
I also test whether differences between mean absolute forecast error of the ECM (MAFE_{ECM}) and mean absolute forecast error of the RW (MAFE_{RW}) are statistically significant or not using a t-test. Table 11 shows all differences are significant for Canada at the 5 percent level.

2.4.2) Japan

Before 1992, Japan's economic growth was extremely large. Japan's strong economic growth ended abruptly in 1992. When the asset bubble collapsed in 1992, Japan suffered a slow and even negative growth rates coupled with price deflation. After the bursting of a bubble, Japan experienced a financial crisis. Even though the asset price had collapsed in 1992, the economy's decline continued for a decade. The period from 1992 to 2002 is called as Japan's "**Lost Decade**" in economic literature. During the Lost Decade, economic statistics were gloomy, and economic agents in the economy were pessimistic. Starting from 1992, Japan had three recessions following ten year period. Figure 3 shows that Japan's economy expanded between 1995 and 1996, but it did not last long and ended up with the Asian financial crisis in 1997-1999. The Asian financial crisis affected Japan severely, and Japan's economy suffered from negative growth rates until the end of

1999. Also, Japan experienced another recession (2001-2002) following the financial crisis in the United States in 2001. As a result, during Japan's Lost Decade, uncertainty in the economy increased.

Figure 3: Real GDP Growth (Quarterly), Japan

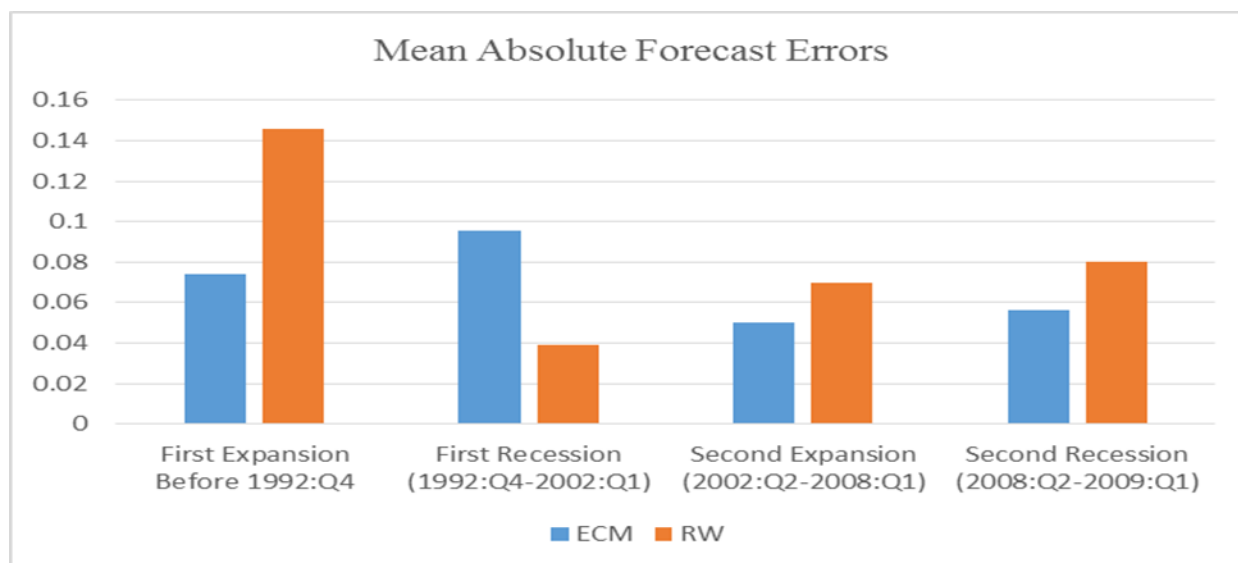


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On the other hand, Japan's economy finally began a sustained expansion in 2002, and this trend continued up to 2008. GDP growth exceeded the growth rates of the United States and the European Union during the same period. However, this expansion was ended by the economic recession in the United States, and Japan entered the recession period again starting from 2008. Therefore, we can separate the expansion and recession periods as follows:

- 1) Before 1992:Q4.....First expansion period
- 2) 1992:Q4-2002:Q1..... First recession period (Lost Decade)
- 3) 2002:Q2-2008:Q1..... Second expansion period
- 4) 2008:Q2-2009:Q1..... Second recession period

Figure 4: Mean Absolute Forecast Errors for Japan



Again, the blue bars show the MAFE's for the ECM and orange bars show the MAFE's for the RW model. Before 1992:Q4 (expansion period), the ECM beats the RW clearly. For the Lost Decade, 1992:Q4-2002:Q1, the RW beats the ECM while the ECM beats RW for the expansion period, 2002:Q2-2008:Q1, as expected. On the other hand, for the second recession period 2008:Q2-2009:Q1, the ECM forecasts outperform the RW forecasts, contrary to our expectations. However, this is not completely true, and I add Figure 5 in order to explain what is happening exactly in the last recession period.

Figure 5: Absolute Forecast Errors for Japan

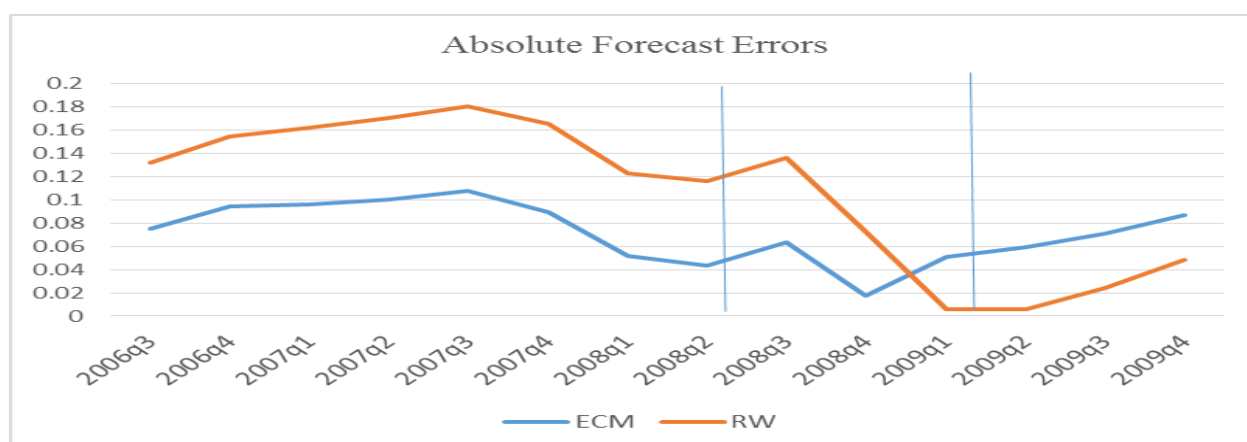


Figure 5 shows the AFE for the period between 2006:Q3-2009:Q4. The last recession period, 2008:Q2-2009:Q1, is shown between vertical blue lines. As is shown in Figure 5, the ECM forecasts outperform the RW forecasts before the recession period in 2008. In other words, economic agents adjust their expectations on exchange rates by observing fundamental variables before the recession. When the recession in 2008 starts, the economic agents still observe the fundamentals. When they are sure that this is a huge recession, they start to give more weights to the current information. Before the recession in 2008 ends, the RW finally starts to beat the ECM for some delay. While the ECM beat the RW forecasts during the recession period, 2008:Q2-2009:Q1, the RW forecasts outperform the ECM forecasts during 2009, and we still see the effect of the recession during 2009. The data ends up at 2009:Q4, since $k=16$ and we do not see beyond this period. As shown in Figure 3, Japan's economy suffers from the recessions starting from 2008, and each short expansion is followed by a recession. For example, Japan is hit by an earthquake and tsunami in 2011 after the short expansion between 2009:Q2-2010:Q3. Therefore, I extended my data to include the recession and tsunami period, 2010:Q4 -2011:Q2, and combined with the recession period 2008:Q2-2009:Q1. Figure 6 shows these results.

Figure 6: Mean Absolute Forecast Errors for Japan

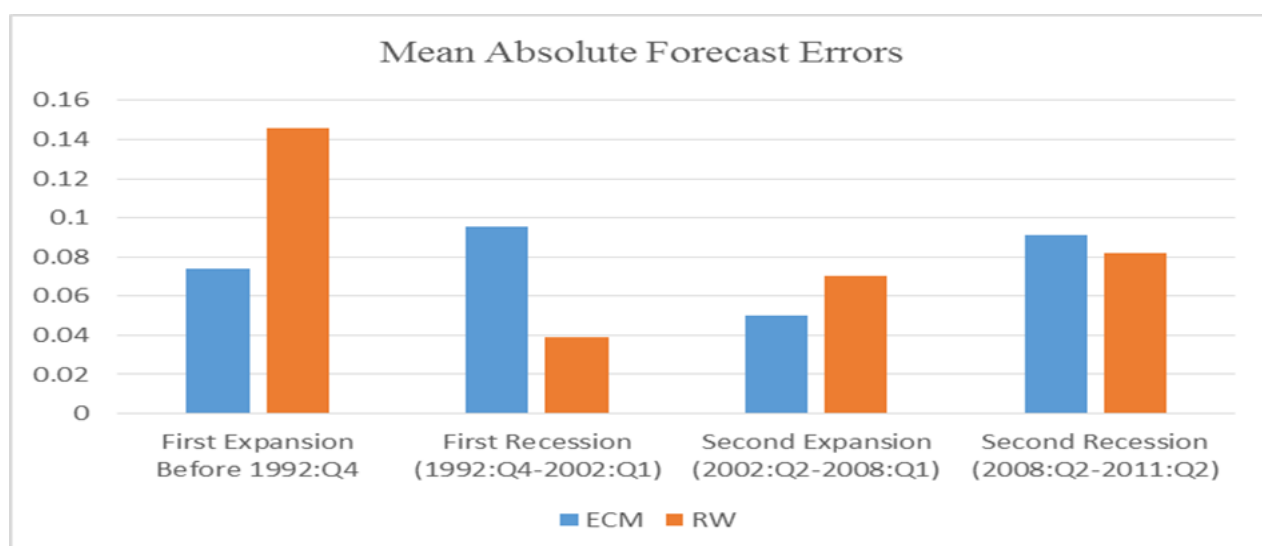


Figure 6 shows the MAFE's for both the RW and ECM similar to Figure 4. As is seen in Figure 6, the only difference is that the MAFE's in the second recession are given based on combining the consecutive two economic recessions, 2008:Q2-2009:Q1 and 2010:Q4-2011:Q2. As expected, the RW beats the ECM when two consecutive economic recessions were combined.

Table 12: Japan, t-test

Japan	Before 1992:Q4	1992:Q4- 2002:Q1	2002:Q2- 2008:Q1	2008:Q2- 2011:Q2
MAFE _{ECM} /MAFE _{RW}	0.50*	2.45*	0.71**	1.11

Note: The coefficients show the MAFE_{ECM}/MAFE_{RW} for the corresponding period. * and ** denote MAFE_{ECM} - MAFE_{RW} is significant at the 5 and 10 percent level, respectively.

Table 12 shows that all MAFE_{ECM} - MAFE_{RW} differences are significant for Japan at the 10 percent level except for the combined last two consecutive recessions. However, if I had a chance to extend my data period to include another recession, 2012:Q2-2012:Q4, it would be more likely to see MAFE_{ECM} - MAFE_{RW} differences also are significant for the combined last three consecutive recessions, 2008:Q2-2009:Q1, 2010:Q4-2011:Q2, and 2012:Q2-2012:Q4. The period starting from 2008:Q2 might be considered as the second Lost Decade of Japan.

2.4.3) Switzerland

Switzerland has mainly two recession periods for the period between 1990 and 2013. As seen in Figure 7, the first one is between 1990:Q3 and 1992:Q4 (early 1990s recession in Europe and United States), and the second is between 2008:Q4 and 2009:Q2 following the recession in the United States. At the beginning of the 1990s, Switzerland's economy showed negative growth, having the weakest economic growth in Western Europe. According to Switzerland's official national accounts, real output actually declined in 1991 and 1992. Switzerland's GDP then expanded between 1993 and 2008. The real growth came to 2% in 2008, while it contracted in 2009.

To sum up, Switzerland suffered from a recession from 1990:Q3 to 1992:Q4. The Swiss economy generally shows high growth rates during the following years; however, this expansion trend is interrupted by the recession from 2008:Q4 to 2009:Q2. Therefore, we can separate the expansion and recession periods as follows³:

- 1) 1990:Q3-1992:Q4.....First recession period
- 2) 1993:Q1-2008:Q3.....First expansion period
- 3) 2008:Q4-2009:Q2.....Second recession period

Figure 7: Real GDP Growth (Quarterly), Switzerland



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³ According to Figure 7, one can consider that there is another recession between 2002:Q4 and 2003:Q2. However, this recession affects real GDP only slightly; therefore, it is reasonable to expect that economic agents will not change their expectations on exchange rates dramatically for this mild recession. In other words, since real GDP is affected only slightly in this period, the uncertainty and pessimism in the economy will not be as deep as other two recessions. As a result, it is not unrealistic to consider that economic agents will not give more weight to the current information for this period. Therefore, I did not exclude this period from the huge expansion period between 1993:Q1 and 2008:Q3.

Figure 8: Mean Absolute Forecast Errors for Switzerland

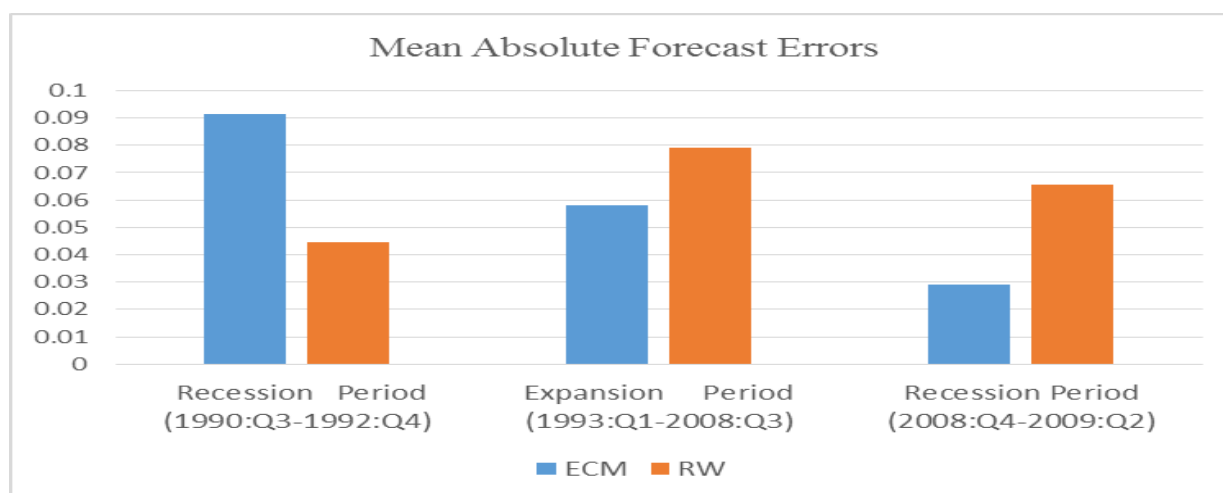


Figure 8 shows the MAFE for the ECM and the RW. The first blue and orange bar show the MAFE of the ECM and the RW for the first recession period, 1990:Q3-1992:Q4, and the RW beats the ECM. The second blue and orange bar show the MAFE of the ECM and the RW for the expansion time, 1993:Q2-2008:Q3, and the ECM beats the RW. However, the ECM outperforms the RW for the last recession period, 2008:Q4-2009:Q2, contrary to our expectations. How can we explain this controversy?

There might be two reasons for this controversy. Since Switzerland and the United States are not closely linked economies, and Switzerland is not one of the main trade partners of the United States, the financial crisis in the United States at 2007:Q4 does not affect Switzerland as much as it does Japan and Canada. In other words, Japan is one of the main trade partner of the United States, and Canada is both the main trade partner and neighbor of the United States. Therefore, economic agents in Canada and Japan feels the effects of the recession deeper than Switzerland. Also, there is a very long period that the ECM beats the RW before Switzerland's second recession period, and economic agents get used to observing market fundamentals during this long period. As a result, the second recession is probably not long and deep enough to change

the expectations on exchange rates and give more weight to the current information for the economic agents in Switzerland. Consequently, the economic agents do not change their expectations for the second recession period, and they still observe market fundamentals.

Table 13 shows that all $MAFE_{ECM} - MAFE_{RW}$ differences are statistically significant at the five percent level.

Table 13: Switzerland, t-test

Switzerland	1990:Q3-1992:Q4	1993:Q1-2008:Q3	2008:Q4-2009:Q2
$MAFE_{ECM}/MAFE_{RW}$	2.05*	0.73*	0.44*

Note: The coefficients show the $MAFE_{ECM}/MAFE_{RW}$ for the corresponding period. * denotes $MAFE_{ECM} - MAFE_{RW}$ is significant at the 5 percent level.

Table 14 shows the ratio of the $MAFE_{ECM}/MAFE_{RW}$ of the whole forecast period for the three countries instead of considering the time varying nature of exchange rates. These results show that if we do not take into account time varying nature of exchange rates, the ECM beats the RW for Canada and Switzerland while the RW beats the ECM for Japan during the whole forecast period. On the other hand, while the ECM beats the RW for Canada for the whole forecast period, the RW beats the ECM for its first recession period, 1990:Q2-1991:Q1. Therefore, if we overlook the time varying nature of the exchange rates, we miss the valuable information that some specific subperiods might have different results contrary to the whole forecast period.

Table 14: $MAFE_{ECM}/MAFE_{RW}$ Ratio for the Whole Forecast Period

Countries	Forecast Period	$MAFE_{ECM}/MAFE_{RW}$
Canada	1990:Q1-2009:Q4	0.90
Japan	1990:Q1-2009:Q4	1.24
Switzerland	1990:Q1-2009:Q4	0.85

2.5) Robustness of Results

I randomly chose different in-sample portions and window widths in order to determine the sensitivity of results by the choice of in-sample portions and window widths. Then, I derived forecast values by applying the same procedure discussed above and give the ratio of $MAFE_{ECM}/MAFE_{RW}$ based on each country's corresponding recession and expansion periods starting from 1990:Q1. The results are shown in Table 15, 16, and 17 for each country.

Table 15: Canada, $MAFE_{ECM}/MAFE_{RW}$ Ratios for the Expansion and Recession Periods

Window Width(year)	Initial In-Sample Portion	1990:Q2-1991:Q1	1991:Q2-2008:Q3	2008:Q4-2009:Q2
7	1973:Q2-1980:Q1	1.32	0.58	2.50
7	1979:Q4-1986:Q3	1.32	0.58	2.50
7	1982:Q3-1989:Q2	1.32	0.58	2.50
10	1973:Q2-1983:Q1	1.32	0.76	2.47
12	1973:Q2-1985:Q3	1.33	0.74	2.34
14	1975:Q1-1989:Q4	1.31	0.79	1.93
16	1973:Q2-1989:Q4	1.28	0.80	1.82
26	1973:Q2-1999:Q4			1.56

Note: The numbers in the table show the ratio of $MAFE_{ECM}/MAFE_{RW}$.

Table 16: Japan, $MAFE_{ECM}/MAFE_{RW}$ Ratios for the Expansion and Recession Periods

Window width(year)	Initial In-Sample Portion	Before 1992:Q4	1992:Q4-2002:Q1	2002:Q2-2008:Q1	2008:Q2-2009:Q1
7	1973:Q2-1980:Q1	0.65	1.39	0.68	0.51
10	1973:Q2-1983:Q1	0.60	1.63	0.80	0.69
12	1973:Q2-1985:Q3	0.48	1.74	0.71	0.75
14	1975:Q1-1989:Q4	0.49	2.21	0.79	0.75
16	1973:Q2-1989:Q4	0.50	2.45	0.71	0.70
26	1973:Q2-1999:Q4			0.71	0.79

Note: The numbers in the table show the ratio of $MAFE_{ECM}/MAFE_{RW}$.

Table 17: Switzerland, $MAFE_{ECM}/MAFE_{RW}$ Ratios for the Expansion and Recession Periods

Window width(year)	Initial In-Sample Portion	1990:Q3-1992:Q4	1993:Q1-2008:Q3	2008:Q4-2009:Q2
7	1973:Q2-1980:Q1	1.21	0.74	0.32
10	1973:Q2-1983:Q1	1.07	0.81	0.30
12	1973:Q2-1985:Q3	1.83	0.86	0.82
14	1975:Q1-1989:Q4	1.95	0.84	0.61
16	1973:Q2-1989:Q4	2.05	0.73	0.44
26	1973:Q2-1999:Q4			0.20

Note: The numbers in the table show the ratio of $MAFE_{ECM}/MAFE_{RW}$.

The first columns of Tables 15, 16, and 17 show different window widths. The second columns of the tables show the selected initial in-sample portions. The third, fourth, fifth, and sixth columns of the tables show the ratio of $MAFE_{ECM}/MAFE_{RW}$ for the corresponding recession and expansion periods starting from 1990:Q1 for each country. If the ratio is higher (lower) than one, then RW (ECM) beats the ECM (RW).

Table 15 shows the ratio of $MAFE_{ECM}/MAFE_{RW}$ based on different window widths and initial in-sample portions for Canada. As shown in Table 15, the magnitude of the ratios changes based on the different window widths, but the relationship between the ECM and the RW models does not change. In other words, if the ECM or the RW outperform each other for any of the recession and expansion periods, then the same successful model still outperforms the other for each window width for the same expansion and recession period. Therefore, we can conclude that using different window widths does not change the results for Canada. Similarly, Table 16 and 17 suggest that choice of the different window width does not change the relationship between the ECM and the RW for Japan and Switzerland, respectively. Depending on these results, no matter what different window width you choose, the results will be robust for each country.

I will use Table 15 in order to show that the results are not sensitive to the choice of in-sample portions. Suppose we fix the window width equal to 7 years (28 quarters). Then, the results are given according to randomly chosen three different initial in-sample portions (second, third, and fourth rows). The ratios are all the same for three of them, since the rolling regressions with fixed window widths give the same estimations and forecast errors for different initial in-sample portions. In other words, the ratios will be the same, no matter what initial in-sample portions you choose, when the window widths are fixed. That is why the results are not sensitive to the choice of the initial in-sample portion when we fix the window width.

2.6) Conclusion

For many years, the standard for evaluating exchange rate models has been an out-of sample fit. Out-of sample means that the data used in model fitting are different from those used in forecasting evaluation. This study is based on criticizing the out-of sample procedure followed by literature. First, I used rolling regressions with fixed window width instead of using rolling regressions with increasing window width. Therefore, the forecast values are derived from most recent observations. Also, we have robust results by choice of initial in-sample portions. Second, I argued that whether the ECM or the RW explains the nature of exchange rates is time varying, and the forecast period is separated for different recession and expansion periods. Then, loss functions are compared according to those periods instead of taking the average of the whole forecast period. Since uncertainty appears to increase during recessions, the RW model is associated with uncertainty and recession periods. On the other hand, the ECM model is associated with expansion periods, since economic conditions are known with more certainty, and economic agents can observe market fundamentals at expansion periods.

Generally speaking, the findings confirm the argument that whether the ECM or the RW explains the nature of exchange rates is time varying. During recessions, the RW explains the exchange rates changes better while, the ECM works better in expansions. I also check the robustness of results by choosing different window widths, and the results are robust.

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