

Revisiting Basic Exchange Rate  
Forecasting Techniques

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An Honours essay submitted to  
Carleton University in fulfillment  
of the requirements for the course  
ECON 4908, as credit toward  
the degree of Bachelor of Arts with  
Honours in Economics.

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Ottawa, Ontario

August 13, 2007



## **ACKNOWLEDGEMENTS**

I would like to thank my supervisor, Zhihao Yu, for his help and guidance in writing this essay.

# CONTENTS

LIST OF ILLUSTRATIONS .....	v
LIST OF TABLES .....	v
Chapter	
1. INTRODUCTION .....	1
2. LITERATURE REVIEW .....	3
3. EFFECTIVE EXCHANGE RATES .....	22
4. METHODOLOGY .....	28
Models	
Data and Time Periods	
Evaluation of Competing Models	
5. RESULTS .....	36
Bilateral Exchange Rate (CAD/USD)	
Canadian Effective Exchange Rate	
6. CONCLUSION .....	46
APPENDIX—DATA SOURCES .....	47
REFERENCE LIST .....	49

## ILLUSTRATIONS

### Figure

1. USD/CAD Exchange Rate, Monthly Closing Rate Average, 2004-2007. .... 22
2. Canadian Effective Exchange Rate, Broad 2004-2007, base year 2000, BIS ..... 23
3. U.S. Effective Exchange Rate, Broad 2004-2007, base year 2000, BIS ..... 23

## TABLES

### Table

1. Test of Real Interest Differential Hypothesis ..... 6
2. Bilson (1978) Summary Statistics from Dynamic Simulation ..... 9
3. Meese and Rogoff (1983) Summary Results, RMSE ..... 16
4. Bilateral Exchange Rates. Summary Results, RMSE and MAE ..... 37
5. Bilateral Exchange Rates. Measures of Goodness of Fit ..... 39
6. Weights Used for Econometric Analysis of Weighted Exchange Rate ..... 41
7. Canadian Effective Exchange Rate. Summary Results for Time Series Models, RMSE and MAE ..... 42
8. Canadian Effective Exchange Rate. Summary Results for Structural Models, RMSE and MAE ..... 44
9. Canadian Effective Exchange Rate. Measures of Goodness of Fit ..... 45

## **INTRODUCTION**

With the advent of the modern flexible exchange rate regime in the early 1970s, came a new era of uncertainty. Previously exchange rates had been closely managed by central banks around the world which had encouraged greater trade through expected exchange rates. With the arrival of floating exchange rates, individuals, firms, and governments could no longer expect a pre-determined exchange rate, but rather would have to face the uncertain and at times volatile exchange rates by formulating their own private forecasts of what the future would hold.

Since the early 1970s a vast literature has emerged which seeks to explain and address the determinants of exchange rates and their volatility. Nearly all economic agents need to make informed decisions regarding future uncertainty and academics, firms, and governments have attempted to bring a greater understanding to the subject. Despite the significant efforts made, there remains significant gaps in the literature. Various studies have attempted to study the significance of specific economic variables in relation to exchange rates or searched for underlying patterns in times series, and yet despite this, there remains a distinct inability to accurately and reliably forecast changes in the exchange rate.

Not only have simple bilateral exchange rates, but multilateral and effective exchange rates have been studied, but to little avail. These measures are meant to provide the user with a more general understanding about the value of a currency relative to a basket of other currencies. Thus forecasting movements in these measures are also of interest, and yet the performance of many models fail to adequately forecast these as well.

The purpose of this paper will be provide a review of some of the relevant exchange literature as it relates to out-of-sample forecasting and examine a variety of simple exchange rate forecasting techniques for their ability to accurately forecast future exchange rate movements.

The paper will begin with a general review of the literature explaining a number of simplistic models developed in the 1970s and 80s and general discussion of the progress of models since that time. The paper will also describe in detail the concept of effective and multilateral exchange rates and how they are computed, as well as their general relevance to the economic community.

The final section of the paper is an econometric review of a number of simple time-series and structural models. The intent of this exercise is to demonstrate the ability of various models to predict exchange rates relative to the 'benchmark' random walk model. Ultimately, this will provide support for the argument that exchange rates are largely unpredictable and follow a random walk.

## **LITERATURE REVIEW**

Since the collapse of Bretton Woods and the beginning of the flexible exchange rate regime, a vast body of literature has emerged which seeks to explain the movement of exchange rates and develop methodologies for the purposes of forecasting and prediction. Though the methods and models have increased in their complexity, they remain weak in their ability to fully explain and forecast.

The earliest and simplest method for forecasting the future exchange rate was to simply use the forward rate. A forward contract represents an agreement to exchange currencies at a specified rate at a predetermined date in the future. Thus many researchers argued that the market consensus for what the future rate would be was represented by the forward rate (Brown 1971, Kaserman 1973). Though simple, this measure is far from perfect. Kaserman (1973) found that he could not reject the null hypothesis that the forward rate was "a perfect predictor of the future spot rate," however he noted that the forward rate was "no where near perfect" and he reminds the reader that biases do exist and that there is considerable variation in the spot rate that is unexplained by the forward rate.

Cornell (1977) examines the topic further and carries out a joint test of market efficiency and accuracy of the Grauer, Litzenberger and Stehle (1976) model. Grauer, Litzenberger and Stehle (1976) had argued that "the difference between the settlement price of a forward exchange contract and the expected future spot price of foreign exchange is a function of the dependence between the future spot price of foreign exchange and and real gross world product." Cornell (1977) found that on average the liquidity premium on forward rates was zero and that the forward rate could "be used as a

proxy for the market's expectations of future spot rates,” while “the systematic risk of open exchange positions is insignificant.” However, despite this, the forward rate remained poor in its ability to accurately forecast future exchange rate changes.

Since these early studies a number of others have been conducted, Hakkio (1980), Hansen and Hodrick (1981), and Korajczyk (1985), amongst others, have tested the unbiased expectations hypothesis and generally found the forward rate was no better at predicting the future spot rate than many linear models. This failure has spurred the growth of a vast array of structural and time-series models which have attempted to explain and forecast exchange rates.

In the early 1970s, the leading theories suggested that the goods market determined the exchange rate. That is, as demand for a country's goods increased, demand for the country's currency must also increase. This increase in demand for a country's currency would put upward pressure on the exchange rate. Though simple and straightforward, this theory ultimately failed to explain the volatile exchange rate movements of the time. When exchange rate and balance of payments data were examined, it was found that the trade balance and the exchange rate were largely uncorrelated.<sup>1</sup> This lack of correlation can be explained by the fact that trade accounts for only a small share of the daily foreign exchange transaction volumes. (Lyons 2001)

The failings of this simple goods market approach encouraged other researchers to put forward various forms of an asset market approach to explain exchange rate changes. These researchers have argued that the asset market is perhaps more important than the

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<sup>1</sup> Using historical data from the U.S. Bureau of Economic Analysis and the U.S. Federal Reserve the correlation between the U.S. exchange rate and the US trade balance was found to be 0.0303.

goods market in explaining exchange rate movements because of the size of international capital/asset flows, and the very nature of financial asset markets.

An earlier view of the asset market approach came from Dornbusch (1977), who suggests a model for a small open economy with perfect capital mobility. Using a hypothesized monetary expansion Dornbusch explains the movement of the exchange rate. With an increase in the domestic money supply, neither the assets market nor the goods market will be in equilibrium. As the money supply increases, interest rates fall and this leads to a depreciation in the exchange rate. However, as people revise their expectations for future increases in the money supply and inflation, the exchange rate overshoots its equilibrium. Dornbusch assumes prices are slow to adjust, therefore demand for the country's goods will slowly put upward pressure on prices and interest rates. As interest rates increase, capital inflows will increase and put upward pressure on the exchange rate. Therefore, an increase in the money supply will lead to a depreciation in the exchange rate, which may overshoot its equilibrium value in the short-term, but will return to its long run equilibrium value as prices adjust. To summarize, Dornbusch's model assumes prices are sticky, in the short-term purchasing power parity (PPP) may not hold, and expectations may cause overshooting.

Frankel (1979) builds further upon the Dornbusch (1977) model and attempts to better quantify it. He maintains that there is a negative relationship between the exchange rate and the interest rate differential and that there is a positive relationship between the exchange rate and the expected long-run inflation differential. He also argues that the exchange rate will overshoot its equilibrium by the difference between the nominal interest rate differential and the expected inflation rate differential. The model put forth

by Frankel, herein referred to as Dornbusch-Frankel, in which logarithms of all values are taken can be reduced and expressed as,

$$e_t = m_t - m_t^* - \phi(y_t - y_t^*) + \alpha(r_t - r_t^*) + \beta(\pi_t - \pi_t^*) + u_t$$

where  $m$  represents the money supply,  $y$  represents real income,  $r$  represents the short term interest rate,  $\pi$  represents the expected inflation rate, and  $*$  represents the foreign country.

Frankel (1979) econometrically tested his model against the Dornbusch model and the Frenkel-Bilson model. For the time period chosen, Frankel was able to show that the coefficient of the interest rate differential was significantly less than zero and the coefficient of expected long-run inflation differential was significantly greater than zero. As such, Frankel provides evidence to reject the Dornbusch and Frenkel-Bilson models, and thus finds support for his model given the difference between the aforementioned coefficients.

Frankel's (1979) results are depicted below in table 1, from which we see Frankel's justification for the specification of the model. Ultimately his tests suggest that the model is robust and potentially suitable for forecasting purposes.

**Table 1 Test of Real Interest Differential Hypothesis (Sample July 1974 - February 1978)**

Technique	Constant	$m-m^*$	$y-y^*$	$r-r^*$	$\pi-\pi^*$	$R^2$	$D.W.$	$\hat{\rho}$	Number of Observations
OLS	1.33 (0.10)	0.87 (0.17)	-0.72 (0.22)	-1.55 (1.94)	28.65 (2.70)	0.80	0.76		44
CORC	0.80 (0.19)	0.31 (0.25)	-0.33 (0.20)	-0.259 (1.96)	7.72 (4.47)	0.91		0.98	43
INST	1.39 (0.08)	0.96 (0.14)	-0.54 (0.18)	-4.75 (1.69)	27.42 (2.26)		1.00		42
FAIR	1.39 (0.12)	0.97 (0.21)	-0.52 (0.22)	-5.40 (2.04)	29.40 (3.33)			0.46	41

*Source:* Frankel, Jeffrey, 1979, On the Mark: A theory of floating exchange rates based on real interest differentials, *American Economic Review* 69, no. 4: p. 615.

A second asset market approach to exchange rates was forwarded by Frenkel (1976) and Bilson (1978) who argued for flexible prices and for purchasing power parity to hold. Frenkel (1976) specifically examined the German experience with hyperinflation during the interwar period (1920-1923) in an effort to determine the effects of monetary policy and inflation on the exchange rate. He chose this time period as the cause of the rapid depreciation of the mark was known to be a monetary disturbance caused intentionally by the German monetary authorities, allowing him to isolate the specific variables of interest.

Frenkel assumed that the assumption of flexible prices is reasonable given the circumstances of his study, but the rationale for purchasing power parity to hold may be less clear. He argues that purchasing power parity appears to hold in instances of severe monetary disturbances as there is typically a high correlation between changes in the price level and the exchange rate. Also he argues that, in general, one might expect a liquidity premium to be present in the exchange rate, but in situations such as this expectations completely overshadow any liquidity premium in the determination of exchange rates.

In empirical tests, Frenkel finds support for his model. Using the limited data available for the period, Frenkel estimates his model to be:

$$\log S = -5.135 + 0.975 \log M + 0.591 \log \pi$$

$$(0.731) \quad (0.050) \quad (0.073)$$

$$R^2 = 0.994 \quad s.e. = 0.241 \quad D.W. = 1.91$$

Overall, this suggests good fit for the period under study.

Frenkel's model provided insight into the impact of monetary disturbances and the role of the two variables, but may be limited in its practicality for forecasting exchange

rates given the nature of his study. He admits that the exchange rate is “determined in general equilibrium by interaction of flow and stock conditions,” thus suggesting that it may not be possible to adequately model and forecast future spot rates with such a simple model.

On a side note, Frenkel (1976) also studies the efficiency of the exchange rate market and the forward rate for the period of interest. Using the data available he is unable to reject the null hypothesis that the exchange rate market is efficient. Regressing the spot rate on the forward rate defined in the previous period he finds good overall fit with an R-square of 0.98, a Durbin-Watson statistic of 1.90, and the coefficients are both reasonable and logical.

Bilson (1978) expands on Frenkel’s (1976) model and attempts to make it more generally applicable. Bilson (1978) still assumes that purchasing power parity holds, but he excludes the inflation rate differential. Instead, Bilson uses the interest rate differential to proxy the market’s inflation expectations. The basis for Bilson’s argument rests in the Fisher effect, which holds that the nominal interest rate is composed of the real interest rate and the market’s expectation of inflation. It is argued that this measure of inflation expectations is better than the use of past inflation data, as it better reflects forward-looking behaviour. The use of the interest rate differential also seems reasonable as covered interest arbitrage would take place if expectations were out of line.

Bilson’s (1978) model also incorporates a proxy to measure, what he calls, the “relative wealth of domestic residents” and the “relative volume of transactions” in the given currencies. He suggests using the ratio of the real incomes of the two countries. Additionally, Bilson includes a lagged variable to account for the slow changes in the

price level to the equilibrium level. The Bilson model, henceforth the Frenkel-Bilson model, can be reduced and expressed as:

$$\ln(S) = \beta_0 + \beta_1 \ln(M_t) + \beta_2 \ln(M_t^*) - \beta_3 (i_t - i_t^*) + \beta_4 \ln(y_t) + \beta_5 \ln(y_t^*) + \beta_6 t + \beta_7 \ln(S_{t-1}) + u$$

Bilson (1978) tested his model against a number of other simple models and finds supportive results. The adjusted regression results presented for the model follow:

$$\begin{aligned} \ln(S_t) = & -0.2494 & + 0.1882 \ln(M_t) & - 0.1848 \ln(M_t^*) & + 0.2600 (i_t - i_t^*) \\ & (0.9007) & (5.172) & (5.172) & (2.741) \\ & - 0.1691 \ln(y_t) & + 0.1911 \ln(y_t^*) & - 0.0009 t & + 0.8122 \ln(S_{t-1}) & + u_t \\ & (3.135) & (3.362) & (3.055) & (23.20) \end{aligned}$$

Standard error of regression = 0.0276    R-squared = 0.9807  
 Estimate of first-order autocorrelation coefficient = 0.2496 (2.336)  
 Durbin-Watson statistic = 1.9707

Based on the model's specification and the data available, it would appear that the model meets most expectations and seems to have good in-sample fit. Bilson also tested the above model against a other models to examine out-of-sample (predictive) fit. The results can be found in table 2 (below).

**Table 2 Bilson (1978) Summary Statistics from Dynamic Simulation**

Statistic	Monetary Model	Dynamic PPP Model	Simple PPP Model
Mean error	0.22	-0.12	-13.33
Standard error	5.67	4.34	11.32
Root-mean-square-error	5.68	4.34	17.55
Range of forecast error	25.26	19.43	49.92

Source: Bilson, John F. O. 1978. The "Speculative Efficiency" Hypothesis. *Journal of Business* 54, no. 3:435-451.

Though the monetary model presented by Bilson is outdone by the dynamic PPP model, the Frenkel-Bilson model does outperform the simple PPP model for out-of-sample prediction. Ultimately Bilson (1978) concludes that the behaviour of the exchange rate for the period under study is “consistent with the predictions of the monetary model.” However, he admits that the “tests undertaken in the paper are not strong enough to yield an indisputable affirmative conclusion on the validity of the model.”

Hooper and Morton (1982) build further on the asset market approach to exchange rates using the Dornbusch-Frankel model as a base. They expand the model with the addition of the current account balance, which they argue contains information about expectations for the long run real equilibrium exchange rate. They suggest that a change in the current account balance foreshadows a change in the real exchange rate. In addition to the current account balance, the authors also include a risk premium in their model and allow for structural changes.

In their empirical tests, the authors find support for the inclusion of the current account, which they argue, “suggests that unexpected changes in the current account and the trade balance serve equally well as indicators of real shocks requiring adjustments in the real exchange rate.” They do not however find significant evidence of a risk premium in the exchange rate. Overall their model appears to have good in-sample fit, but they fail to test their model out-of-sample.

More interestingly, Hooper and Morton (1982) chose not to test their model on simple bilateral exchange rates, but rather they used a trade-weighted dollar exchange rate. That is, the U.S. dollar was priced against a weighted basket of ten major

currencies.<sup>2</sup> Previous studies did not use multilateral exchange rates, but the authors argue that using a weighted exchange rate allows them to factor third-country effects into their model. They argue that this is the correct approach given the inclusion of the current account balance. The use of bilateral exchange rates would effectively eliminate any third country effects and since the current account is both influenced by and itself influences many bilateral exchange rates, a summary measure is deemed more appropriate.

Another early model to explain exchange rate movements was put forth by Dooley and Isard (1979). Dooley and Isard (1979) build upon the earlier works of Branson (1976) and Kouri (1976) and attempt to incorporate the trade balance into a portfolio balance model. The authors argue that “current-account balances can affect exchange rates by shifting the residence of wealth between regions with different portfolio balances.” The foundation of the theory lies in the assumption that asset markets clear and the expected level of exchange rate appreciation is equal to the difference between domestic and foreign interest rates, plus an exchange rate risk premium, where it is assumed that the domestic and foreign bonds are imperfect substitutes for one another. Ultimately the authors test their model using historical data and find poor fit. Their portfolio balance model was only able to explain a small proportion of the variance. They ultimately find that “the major part of observed exchange-rate changes may have been unexpected,” and thus largely not forecastable.

After the failure of the monetary models and portfolio-balance models to explain the decline in the dollar’s value against the German mark in the late 1970s and early 1980s, Frankel (1982) proposed a new model which incorporates real financial wealth. Frankel

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<sup>2</sup> The Belgian, Canadian, French, German, Italian, Japanese, Dutch, Swedish, Swiss, and British currencies were weighted according their multilateral trade shares.

suggests wealth should be added as a “transaction variable” in the money demand function.

Frankel (1982) tests two monetary models with a “real financial wealth” variable included. One version assumes price stickiness, while the other assumes prices to be flexible. When estimating the reduced form of the models, Frankel finds evidence in support of the inclusion of real wealth and good overall fit, though he does not test his model out-of-sample to make future exchange rate change predictions.

One possible area of concern may be the manner in which “real financial wealth” is measured. The concept of real financial wealth may be difficult to proxy. In his empirical tests, Frankel estimates real financial wealth by “adding federal government debt and the cumulation of past current account surplus, on a benchmark of \$400 billion for wealth in 1972, deflated by CPI.” Given the manner in which this proxy is calculated, the model will not be examined further in the empirical analysis which will follow in later sections.

By the mid-1980s a vast literature explaining exchange rates existed and yet scant agreement existed on the subject. A variety of models appeared to have good in-sample fit, but the continued unexpected and unexplained volatility cast doubt upon the accuracy of the various models. The result of such failings was a resurgence in the literature suggesting that the foreign exchange market was indeed weak-form efficient.<sup>3</sup>

As early as 1975, Giddy and Dufey were challenging those who had suggested that the post-Bretton Woods flexible exchange rates could be effectively modeled and forecasted. The authors specified a number of alternative models for predicting exchange rates and empirically tested them against one another. A number of these models would

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<sup>3</sup> According to the weak-form hypothesis, exchange rates reflect all information available, implying that fundamental and trend analysis will not provide additional insight into exchange rate movements. (Bodie, Kane, et al 2003)

also be tested in later studies examining the ability of forecasting models, most of which with similar results. The authors used five forecasting methods with forecast horizons of one day, seven days, thirty days, and ninety days ahead.

The first two forecasting methods were a martingale (random walk) and a submartingale, both of which imply an efficient market. The martingale model suggests that any future change in the exchange rate is unpredictable. The probability that the exchange rate will appreciate is exactly the same as the probability that the exchange rate will depreciate. Therefore, regardless of the information available, the forecaster will predict the future value of the exchange rate to be same as the present value. The second efficient markets approach is the submartingale, which is similar to the martingale except the forecaster will adjust the present value of the exchange rate by factoring in the yield difference between the two countries, thus considering covered interest arbitrage.

Giddy and Dufey (1975), like others, examine the ability of forward rates to predict the future spot rate and also test two simple time-series methods for predicting exchange rates. They use both the Box-Jenkins integrated autoregressive moving average (ARIMA) and Winters' method of exponential smoothing. These two methodologies attempt to forecast future exchange rate movements based on weighted historical movements. In the course of their study, the authors found that the simple martingale method fared the best when analyzed for its out-of-sample forecasting ability at most time-period horizons, while the forward rate proved to be the least accurate of the forecasting methods. The authors used mean square error as their measure of accuracy.

Since the Giddy and Dufey (1975) study, a number of others have suggested that the foreign exchange market is weak-form efficient, however none have had the impact

that was felt when Meese and Rogoff published their 1983 critique, which examined the ability of simple exchange rate models to predict exchange rate movements. The authors studied both structural models as well as time series models and found that “structural models fail to improve on the random walk model in spite of the fact that [the authors] base their forecasts on actual realized values of future explanatory variables” (Meese and Rogoff 1983).

Meese and Rogoff (1983) produced predictions for one to twelve month horizons using various structural models (Dornbusch-Frankel, Frenkel-Bilson, and Hooper-Morton), a martingale, and univariate and multivariate time series models. The authors used a three bilateral exchange rates and a trade-weighted dollar exchange rate and ultimately found that neither structural models nor the time series models provided results better than those of the random walk (martingale). In an attempt to give the structural models the benefit of the doubt, the authors used realized values of explanatory variables to forecast the spot rate and still the random walk outperformed. The results of Meese and Rogoff (1983) can be found in table 3.

The authors suggest three measures to evaluate out-of-sample forecasting accuracy: mean error, mean absolute error, and root mean square error. Meese and Rogoff presented their results using root mean square error as it was deemed most appropriate.

Overall, Meese and Rogoff (1983) found little support for forecasting exchange rates using the methods developed during previous ten years of flexible exchange rates. Amongst others, the authors suggest that the poor performance may have arisen as a result of simultaneous equation bias, sampling error, stochastic movements in the true parameters, and model misspecification. Taken together, this study suggests serious

failings in researchers' efforts to explain and forecast exchange rates and thus lends support to the argument that the foreign exchange market is efficient.

Exchange Rate	Model:	Random walk	Forward rate	Univariate autoregression	Vector autoregression	Frenkel-Bilson	Dornbusch-Frankel	Hooper-Morton
	Horizon							
\$/mark	1 month	3.72	3.20	3.51	5.40	3.17	3.65	3.50
	6 months	8.71	9.03	12.40	11.83	9.64	12.03	9.95
	12 months	12.98	12.60	22.53	15.06	16.12	18.87	15.68
\$/yen	1 month	3.68	3.72	4.46	7.76	4.11	4.40	4.20
	6 months	11.58	11.93	22.04	18.90	13.38	13.94	11.94
	12 months	18.31	18.95	52.18	22.98	18.55	20.41	19.20
\$/pound	1 month	2.56	2.67	2.79	5.56	2.82	2.90	3.03
	6 months	6.45	7.23	7.27	12.97	8.90	8.88	9.08
	12 months	9.96	11.62	13.35	21.28	14.62	13.66	14.57
Trade-weighted dollar	1 month	1.99	N/A	2.72	4.10	2.40	2.50	2.74
	6 months	6.09	N/A	6.82	8.91	7.07	6.49	7.11
	12 months	8.65	N/A	11.14	10.96	11.40	9.80	10.35

Source: Meese, Richard A., and Kenneth Rogoff. 1983. Empirical Exchange Rate Models of the Seventies: Do they fit out of sample? *Journal of International Economics* 14, no. 1:3-24.

In the wake of Meese and Rogoff (1983) a number of further efforts were made to develop and refine structural models, examine the results of Meese and Rogoff in the context of other models and periods, and to examine the causes of the poor out-of-sample fit.

In a follow-up study, Somanth (1986) examines structural models previously tested by Meese and Rogoff as well as other models, including Frankel (1982) and Branson et al (1977), for out-of-sample fit for a later time period. The Somanth study also took lagged considerations into account, since Woo (1985) had previously found evidence to suggest that a monetary approach to forecasting exchange rates with lagged adjustments outperformed the random walk in out-of-sample fit. In addition to using realized values of the explanatory variables, Somanth (1986) also attempted an extrapolative process whereby predictions were made of the explanatory variables, which were then used to predict future exchange rates.

Somanth's (1986) results confirm those of Meese and Rogoff (1983) for the period which they had studied, but he finds evidence that lagged structural models may outperform the random walk. For the Meese and Rogoff period he found that the lagged Bilson model outperformed the random walk. For the period after Meese and Rogoff, November 1980 to December 1983, Somanth found that a number of models outperformed the random walk using both the root mean square error and the mean absolute error as evaluation criteria. For a one year subperiod of the post Meese and Rogoff period, Somanth also finds evidence that lagged structural models outperformed at every horizon.

Meese and Rogoff (1988) revisit the topic of monetary models by empirically examining the relationship between real exchange rates and real interest rates. In their study they find that there does not appear to be a statistically significant relationship between the two variables and as a result they assert that the “real interest differentials do not provide significant improvement over a random-walk model in forecasting real exchange rates.” The authors hypothesize that it is real disturbances and shocks that result in the poor fit of monetary models. They suggest that it is these that cause the volatility, yet they maintain that it would be challenging to determine which real factors impacted the exchange rate and during which periods.

With the late 1980s, a new wave in exchange rate forecasting took hold, researchers began to consider more seriously nonparametric and nonlinear exchange rate forecasting and estimation. However, the results of non-linear estimation and prediction, like structural models, have been mixed.

Baillie and McMahon (1989) showed that bilateral exchange rates were integrated of order one, however they found that changes in bilateral exchange rates were largely uncorrelated over time. They thus argue that bilateral exchange rate changes are likely to be unpredictable using linear models.

Diebold and Nason (1990) used a locally weighted regression (LWR), but were unable to improve upon the prediction accuracy of a simple random walk for ten major currencies and they conclude that their findings suggest that exchange rate nonlinearities are not exploitable for improved prediction.

Though most models to date have failed to provide reliable evidence of the predictability of exchange rates, the literature has suggested long term trends in the

exchange rate data. Engle and Hamilton (1990) examined exchange rate data for the period of 1973 to 1988 using a segmented trend model. In their analysis the authors reject the random walk hypothesis having found evidence of long swings in the exchange rate. The authors are unable to explain the cause of these long swings, but they conclude that the market does not act upon these long swings.

In a follow up to the Diebold and Nason (1990) study, Chinn (1991) uses a locally weighted regression augmented by an alternating conditional expectations (ACE) technique, which “essentially transforms both the independent and dependent variables nonlinearly so as to linearize the relationship between the two transformed variables.” In-sample fit was generally good when compared to that of the random walk in, one-quarter ahead out-of-sample forecasts the random walk still outperformed, but in 4-quarter ahead forecasts Chinn’s methodology appears to suggest good predictive power. He softens his conclusion by saying that these results would tend to suggest, not confirm, that “the linear martingale model is not always the optimal model of the exchange rate.”

Cheung (1993) examines the long term exchange rate data and finds evidence of long memory in exchange rates and thus proposes the use of a fractionally integrated autoregressive moving average (ARFIMA) model to forecast exchange rates. Cheung found that exchange rates are more complex than implied by the simple random walk, however when he tested the ability of his model to forecast exchange rates, the results were no better than those of a simple random walk.

With the failure of models to reasonably predict short term spot exchange rates, Mark (1995) uses regression analysis to analyze the deviation of exchange rates from their fundamental value, which is derived using a simple monetary approach. Mark found

that short term prediction (1-4 quarters ahead) was generally no better than a simple random walk, however forecasts for 16 quarters ahead were generally better in their performance. He found that of the four exchange rates tested using this 16 quarter ahead forecasting method, three of the currencies (Deutschmark, Swiss Franc, and the Yen) outperformed the benchmark random walk. Mark's (1995) findings are in line with those of Campbell and Shiller (1988) and Fama and French (1988) who examined the predictability in long term stock returns and found evidence of long-term predictability, while the short run was best characterized by a random walk.

A variety of other times series approaches have been undertaken, however there has been a general consensus that these models offer little additional value. Frankel and Rose (1995) suggest there may be little value to continue using time series modeling altogether when considering medium or high frequency exchange rates. Since this time, a new breed of alternative estimation techniques have come forth in the literature which attempt to address the fact that exchange rates are non-linear and linearly unpredictable (Baharumshah *et al* 2003). Amongst others, researchers have experimented using exponential generalized autoregressive conditional heteroskedasticity (GARCH) and self-exciting threshold autoregressive (SETAR) models (Baharumshah *et al* 2003).

Plasmans, Verkooijen, and Daniëls (1998) applied an artificial neural networks (ANN) approach to structural exchange rate models. The authors define ANN as,

*A class of nonlinear models inspired by the neural architecture of the human brain. These models are capable of learning through interaction with their environment by a process that can be viewed as a recursive statistical procedure.* (Plasmans, Verkooijen, and Daniëls (1998) p. 543)

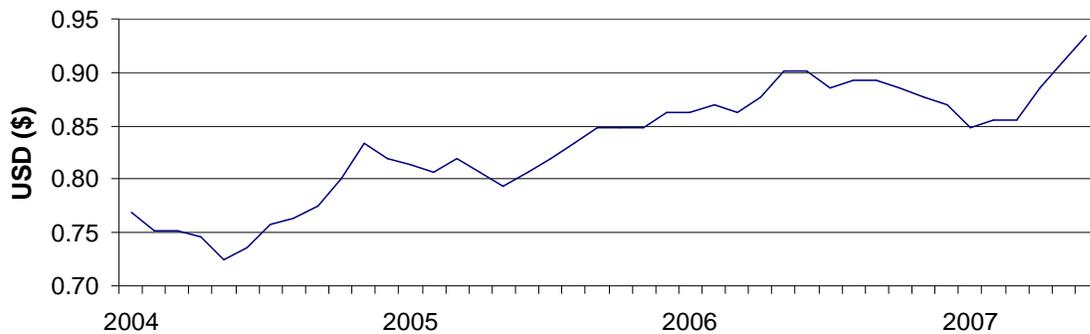
The authors argue they are the first to incorporate such an approach to structural models. Using simple monetary and portfolio-balance models, the authors test their models using a number of currencies and root mean square error as the measure of accuracy. When compared to the results of a simple autoregression and random walk, the models are generally unimpressive. The authors do not find support of a long-run relationship between economic fundamentals and the bilateral exchange rates studied. They do however note that biased estimation generally lead to better forecasts/predictions.

Ultimately, after more than thirty years of model building and testing, there remains to be seen a model which can reasonably and consistently outperform a simple random walk. The literature surveyed suggests real frustration on the part of academia to fully understand the causes of sometimes violent and ever-changing exchange rates. Many have alluded to the fact exchange rates are likely too complex, almost certainly non-linear and constantly evolving, making a complete understanding of the determinants highly unlikely.

## EFFECTIVE EXCHANGE RATES

The preceding discussion has focused largely on bilateral exchange rates, which is the direct relationship between two currencies and though important, they do not provide a full understanding of the value of a currency. A bilateral exchange rate prices one currency in another, it does provide any insight into the currencies' general behaviour. Consider the Canadian-U.S. exchange rate in recent years which is depicted below in figure 1.

In the diagram, we see a general appreciation of the Canadian dollar against the American dollar. The economic meaning of this appreciation might seem clear- one Canadian dollar can buy more U.S. dollars than previously, however the implication of such may be less clear. From economic intuition, we might expect that exports from the U.S. to Canada will increase, while exports from Canada to the U.S. will decrease. Aside from a simple statements such as this, generalization is difficult. We are not provided with any indication about either currency's general movements against other currencies or baskets of currencies. Black (1976) argues that a simple bilateral exchange rate "may give a very inaccurate idea of real changes in international purchasing power parity for any given currency."

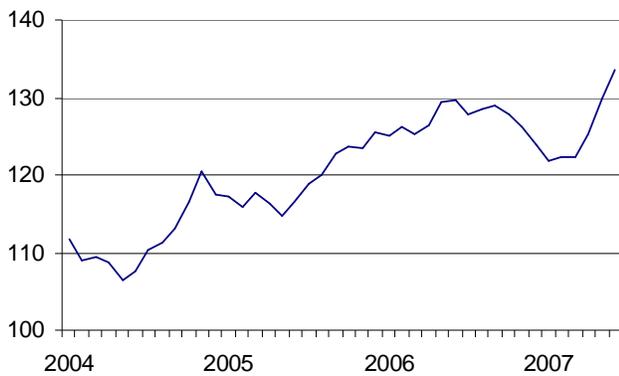


**Fig. 1. USD/CAD Exchange Rate, Monthly Closing Rate Average, 2004-2007.** *Source:* Bank of Canada, Monthly Average Closing Rates

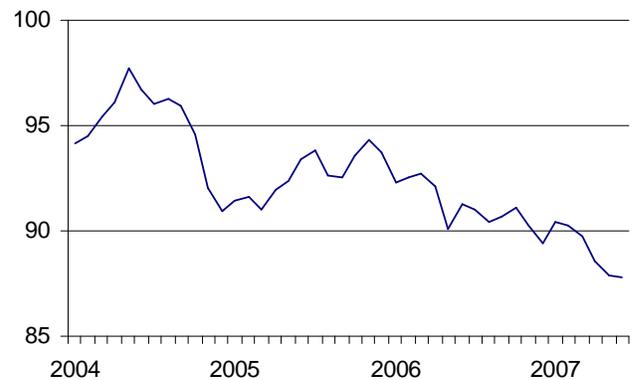
The concept of effective exchange rates attempts to address this shortcoming. An effective exchange rate is a weighted average of many bilateral exchange rates and acts a general measure of the value of a currency. Such measures provide valuable information about the behaviour of a currency and they lend themselves to general trade and forecasting discussions.

Effective exchange rates are calculated by weighting a number of bilateral exchange rates, though there exists many different methods for assigning or calculating weights. In earlier practices, it was common to simply weight each bilateral exchange rate on the basis of the country's trade share- either export, import, or both. The rationale for using trade shares is that the effective exchange rate can then be used in discussions about the countries competitiveness. If we saw an effective exchange rate appreciating, we could easily come to conclusions about the impact it would have on exports, imports, etc.

Reconsider the Canada-U.S. example by examining figures 2 and 3 below. These graphs depict the effective exchange rates for the two countries as calculated by the Bank for International Settlements.



**Fig. 2. Canadian Effective Exchange Rate, Broad 2004-2007, base year 2000.** *Source: BIS*



**Fig. 3. U.S. Effective Exchange Rate, Broad 2004-2007, base year 2000.** *Source: BIS*

Given the effective exchange rate indices we can make more informed statements about the two currencies. Though the above graphs provide similar information as that given in Figure 1, we can see a difference in the magnitude. The U.S. currency does not appear to have depreciated by as much as is suggested by the bilateral exchange rate.<sup>4</sup> These results reflect the fact that the U.S. is Canada's most significant trading partner, while Canada makes up only a small portion of U.S. trade. Thus, from the graphs above we see a depreciation of the U.S. dollar against the Canadian dollar, effectively has much greater impact on Canadian competitiveness than U.S. competitiveness, all else equal.

Though practical, there are problems associated with effective exchange rate indices. The problem of weight choice is significant. The manner in which weights are chosen must have a theoretical foundation and must in some manner account for ever-changing trade shares. Also, the simple methodology described previously takes many bilateral exchange rates into account by weighting trade shares (country of interest vs. foreign countries), however it does not account for the relationships between foreign countries. That is, it does not consider how U.S.-Mexican trade/exchange rate will affect Canadian-U.S. trade/exchange rates. And lastly, indexes such as these are not price indexes of tradeable goods (Artus and Rhomberg (1973)).

In the wake of these criticisms, a variety of refinements have been carried out. In order to capture third market interactions, weights have been chosen to better reflect total trade (Stein, Fellner, Seevers (1974)). Artus and Rhomberg (1973) provided one of the earliest critiques regarding weight calculation and provided an alternative weighting system, which would become the motivation for today's system of weighting. Artus and

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<sup>4</sup> For the period Jan 2004 – June 2007. Bilateral exchange rate: USD/CAD increased by 21.5%, Canadian effective exchange rate increased by 19.5%, and the U.S. effective exchange rate decreased by 6.8%.

Rhomberg identified countries, groups of countries, and groups of goods, for which they devised a system of supply and demand equations which, when solved, would allow the user to “estimate the effect on the trade balance of each country of a single exchange rate change or of an exchange rate realignment in which several rates change at the same time.” Their model was idealistic and remains largely impractical given its use of demand and supply elasticities.

One short-coming that was not easily addressed and remains complex is the fact that trade patterns are constantly changing and evolving. Since trade patterns are ever-changing, weights can easily become outdated and result in misleading forecasts of the effects of changing exchange rates. Some economic institutions, the International Monetary Fund amongst others, have tended to shy away from revising their weights on an ongoing basis, while others like the U.S. Federal Reserve do take time variation into account. Researchers have suggested that theoretically, weights should be changed on an on-going basis. Ellis (2001) suggests an idealistic, but impractical, Tornqvist index, while Chinn (2005) suggests more practical and realistic approximations using a Laspeyres (base year weighted) index.

Though the IMF has been reluctant to update weights on an on-going basis, some authors have argued that such a practice would be greatly beneficial and it would provide a more accurate view of the current value of a unit of currency as changing trade patterns can easily lead to misleading effective exchange rate values.

Until just recently the weights used by the IMF, and many other institutions, were grossly outdated and not reflective of the current state of the world. The weights were based on data from the late 1980s and early 1990s, failed to effectively take services into

account, and were not consistent between the developed and developing world. Bayoumi, Lee, and Jayanthi (2005) devised a new methodology which is now based on data from 164 countries and incorporates the countries' shares of manufactures, (non-tourism) services, commodities, and tourism into the countries' weightings. Also, the system of weighting is applied consistently to all countries. This methodology has been largely adopted by banks and financial institutions as the standard, including the Bank of Canada.

The Bank of Canada tracks the “Canadian-dollar effective exchange rate” (CERI), which is an average of Canada’s six major trading partners’ currencies, weighted according the IMF’s methodology (Ong (2006)), while the U.S. Federal Reserve has a number of indices to measure the value of the American dollar and like other economic variables, they maintain both a broad and narrow measure of the effective exchange rate. The narrow index (*Major Currencies Index*) is composed of the major trading partners, while the broader measure (*Broad index*) is composed of the major and minor trading partners (Leahy (1998)). The Bank for International Settlements and the International Monetary fund, amongst others, also maintain various measures for effectively measuring changes in currencies.

Given the nature of these indices, their practicality for forecasting changes in trade is evident; however they do not necessarily lend themselves to forecasting. It may be possible to use time-series techniques to forecast these indexes, however using fundamental variables is made very difficult. The narrow indices may use six to ten different currencies, while the broader indices can use upwards of forty or fifty currencies. Many of the fundamental forecasting models require information for each of the countries to be used in the calculation, potentially leading to models with upwards of

forty to fifty variables, or more, as is the case for the multilateral exchange rate model put forth by Artus and Rhomberg (1973). Given the number of variables and the need to forecast these in order to forecast the exchange rate index, the likelihood of accurate forecasts of effective exchange rates is greatly diminished.

In the literature surveyed, very few researchers made meaningful attempts to explain the determinants of an exchange rate index. Hooper and Morton (1982) argued that such a practice was advantageous as it would include third-market effects, which would otherwise be omitted when only bilateral exchange rates were used. Their model attempted to explain exchange rate index movements, however it was Meese and Rogoff (1983) and Somanth (1986) who modified the model to test its ability to predict out-of-sample exchange rate (index) movements, with little success over the standard benchmark random walk.

## **METHODOLOGY**

The purpose of this section is to evaluate a number of simple forecasting techniques that have been put forth. Three specific structural models will be examined together with a three simple time series methods to examine their ability to accurately forecast exchange rate movements.

The various models will be tested using both a bilateral exchange rate and trade-weighted exchange rate and evaluated on the basis of their ability to accurately forecast future exchange rate changes at varying horizons. Previous work has suggested that weighted-exchange rates better capture changes in the value of a currency given third market changes and for this reason the results will be of interest. Though this may true, it is also likely to be difficult to provide a robust model given the pattern of international trade.

The three structural models to be tested are: (1) the Dornbusch-Frankel sticky-price model, (2) the Frenkel-Bilson flexible price model, and (3) the Hooper-Morton model. These three models are three of the earliest models in the exchange rate literature and have undergone significant testing since their first publication and continue to be three of the more important models given their strong theoretical foundations. They have been chosen for empirical analysis here since they remain simple by their design and have limited data requirements. In the literature surveyed many models were significant in their scope, some with upwards of forty equations, which would be simply not impractical given the purpose of this study. Also, the data requirements are limited in that they require widely available economic data which can be easily found.

The additional simple time series techniques include a simple equally weighted moving average, univariate autoregressions, and a simple random walk. Three simple techniques were chosen to starkly contrast the structural models. Having surveyed the exchange rate literature, the evidence suggests that exchange rates are largely unpredictable and we do not expect models to outperform even the simplest random walk or moving average.

In all cases, except the random walk, rolling regressions are used to make predictions *ex ante*. That is, all the data previously available is used to make a prediction for the upcoming period and at the end of each period the data set is augmented to include the new information. In this manner we attempt to make the forecasting process as realistic as possible.

The models to be tested will now be described in further detail.

### **Dornbusch-Frankel**

The Dornbusch-Frankel model was devised by the two authors during the late 1970s as a means for understanding what affects the exchange rate and it was not until latter than the model was tested for out-of-sample fit. The model can be described by:

$$e_{t+1} = a_1 + a_2(m_t - m_t^*) - a_3(y_t - y_t^*) + a_4(r_t - r_t^*) + a_5(\pi_t - \pi_t^*) + u_t$$

where,

$e_{t+1}$  = the log of the (forecasted) exchange rate for time  $t + 1$

$m_t$  = the log of the money supply at time  $t$

$y_t$  = the log of real income at time  $t$

$r_t$  = the log of the short term interest rate at time  $t$

$\pi_t$  = the log of inflation at time  $t$

\* - denotes the variable as being for the foreign country.

## Frenkel-Bilson

The Frenkel-Bilson model was initially formulated to explain exchange rate movements, but was later used as an example for forecasting. The model is similar in many respects to that of the Dornbusch-Frankel model. The model takes the following form:

$$e_{t+1} = a_1 + a_2 m_t + a_3 m_t^* - a_4 (r_t - r_t^*) + a_5 y_t + a_6 y_t^* + a_7 t + a_8 e_t + u_t$$

where,

$e_{t+1}$  = the log of the (forecasted) exchange rate for time  $t + 1$

$m_t$  = the log of the money supply at time  $t$

$y_t$  = the log of real income at time  $t$

$r_t$  = the short term interest rate at time  $t$

$t$  = a time variable

$e_t$  = the log of the exchange rate from the previous period.

\* - denotes the variable as being for the foreign country.

Recall that Frenkel-Bilson assume that purchasing power parity holds in their model, while the Dornbusch-Frankel model allows for deviations from purchasing power parity.

## Hooper-Morton

The third structural model, the Hooper-Morton model, is an extension of the Dornbusch-Frankel model model. The Hooper-Morton model allows for deviations from the long run real exchange rate through the inclusion of the trade balance(s). The model takes the form:

$$e_{t+1} = a_1 + a_2 (m_t - m_t^*) + a_5 (y_t - y_t^*) - a_4 (r_t - r_t^*) + a_5 (\pi_t^e - \pi_t^{e*}) + a_6 TB_t + a_7 TB_t^* + u_t$$

where,

$e_{t+1}$  = the log of the (forecasted) exchange rate for time  $t + 1$

$m_t$  = the log of the money supply at time  $t$

$y_t$  = the log of real income at time  $t$

$r_t$  = the short term interest rate at time  $t$

$\pi_t^e$  = the expected level of inflation at time  $t$

\* - denotes the variable as being for the foreign country.

### **Equally Weighted Average**

In addition to the structural methods, a number of simple time series techniques will also be tested. The first of which is an equally weighted average. An average of the previous 2, 3, 6, 9, and 12 periods will be computed and checked for its accuracy in the prediction of the future exchange rate.

$$e_t = \frac{1}{n} \sum_{i=1}^{t-n} e_{t-i}$$

The inclusion of the equally weighted method is simply due to its utter simplicity. Given the additional information used to make forecasts using the structural models above, one would expect them to outperform this overly simplistic method.

### **Autoregressions**

The second, simple, time series technique to be used is a simple autoregression. In a similar manner as before, forecasts about future changes in the exchange rate will be made using recent changes in the exchange rate. Rather than simply averaging the previous  $x$  months' changes, this method will involve estimating a model based on historical data and examining the autocorrelations (partial autocorrelations) to determine the appropriate lag length and the weights given. With each successive period the model will have to be re-estimated with the inclusion of the new, and more recent, data.

The model will thus take the following form:

$$e_{t+1} = a_0 e_t + a_1 e_{t-1} + \dots + a_n e_{t-n} + u_t$$

Three univariate regressions will be estimated for each series. Upon initial analysis of various estimations, it appeared that typically the first one to three lags had a significant autocorrelation, thus all three models will be estimated for simplicity and ease of calculations.

### **Random Walk**

The final model to be tested is a simple random walk. Many have argued that exchange rates, like many financial assets' prices, follow a random and non-predictable walk. If exchange rates do follow a random walk, then the probability that the exchange rate will appreciate is exactly equal to the probability that it will depreciate, therefore the rational forecast would be the current price. That is, we would forecast the exchange rate in period  $t + 1$  to be the same as it is in period  $t$ , and any difference would simply be random error.

$$e_{t+1} = e_t + u_t$$

### **Data and Time Periods**

For the purpose of this study, the tests will be conducted for the period from January 1997 to June 2007. The selection of this time period was largely as a result of two factors. The first factor influencing the choice of time periods is the availability of data. Given the nature of the structural models and the number of countries for which data is necessary, it would be difficult to readily obtain data for all the variables for a longer time period. The second factor for the choice of the time period is the manner in which the trade-weighted exchange rate (CERI) is assigned its weights. The weights are updated infrequently and yet trade patterns are constantly changing and evolving. Therefore, choosing a period

beginning earlier than the mid-1990s might not be appropriate given the weights for the CERI were chosen on the basis of more recent trade patterns.

In terms of frequency, monthly data was chosen. Many of the variables are slow to change and the forecasting horizons were longer, thus, as in other studies, monthly data seemed suitable. In order to be consistent, month-end values of the variables were used wherever possible. Also much economic data undergoes seasonal adjustment, however an effort was made to use non-seasonally adjusted data whenever possible. Meese and Rogoff (1983) caution against using adjusted data as inconsistencies may exist in the adjustment process for different variables and these adjustments may ultimately skew the results of the experiment.

The data used to forecast the bilateral Canada-U.S. exchange rate came from largely governmental sources, while the data used to forecast the trade-weighted exchange rate came from OECD. In order to weight economic variables according to their share of trade, comparable data was necessary. The OECD provides such comparable data in a large online database and was conducive to the purpose of this study.

Given the nature of many of the variables it is necessary to make choices about the data to be used. The first variable in most models was domestic and foreign money supplies. In the literature various measures of money supply were chosen, however the emphasis was generally on a narrow measure of money supply. For Canada and the United States, M1 (not seasonally adjusted) was chosen to represent the domestic and foreign money supplies. In the case of forecasting the CERI, OECD provides a “narrow money” measure which can be used to compare money supplies. This measure, however,

is seasonally adjusted, but given the need for comparable data it was still used for this study.

The next variable requiring clarification is real income. Ideally an economic variable like real GDP would be desirable, but such data is not typically available on a monthly basis. As Frenkel (1982) suggests, an industrial production index is used to proxy this on a monthly basis. Though imperfect, it acts as a suitable proxy as income is certainly related to production.

Short term and long term interest rates were chosen to be the current interest rate on the three month government treasury bill and the yield on ten year government bonds, respectively. The two interest rates appear to be standard choices given the literature and available from most central banks.

The expected level of inflation is calculated as the spread between short and long term interest rates. This is described as being one suitable manner for proxying inflation rate expectations by Meese and Rogoff (1983).

For the purpose of this study, the data from the first five years, January 1997-December 2001, will be used for the first regression used to make the first forecast for March 2002. After which time, estimated regression functions will be estimated each month to make updated *ex ante* forecasts for the remainder of the period. Forecasts will be made for 3, 6, 9, and 12 months ahead. Therefore, for each series there will be between 111 and 120 individual forecasts from which we can evaluate the method's forecasting accuracy.

## Evaluation of Competing Models

The various models and time horizons will produce many different series of forecasts which can be compared with one another for their accuracy. The common practice as put forth by Meese and Rogoff (1983) is to evaluate a technique's accuracy by calculating: (1) the mean error, (2) the absolute error, and (3) the root mean square error.

$$\text{mean error} = \sum_{s=0}^{N_k-1} [F(t+s+k) - A(t+s+k)] / N_k$$

$$\text{mean absolute error} = \sum_{s=0}^{N_k-1} |F(t+s+k) - A(t+s+k)| / N_k$$

$$\text{root mean square error} = \left\{ \sum_{s=0}^{N_k-1} [F(t+s+k) - A(t+s+k)]^2 / N_k \right\}^{1/2}$$

Meese and Rogoff (1983) use root mean square error as their principle measure of accuracy, thus it will also be used as the principle measure in this study. Somanth (1986) uses the same three measures as Meese and Rogoff, however he makes greater use of the mean error and the mean absolute error. He argues that the “mean absolute error is a better criterion than root mean square error if we allow for the possibility of fat-tailed distributions.” For this reason, both mean square error and mean absolute error will be presented in the following section.

## RESULTS

### **Bilateral Exchange Rate (CAD/USD)**

The results of the rolling regressions tend to confirm *a priori* beliefs regarding the nature of the floating exchange rates. Mussa (1979) argued that exchange rates followed a random walk, and amongst other Meese and Rogoff's (1983) study added weight to this assertion. Similarly, the performance of the models chosen also tend to suggest that exchange rates follow a random walk.

Table 3, found on the following page, provides the results from testing the various models using the Canada-U.S. bilateral exchange. In general, the simple random walk typically has the lowest root mean square error and mean absolute error values amongst the models tested for all horizons. Since no model can significantly outperform the random walk, this survey tends to support earlier works which found that structural models were generally unable to improve on the simple random walk, despite the additional information used to make forecasts.

As may have been expected, the accuracy of the various models decreases as the time horizon increases. Forecasts made twelve months prior to realizing the actual value fared relatively poorly when compared to those predictions made for only three months ahead. In terms of model accuracy, the naïve time series methods seem to have outperformed the structural models, but did not seem to outperform the simple random walk.

**Table 4 Bilateral Exchange Rates. Root Mean Square Error (RMSE) for 3, 6, 9, and 12 month ahead forecasts**

Model:		Random Walk		AR(1)		AR(2)		AR(3)	
Exchange Rate	Horizon	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
USD/CAD	3 Months	0.01510	0.01169	0.03239	0.02711	0.03181	0.02692	0.03160	0.02668
	6 Months	0.02074	0.01634	0.04033	0.03275	0.03881	0.03183	0.03820	0.03135
	9 Months	0.02453	0.01893	0.05122	0.04000	0.04878	0.03861	0.04810	0.03732
	12 Months	0.02902	0.02303	0.06263	0.04785	0.05993	0.04805	0.05915	0.04622

Equally Weighted Average											
Model:		2 Months		3 Months		6 Months		9 Months		12 Months	
Exchange Rate	Horizon	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
USD/CAD	3 Months	0.01803	0.01416	0.01856	0.01482	0.02003	0.01599	0.02170	0.01771	0.02389	0.01989
	6 Months	8.98642	0.01979	0.02504	0.01979	0.02607	0.02086	0.02797	0.02281	0.03003	0.02466
	9 Months	0.02728	0.02143	0.02790	0.02203	0.03024	0.02427	0.03235	0.02640	0.03451	0.02854
	12 Months	0.03299	0.02690	0.03374	0.02764	0.03567	0.02970	0.03775	0.03175	0.04002	0.03367

Model:		Dornbusch-Frankel		Frenkel-Bilson		Hooper-Morton	
Exchange Rate	Horizon	RMSE	MAE	RMSE	MAE	RMSE	MAE
USD/CAD	3 Months	0.04692	0.04028	0.04669	0.04006	0.04066	0.03219
	6 Months	0.05768	0.04675	0.05314	0.04277	0.05596	0.04868
	9 Months	0.05565	0.04780	0.05416	0.04023	0.06463	0.05321
	12 Months	0.05340	0.04315	0.05290	0.04489	0.07077	0.06243

It is interesting to note, the performance of an equally weighted average of the previous two or three months outperformed the autoregressive method, suggesting that despite the additional information used to forecast the exchange rate, the autoregression fails to improve upon a simple average of the previous rates. This seems to suggest that additional information does not benefit in the prediction of the exchange rates and may thus support the contention that exchange rate movements are largely unpredictable.

The three structural models also prove insightful. Rolling regressions were used to imitate the decision making process. As time progress new and additional information is used to make revised predictions. Ultimately the predictions were compared to realized exchange rates to measure their out-of-sample fit, or more generally, their accuracy. Having already examined the models for their out-of-sample fit, it is possible to consider the models with respect to their in-sample fit. Consider the  $R^2$  and *adjusted- $R^2$*  values for the final regression of each series which can be found in table 5 on the following page.

Though an imperfect measure for in-sample fit and the ability to compare  $R^2$  values between models is limited, it does give the reader an idea for the models' in-sample accuracy. These results tend to suggest that the Dornbusch-Frankel model is greatly outperformed by the other two models. However, when out-of-sample fit is considered, its performance appears marginally better than the Hooper-Morton model.

It should also be noted that in many instances coefficients were found not to be significant and the signs associated with them were not as expected. Taken together with the in-sample fit, the results seem to suggest that the models are either missing crucial variables or they are not of the appropriate form.

**Table 5 Bilateral Exchange Rates, R-square and Adjusted R-square values for final regressions of each series**

Model:		Dornbusch-Frankel		Frenkel-Bilson		Hooper-Morton	
Exchange Rate	Horizon	R-square	Adj R-square	R-square	Adj R-square	R-square	Adj R-square
USD/CAD	3 months	0.56190	0.54700	0.93040	0.92620	0.81930	0.80970
	6 months	0.55240	0.53680	0.53680	0.93180	0.80570	0.79540
	9 months	0.50030	0.48250	0.48250	0.92770	0.80920	0.79880
	12 months	0.46830	0.44880	0.44880	0.92140	0.82950	0.81990

## **Canadian Effective Exchange Rate**

The Canadian Effective Exchange Rate (CERI), as calculated by the Bank of Canada, was chosen to be trade-weighted effective exchange rate to be tested empirically. In order to do so, it was necessary to use comparable data as provided by the OECD, however comparable data for all the countries used to calculate the CERI was not available. Only limited comparable data was found for Mexico, thus introducing a significant difficulty for this study. Given the absence of a complete data set, additional series were tested.

The CERI is a weighed average of the exchange rates between Canada and six of its major trading partners, of which Mexico is one of. The weight associated with the Mexican peso is small (0.0324) relative to other trading partners like the United States or Europe. Thus, slightly different series were tested.

The first series of tests involved forecasting the CERI using data for the five other trading partners and recalculating the weights of each country by excluding Mexico, the peso did remain in the calculation of the CERI however.

The second series of tests involved forecasting a revised CERI using the data for the five other trading partners. In this instance the CERI was revised to be a weighted average of the five other major trading partners and the weights were recalculated by excluding Mexico.

The final series to be tested is the Canadian Six (C-6). This was the predecessor of the CERI and is still calculated using the old weights. Different countries factor into the calculation of the C6- Mexico and China are excluded and replaced with Sweden and Switzerland, who were previously of greater relative importance in Canadian trade.

**Table 6 Weights Used for Econometric Analysis of Weighted Exchange Rate**

CERI		CERI excl. Mexico		C-6	
U.S. dollar	0.7618	U.S. dollar	0.7873	U.S. dollar	0.8584
Euro	0.0931	Euro	0.0962	Euro	0.0594
Japanese yen	0.0527	Japanese yen	0.0545	Japanese yen	0.0527
Chinese yuan	0.0329	Chinese yuan	0.0340	British pound	0.0217
Mexican peso	0.0324	British pound	0.0280	Swiss franc	0.0043
British pound	0.0271			Swedish krona	0.0035

*Source:* Ong, Janone. 2006. A New Effective Exchange Rate Index for the Canadian Dollar. *Bank of Canada Review* Autumn, 41-47.

Three different series are calculated in an effort to effectively test the theory in the absence of comparable economic data.

As before, it is useful to begin with an examination of the three time series methods used for forecasting changes in the weighted exchange rate. The root mean square error and mean absolute error values for each of the techniques can be found in table 7 on the following page.

The values of the test statistics are much closer in proximity to one another than was the case when examining the bilateral exchange rates. This seems to suggest that the various methods are roughly equivalent when examined in the context of the chosen time period. Though there is not clear evidence that the random walk would provide the most accurate forecasts, there is also not evidence to suggest that any of the other models can outperform the random walk. Therefore, the results tend to confirm those of the previous studies.

**Table 7 Canadian Effective Exchange Rate Index time series forecasts. Root Mean Square Error (RMSE) for 3, 6, 9, and 12 month time horizons.**

Model:		Random Walk		AR(1)		AR(2)		AR(3)	
Exchange Rate	Horizon	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
CERI	3 Months	0.01275	0.00990	0.00843	0.00694	0.01737	0.01331	0.00794	0.00635
	6 Months	0.01844	0.01425	0.01148	0.00954	0.01086	0.00898	0.01083	0.00894
	9 Months	0.02191	0.01653	0.01522	0.01284	0.01434	0.01207	0.01414	0.01176
	12 Months	0.02558	0.02011	0.01827	0.01562	0.01733	0.01475	0.01698	0.01435

Model:		Equally Weighted Average									
		2 Months		3 Months		6 Months		9 Months		12 Months	
Exchange Rate	Horizon	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE	RMSE	MAE
CERI	3 Months	0.01626	0.01241	0.01688	0.01276	0.01840	0.01383	0.01992	0.01553	0.02182	0.01740
	6 Months	0.03590	0.07661	0.35291	0.07689	0.35411	0.07860	0.35468	0.08040	0.35467	0.08206
	9 Months	0.02443	0.07784	0.02492	0.07811	0.02675	0.07995	0.02848	0.08195	0.03031	0.08374
	12 Months	0.02887	0.02322	0.02948	0.02379	0.03115	0.02567	0.03290	0.02734	0.03478	0.02894

Since comparable data was unavailable for Mexico, the results of the three different weighted exchange rates will be presented together in table 8 on the following page. As was the case previously, the results for the three different sets indicate an inability to out-perform the random walk. The values of the test statistics for each of the models is significantly higher than those calculated for the time series techniques, suggesting they would make poor out-of-sample forecasts when compared to the simplistic time series models.

Also, when the different models are compared, it would appear that the CERI fares the best overall. This might be reasonably expected given its weights are chosen on the basis of “current” trade patterns, or at least more current than the other two models.

When examining the models for in-sample fit, the structural models appear better suited for explaining variation in bilateral exchange rates than for the weighted exchange rate. Again, measures of goodness-of-fit are presented in table 9. The measures for goodness of fit are generally lower and in some instances significantly lower than those for the bilateral exchange rate. These results may suggest that these models are not well-suited for forecasting trade-weighted exchange rates at such horizons.

Ultimately, the results of testing the trade-weighted exchange rates support the conclusions reached from the bilateral exchange rate testing. Simple models such as those tested have failed to improve the accuracy of forecasting. The models tested use additional and relevant economic information, yet they offer no more accuracy than a simple random walk.

**Table 8 CERI, CERI excluding Mexico, and C6. Root Mean Square Error (RMSE)**

Model:		Dornbusch-Frankel		Frenkel-Bilson		Hooper-Morton	
Exchange Rate	Horizon	RMSE	MAE	RMSE	MAE	RMSE	MAE
CERI	3 months	0.19840	0.19044	0.12615	1.13913	0.13498	0.11059
	6 months	0.21281	0.20560	0.21007	1.99165	0.12354	0.10658
	9 months	0.22471	0.21916	0.20903	2.02288	0.12025	0.10679
	12 months	0.22688	0.22317	0.11013	1.04218	0.11465	0.10509
CERI without Mexico	3 months	0.27853	0.27327	0.10855	0.97281	0.20140	0.17383
	6 months	0.29376	0.28883	0.20226	1.92220	0.18864	0.16114
	9 months	0.30527	0.30136	0.20616	1.99727	0.18815	0.16510
	12 months	0.30725	0.30456	0.11448	1.09202	0.18654	0.17001
C-6	3 months	0.32249	0.31680	0.36380	3.07917	0.21344	0.18496
	6 months	0.32345	0.31840	0.45780	4.38024	0.17491	0.14618
	9 months	0.33605	0.33215	0.36788	3.49980	0.18865	0.16269
	12 months	0.34140	0.33870	0.18671	1.82845	0.18245	0.16729

**Table 9 CERI, CERI excluding Mexico, and C6. R-square and adjusted R-square**

Model:		Dornbusch-Frankel		Frenkel-Bilson		Hooper-Morton	
Exchange Rate	Horizon	R-square	Adj R-square	R-square	Adj R-square	R-square	Adj R-square
CERI	3 months	0.44360	0.42420	0.89740	0.89100	0.82400	0.81460
	6 months	0.35440	0.33140	0.85020	0.84060	0.80230	0.79150
	9 months	0.29970	0.27400	0.84030	0.82980	0.80270	0.79170
	12 months	0.28130	0.25420	0.84770	0.83740	0.79290	0.78090
CERI without Mexico	3 months	0.44480	0.42550	0.90310	0.89700	0.82880	0.81970
	6 months	0.35380	0.33070	0.85720	0.84800	0.80420	0.79360
	9 months	0.30410	0.27850	0.84850	0.83850	0.80640	0.79550
	12 months	0.28780	0.26090	0.84980	0.83960	0.79370	0.78180
C-6	3 months	0.27300	0.24780	0.62000	0.59630	0.54020	0.51580
	6 months	0.23420	0.20680	0.56970	0.54210	0.56060	0.53660
	9 months	0.18150	0.15150	0.54270	0.51250	0.54660	0.52120
	12 months	0.16610	0.13470	0.57750	0.54870	0.55830	0.53280

## **CONCLUSION**

The analysis in the preceding sections has suggested that exchange rates follow a random walk. That is, they are largely unpredictable. The literature review summarized a number of studies which suggest and in many instances it has been proven empirically that the models which have to-date been developed are generally poor in their ability to forecast future changes. In many instances even the most complex models can not outperform the simple random walk, thus suggesting that the best predictor of the future exchange rate is simply the current rate.

The purpose of this paper was to revisit a number of simple forecasting models and test them for accuracy. Ultimately these models have failed, but it should be noted that there exist many more recent models which have made use of more advanced time series and non-linear estimation techniques, which were generally beyond the scope of this paper. Some authors have shown strong performances in their models, however the consensus remains that the exchange rate is largely unpredictable.

## APPENDIX -- DATA SOURCES

### Bilateral Exchange Rate Data

**Bilateral USD/CAD Exchange Rate** - Federal Reserve Statistical Release. Online and available at: <http://www.federalreserve.gov/releases/h10/Hist/default1999.htm>

**Canadian Short Term Interest Rate** - 3 Month Treasury bill. Bank of Canada. Online and available at: Bank of Canada. <http://www.bank-banque-canada.ca/en/rates/tbill-look.html>

**U.S. Short Term Interest Rate** - 3-Month Treasury Bill. Federal Reserve Bank of St. Louis. Online and available at: <http://research.stlouisfed.org/fred2/categories/22>

**Canadian Long Term Interest Rate** - Long10 Year Canadian Government (benchmark) bond. Bank of Canada. Online and available at: <http://www.bank-banque-canada.ca/en/rates/bond-look.html>

**U.S. Long Term Interest Rate** - 10-year US Government securities/Treasury constant maturities (nominal). Federal Reserve Statistical Release. Online and available at: <http://www.federalreserve.gov/releases/h15/data.htm>

**Canadian Money Supply** – M1 (millions). Statistics Canada Cansim II Series V37151, Table 176-0025

**U.S. Money Supply** – M1 (billions). Federal Reserve Bank of St. Louis. Online and available at: <http://research.stlouisfed.org/fred2/categories/24>

**Canadian Trade Balance** - Balance of Payment: Current Account. Statistics Canada. CANSUM II Series V114494. Table 376-0003.

**U.S. Trade Balance** - Balance on Current Account, NIPA's. Federal Reserve Bank of St. Louis. Online and available at: <http://research.stlouisfed.org/fred2/categories/108>

**Canadian Real Income** - Industrial Production Index, original, 2000=100. United Nations Economic Commission for Europe. Production index. Online and available at: <http://w3.unece.org/pxweb/database/STAT/2-ME/5-MEPW/5-MEPW.asp>

**U.S. Real Income** - Industrial Production Index. Federal Reserve Bank of St. Louis. Online and available at: <http://research.stlouisfed.org/fred2/series/INDPRO>

## Canadian Effective Exchange Rate

Using the OECD Source online database the following (comparable) statistics were gathered from the “Main Economic Indicators - Comparative Subject tables” for the countries of interest:

- **Industrial Production** - units: 2000 = 100 - Series adjusted for seasonal variations
- **Consumer Prices- All Items** - units: 2000 = 100
- **Short-term Interest Rates** - units: Per cent per annum
- **Long-term Interest Rates** - units: Per cent per annum
- **Monetary Aggregates: Narrow Money** - units: 2000 = 100 - Series adjusted for seasonal variations
- **Monetary Aggregates: Broad Money** - units: 2000 = 100 - Series adjusted for seasonal variations
- **Current Balance** - units: Billions US dollars - Series adjusted for seasonal variations
- **Exchange Rates** - units: National currency units per US dollar

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