Exchange Rate Predictability: Evidence from Canada

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Abstract

Exchange rate forecasting has proven to be a difficult task, specifically in terms of the Meese and Rogoff puzzle. The fundamental question that I address is: which model best forecasts changes in the nominal exchange rate, a macroeconomic model or a random walk with drift? I use the ordinary least square method to estimate several macroeconomic models of bilateral exchange rates, and then I compare the ability of the macroeconomic models to forecast movements in the exchange rate to that of the random walk using data at the daily frequency. I use measures of forecast error and directional accuracy to evaluate the models. I find that the macroeconomic model outperforms the benchmark for the exchange rates between the Canadian Dollar and the currencies of the United Kingdom, Japan, Korea and the United States.

1 Introduction

The exchange rate is the price of a domestic currency expressed in terms of a foreign currency, for example, the price of the Canadian dollar in terms of the US dollar. Economists have struggled to develop models to predict nominal exchange rate fluctuations using macroeconomic variables. A body of literature shows that empirical models have had limited success in explaining the connection between exchange rate movements and macroeconomic fundamentals (e.g., Meese and Rogoff 1983). In particular, the Meese and Rogoff puzzle, which is the proposition that structural exchange rate models cannot outperform a random walk in out-of-sample forecasting of exchange rates, has stimulated prolific research in the area.

Recent studies, however, show that commodity price changes are an important driver of the Canadian dollar - United States dollar (CAD-USD) exchange rate (e.g., Cayen et al., 2010; Ferraro, Rogoff and Rossi, 2015). For example, Ferraro et al. (2015) conclude that oil prices have predictive ability in forecasting movements of the bilateral CAD-USD exchange rate. However, observation of recent trends during the 2000-2007 period commodity price increase, and more recently the fall in oil prices in 2014, suggests that commodity prices may not be the only important drivers of exchange rate movements.

The purpose of this paper is to evaluate the predictive power of macroeconomic fundamentals, such as the interest rate differential, as compared to that of commodity price indexes, in explaining changes in nominal bilateral exchange rates between Canada, on the one hand, and Mexico, Japan, South Korea, the United States and the United Kingdom on the other. Based on measures of point forecast accuracy and directional accuracy, I compare the performance of a macroeconomic fundamentals model with a random walk with drift benchmark model. The contribution of this paper is to extend the work of Berg et al. (2016), who estimate a model of the bilateral Canada-US exchange rate, by including a larger set of countries. Based on the Annual Report on Canada's Trade and Investment Performance released by Global Affairs Canada, I select Canada's most important trade partners and test the aforementioned model.

The paper is organized as follows. Section 2 introduces the literature review. Section 3 presents the methodology. Section 4 discusses key results of the analysis and finally, section 5 concludes the paper.

2 Literature review

2.1 A brief history of exchange rates

The Bretton Woods system of fixed exchange rates originated at a conference held on July 1^{st}, 1944, in Bretton Woods, New Hampshire. Leaders of the Second World War Allied nations conceived the foundations of two international institutions, the International Monetary Fund (IMF) and the World Bank. The IMF was officially launched in December 1945; its original purpose was to be an institution "charged with overseeing the international monetary system of exchange rates and international payments that enables countries and their citizens to buy goods and services from each other." (IMF 2017a). According to The Economist Explains (2014), this conference formed the foundations of an international monetary system based on fixed exchange rates known as the Bretton Woods system. Amadeo (2017) points out four important facts behind the creation of this system: a desire to avoid the chaos that ruled the international financial system between the First and the Second World War, the collapse of the gold standard monetary system, the Great Depression, and the rise of protectionism.

The Bretton Woods system was preceded by the gold standard, an international monetary system in which the participating countries were committed to fixing the prices of their domestic currencies in terms of a specified amount of gold. This meant that each country guaranteed the convertibility of their currency for its value in gold. The classic gold standard existed between 1880 to 1914. The period between the First and Second World War is not clearly identified as the gold standard, given the instability in the international monetary system during this period.

The Bretton Woods system existed from 1945 until 1971. Hamada and Patrick (1987) point out three principles of this system:

- Exchange rates were fixed, with adjustments being allowed only in the case of a "fundamental disequilibrium" in the balance of payments.[1]

- The US dollar became the reserve currency, replacing the role that gold played in the classical gold standard. All countries participating in the system, except for the US, would peg their currencies to the US dollar.
- Adjustments in the balance of payments would be carried out via the macroeconomic policies of the non-reserve countries, i.e., all countries other than the US. If necessary, exchange rates could be realigned.

In 1971, President Richard Nixon of the United States terminated the convertibility of the dollar into gold, which resulted in the end of the Bretton Woods system. According to the IMF (2017b), the US dollar was constantly challenged to keep the parities established at Bretton Woods during the 1960s, but it was during the 1971 crisis that the system became disfunctional. The debacle of the system was triggered by the expansive fiscal policy adopted by the previous president Lyndon Johnson and military spending due to the Vietnam War. During the period between 1971 and 1973, there were a few attempts to reinstate the old gold-dollar fixed exchange rates; however, by 1973, the US, the United Kingdom and other countries had adopted floating exchange rate systems.

In particular, Hamada and Patrick (1987) highlight the attempt by the Japanese authorities to re-establish a fixed exchange rate, with a new parity between the US Dollar and the Japanese Yen and with a greater degree of flexibility. This attempt, along with others by different countries, failed. Hamada and Patrick (1987) attribute the failure of the Japanese authorities to financial crises in Europe and an increased demand for the yen. Thus, since February 1973, Japan has adopted a floating exchange rate.

The Bank of Korea, Korea's central bank, has adopted a free floating system since December 1997. Early in the 1990s, Korea had a market average exchange rate (MAR), a semi-fixed exchange rate system in which the Bank of Korea occasionally intervened (Park, Chung and Wang, 2001). This exchange rate regime was one of the measures adopted to overcome the 1997 Asian

[1] There was no formal definition of what would consist a fundamental disequilibrium.

financial crisis. On July 2^{nd}, 1997, Thailand's central bank floated its national currency after a speculative attack. This event is highlighted by The Economist (2007) as the trigger of this major financial and economic crisis. Korea was one of the countries worst hit by the crisis, forcing the IMF to intervene with a bail-out programme.

Mexico introduced a floating exchange rate on December 19^{th}, 1994, replacing the previous system in which the exchange rate floated within a band which widened on a daily basis. Carstens and Werner (1999) point out that, at that time, the Bank of Mexico became unable to maintain the predetermined parity with the US dollar, due to a crisis in the balance of payments caused by negative external and domestic shocks. The peso steadily depreciated through the second half of the 1990s, and together with the signature of the North American Free Trade Agreement, Mexico's economy recovered (Financial Times, 2009). Thus, it has been more than twenty years since the Bank of Mexico has adopted a monetary system in which the exchange rate is determined by the free market without the intervention of the authorities.

2.2 Floating exchange rates in Canada

In the international trade context, Canada is classified as a small open economy, referring to the fact that it exchanges goods and services with other countries and it is also involved in international financial transactions. Nevertheless, the Canadian economy does not influence key macroeconomic variables like the price of internationally traded goods, such as oil. Hence, one can assume that Canada is a price-taker in this market. The value of the domestic currency expressed in terms of another foreign currency is relevant because it affects the prices and the volume of goods and services traded.

In 1950, Canada became the first major country to adopt a floating exchange rate. This policy was reversed during the period between 1962 and 1970, when the Canadian economy briefly returned to a fixed exchange rate. Thus, the floating exchange rates have been a reality in Canada for almost 50 years (Bank of Canada, 2012). In this currency system, the external value of the Canadian dollar floats against foreign currencies and its price is determined by the demand for and supply of Canadian dollars in the foreign exchange market.

The monetary policy framework in Canada features free capital mobility and monetary autonomy. Therefore, the Canadian dollar does not have a fixed foreign exchange rate, and neither the Bank of Canada nor the Federal government have any particular target for the currency. This characteristic is a result of the macroeconomic policy trilemma, also known as the impossible trinity, a concept in international economics which states that it is impossible to have a fixed foreign exchange rate, free capital movement and an independent monetary policy at the same time (O'Sullivan 2016).

Although it does not have an explicit target for the exchange rate, the Bank of Canada recognizes that the value of the Canadian dollar in the long run is influenced by fundamental macroeconomic factors (Bank of Canada, 2012). Such factors include Canada's economic growth and inflation, the level of interest rates, its fiscal position, and productivity performance relative to other countries, particularly the United States, Canada's major trade partner. Additionally, given the fact that Canada is a key producer of commodities, the world demand for these goods and the prices of commodities are also an important driver of the value of the Canadian dollar. However, given that currency markets can be volatile, the Bank of Canada may intervene in the foreign exchange markets in order to counter disruptive short-term shocks in the Canadian dollar. These interventions are very exceptional events and are under the scrutiny of the federal government (Bank of Canada, 2010).

2.3 China and exchange rate manipulation

China is one of the major trade partners of Canada, and so it would be interesting to test the predictive ability of macroeconomic fundamentals in terms of movements in the nominal Canadian Dollar Chinese Yuan Renminbi (CAD-RMB) exchange rate. However, there are strong concerns about exchange rate manipulation of the Chinese Yuan Renminbi. The argument is that Chinese authorities intervene in the exchange rate market, keeping China's currency artificially low. This procedure increases China's competitiveness in the international markets. Bayraktar

(2014) identifies a body of literature which argues that the economic success of China is linked to its competitiveness in international markets, with Chinese policy makers adopting policies to keep the value of the renminbi low.[2] Back in 2013, the then governor of the Bank of Canada, Mark Carney, warned that the Canadian economy could suffer from a currency exchange war. He argued that as a smaller economy, Canada did not have the flexibility of the US and it would be particularly vulnerable to currency manipulation. Thus, I do not include the CAD-RMB exchange rate in my analysis.

2.4 Why do forecasts of the exchange rate matter?

Even though the Bank of Canada does not have a target for the exchange rate, being able to predict movements in the exchange rate is important in terms of monetary policy-making. The Monetary Conditions Index (MCI) is defined as a weighted sum of the changes in the short-term interest rate (the 90-day commercial paper rate) and the exchange rate (as measured by the C-6 index[3]) from a given base period. The weight of the exchange rate is one-third that of the interest rate, a three per cent change in the exchange rate being roughly equivalent to a one percentage point (100 basis points) change in interest rates. A change in the MCI gives a measure of the degree of tightening or easing in monetary conditions. According to Ericsson et al. (1997), "MCIs are (...) used as indicators of monetary conditions and as operational short-run targets for monetary policy by the Bank of Canada".

As Wieland and Wolters (2013) observe, policy-makers use forecasts to project the consequences of a given monetary policy. Moreover, Rossi (2013) points out that exchange rate projections are important for the central banks of economies that participate intensively in commodities' trading. For instance, one of the models used by the Bank of Canada is Amano and van Norden's (1995), in which real exchange rates depend on commodities prices, among other variables.

[2] See Wu, Rongfang and Di (2010); Feldstein (2011); Cheung, Chinn and Fujii (2009).

[3] The C-6 exchange rate is an index of the weighted-average foreign exchange value of the Canadian dollar against major foreign currencies. The six foreign currencies in the C-6 index are the U.S. dollar, the euro, the yen, the U.K. pound, the Swedish krona, and the Swiss franc.

2.5 The Meese and Rogoff puzzle

The ability of empirical models to explain exchange rate movements has attracted a large number of studies since 1983, when Richard Meese and Kenneth Rogoff published a paper in which they compare the out-of-sample forecasting accuracy of time-series models and structural models of exchange rates. Their main conclusion, that the random walk model could not be outperformed by exchange rate models in out-of-sample forecasting, became well known in the literature as the Meese and Rogoff puzzle. Meese and Rogoff arrive at this conclusion by demonstrating that none of the macroeconomic and time series models they used produced a lower root mean square error (RMSE) than the random walk. The Meese and Rogoff study implies that traditional macroeconomic factors such as interest rates and output differentials have no predictive power for exchange rate movements.

Rossi (2013) observes that most studies comparing the out-of-sample forecasting performance of macroeconomic factors models conclude that the random walk model is the best predictor of changes in exchange rates. According to the random walk without drift, the best predictor of exchange rates tomorrow is the exchange rate today, and so exchange rate changes are completely unpredictable:

$$E_t s_{t+h} - s_t = 0 \tag{1}$$

where s_t is the change in the log bilateral nominal exchange rate, and where h indicates the step-ahead forecast period. Alternatively, the random walk with drift can also be used as a benchmark. In this case, exchange rate changes are predictable but independent of other macroeconomic variables:

$$E_t s_{t+h} - s_t = \alpha \neq 0 \tag{2}$$

Moosa and Burns (2015) present a study that demystifies the Meese and Rogoff Puzzle. Their first critique is that Meese and Rogoff did not conduct any formal tests to determine the statistical significance of the difference between the forecasting errors of the macroeconomic models and the random walk. They also argue that the Meese and Rogoff result is a natural outcome given the features of financial prices such as exchange rates and stock prices. The idea is that when the underlying exchange rate is relatively stable, the forecasting error of the random walk will be small. Departing from a situation of a stable price, and with the forecasting error of the random walk smaller than that of the structural model, the random walk will always have a smaller forecasting error (and so, better performance) as long as its error does not grow faster than that of the structural models.

Moosa and Burns' (2015) analysis concludes that the random walk cannot be outperformed by static specifications of exchange rate models when forecasting accuracy is evaluated solely by the magnitude of the forecasting error. Hence, they suggest the use of alternative measures of forecasting accuracy such as directional accuracy and the adjusted root mean square error. They provide evidence confirming that the random walk can be outperformed in exchange rate forecasting when forecasting accuracy is evaluated in terms of measures that take into account more than just the magnitude of the forecasting error.

2.6 Macroeconomic fundamentals and movements in the nominal exchange rate

In this section I will review the recent body of literature which has identified macroeconomic fundamentals as better predictors of changes in the nominal exchange rate than the random walk.

Cayen et al. (2010) use a panel of six real US dollar bilateral exchange rates to identify macroeconomic developments that drive exchange rates in the long run.[4] By employing an approach that combines dynamic factor models and state-space models they were able to find that US fiscal policy and commodity prices have played important roles in determining the real US dollar bilateral exchange rate for the cases examined.

Garmulewicz and Voss (2016) use the methods of Engel and West (2005) to assess forward looking models of the exchange rate with respect to macroeconomics fundamentals. They focus on the Canada-US dollar (CAD-USD) exchange rate over the period between 2000 and 2015.

[4] The six countries are Australia, Canada, the Euro zone, Japan, New Zealand, and the United Kingdom.

Their main results are that commodity prices and the CAD-USD exchange rate have a statistically significant Granger causality relationship. Additionally, they found evidence that movements in the CAD-USD exchange rate are consistent with structural forward looking models.

Ferraro et al. (2015) present evidence that realized commodity prices are related to daily nominal exchange rates of commodity currencies such as the Canadian dollar. They use the following equation of a relatively simple commodity price model:

$$\Delta s_t = \alpha + \beta \Delta p_t + u_t, \quad t = 1, ..., T, \tag{3}$$

where Δs_t and Δp_t are the first differences of the logarithm of the exchange rate and the commodity price respectively. They also provide evidence suggesting that the relationship is statistically and economically significant. The predictive relationship is significant and stronger in out-of-sample fit exercises with daily data then with lower-frequency data. These results are strikingly different from the conventional results in the literature. As mentioned before, the Meese and Rogoff puzzle has dominated the field of exchange rate forecasting.

According to Ferraro et al. (2015), the differences between their empirical results and those of the conventional literature are due to two main factors. First, they use daily data, while conventional studies consider data at monthly or quarterly frequencies. Second, they innovate in terms of the macroeconomic fundamentals used as explanatory variable. Previous studies use the interest rate, output and money differentials as explanatory variables, while they use oil prices. Hence, I take into account these two factors in my study.

Berg et al. (2016) also find that energy and non-energy commodity prices are useful for explaining contemporaneous variations of the CAD-USD nominal exchange rate. Building upon the analysis of Ferraro et al. (2015), and using the Diebold-Mariano (1995) test of equal predictive ability, they were able to demonstrate that macroeconomic models including energy and non-energy commodity price indexes as explanatory variables perform better than the random walk model.

Overall, recent empirical work has achieved some degree of success in showing that macroeconomic fundamentals play an important role in understanding movements in the bilateral CAD-USD exchange rate. In particular, the work of Berg et al. (2016) shows that it is possible to construct a simple model that performs better than the random walk using macroeconomics fundamentals as explanatory variables.

3 Methodology

3.1 Empirical approach

My purpose is to compare the performance of two models, a macroeconomic model and the random walk with drift in terms of forecasting movements in the exchange rate. I follow the approach of Berg et al. (2016) and Ferraro et al. (2015) and estimate the following structural model of the exchange rate:

$$s_t = \alpha + \beta x_t + u_t, \qquad t = 1, ..., T, \tag{4}$$

where s_t is first difference of the logarithm of the bilateral nominal exchange rate, x_t is a macroeconomic fundamental, u_t is the regression error and T is the total sample size. The model is estimated by the standard ordinary least squares (OLS) method. Each macroeconomic factor is tested separately, which means that for each exchange rate I run six regressions, one for each factor plus the random walk with drift as benchmark. The next section describes in detail which macroeconomic fundamentals I take into account.

Ferraro et al. (2015) highlight the fact that this model uses the realized value of the fundamental. The explanation for this strategy concerns the Meese and Rogoff puzzle; the goal is to show that it is possible to beat the random walk model's exchange rate forecasts by using macroeconomic factors. Thus, the model is estimated with rolling-in-sample windows to obtain one-day-ahead forecasts conditional on the realized value of the macroeconomic fundamental. To analyze the predictive ability of the economic fundamental I evaluate the model's performance in terms of its out-of-sample forecast performance. In this study, I report results based on different window sizes, ranging from 20 to 50 per cent of the full sample. The following equation denotes the out-of-sample one-step-ahead forecast:

$$s_{t+1}^{f} = \hat{\alpha}_t + \hat{\beta}_t x_{t+1}, \quad t = R, R+1, ..., T-1, \tag{5}$$

where $\hat{\alpha}_t$ and $\hat{\beta}_t$ are the parameter estimates from the rolling window $\{t-R+1, t-R+2, ..., t\}$ and R is the size of the in-sample estimation window.[5]

Ferraro et al. (2015), who consider the case of commodity prices, provide two reasons for using the realized value of the change in a commodity price rather than a predictor of the change in commodity prices when evaluating the forecast accuracy of the model. First, forecasting daily future changes in the commodity price is not a trivial process, since they depend on political decisions and unpredictable supply shocks. Second, the past values of commodity prices may not provide good forecasts of future values of commodity prices. One could end up rejecting the predictive ability of commodity prices in terms of movements in the exchange rate, not because the relationship is poor, but due to poor forecasts of future commodities price changes generated by the lagged variable.

The body of literature on exchange rate forecasts traditionally considers the random walk model as the benchmark model. Rossi (2013) points out that the random walk without drift or the random walk with drift are the usual choice of benchmark models in the literature of exchange rate movements. Moreover, Ferraro et al. (2015) and Meese and Rogoff (1983) presented their analysis using both the random walk and random walk with drift as benchmarks. In this study, I consider only the random walk with drift as the benchmark. This model is denoted by the equation below:

$$s_t = \alpha + \varepsilon, \tag{6}$$

This model implies that the forecast of changes in the exchange rate is equal to a constant factor, $\hat{\alpha}$.

[5]The command *rollreg* developed by Christopher F. Baum is used for rolling regression estimates. More information on this command is available at `http://fmwww.bc.edu/repec/bocode/r/rollreg.html`

3.1.1 Selection of the performance measure

Rossi (2013) describes a process for evaluating a model's out-of-sample forecasting ability. First, the sample is divided into two subsamples, the in-sample and the out-of-sample. The former consists of observations from 1 to R, and the later consists of observations $R+h$ to $T+h$, of size $T-R$. Then, using the rolling window regression method, the parameter of interest is re-estimated progressively over time using the most recent R observations, where R is the estimation window size. Next, with the forecasts generated, the forecasting ability of a given model is measured by a loss function. In the original paper, Meese and Rogoff (1983) use the Root Mean Squared Forecast Error (RMSFE). According to their criterion, a model forecasts better than the random walk if its RMSFE measure is lower than the RMSFE obtained from the random walk.

I follow Berg et al. (2016) and evaluate the predictive ability of macroeconomic factors by looking at point forecasts and directional accuracy. The first procedure consists of computing the mean-squared prediction errors (MSPE) for all models. The mean-squared prediction error measures the expected squared distance between the true value and the value predicted by the model for a specific observation:[6]

$$MSPE = \frac{1}{H}\sum_{t}^{T}(s_t - \hat{s}_t)^2. \tag{7}$$

If the relative MSPE is less then 1, then we have evidence suggesting that the structural model performs better than the random walk, i.e., if

$$\text{if } \frac{MSPE^{macro}}{MSPE^{rw}} < 1 \tag{8}$$

where $MSPE^{macro}$ is for the macroeconomic fundamental model, and $MSPE^{rw}$ is for the random walk model, then the macroeconomic fundamental model outperform the random walk.

In this study, I obtain pairs of competing one-step-ahead forecasts for movements in the ex-

[6]The root mean squared forecast error (RMSFE) is the square root of the mean-squared prediction error (MSPE). They therefore measure the same thing and lead to the same conclusions.

change rate, from the macroeconomic model and from the random walk. Additionally, I compute the forecast errors $\hat{\varepsilon}_t^{macro}$ and $\hat{\varepsilon}_t^{rw}$ respectively. Then the *MSPE* of each model is computed , and the two are compared.

As Franses (2016) observes, there will always be a set of forecasts that scores lower on some criterion. This observation leads to the recommendation that one should test whether any observed differences in forecast performance are statistically significant. Hence, I compute the statistical significance of the gains in predictive accuracy using the Diebold-Mariano (1995) test of equal predictive ability. This test is based on the loss function $l_{i,t} = f(s_t, \hat{s}_{i,t})$, where i represents the model (macroeconomic model or random walk). In this study, I use the MSPE as loss function. The sample mean loss differential is denoted by $\bar{d}_{macro,rw}$,which is given by:

$$\bar{d}_{macro,rw} = \frac{1}{T}\sum_{1}^{T}(l_{macro,t} - l_{rw,t}), \tag{9}$$

and $\hat{\hat{\sigma}}_{macro,rw}$ is a consistent estimate of the standard deviation of $\bar{d}_{macro,rw}$. The Diebold and Mariano test statistic for one-step ahead forecasts is

$$DM = \frac{\bar{d}_{macro,rw}}{\hat{\hat{\sigma}}_{macro,rw}} \sim N(0,1) \tag{10}$$

The null hypothesis of the test states that there is no difference in the accuracy of the two competing forecasts:

H_0 : Macroeconomic model and random walk have equal predictive power.

H_1 : Macroeconomic model forecasts better than the random walk.

The final procedure consists of testing each forecast's accuracy. I calculate the success ratio of each forecast, which is the frequency of correct predictions by the model in terms of appreciation or depreciation of the bilateral nominal exchange rate. Pesaran and Timmerman (1992) suggest a procedure for testing the accuracy of forecasts in terms of correct prediction of the direction of change in the variable under consideration. The procedure is based on the proportion of times that the direction of change in the variable of interest (in this study, the bilateral nominal exchange rate) is correctly predicted in the sample. This test is relatively simple, because it does not require quantitative information on the variable of interest; the only data required are the signs of the variable of interest and of the prediction.

Consider the case in this study, where $x_t = \hat{E}(s_t|\Omega_{t-1})$ is the predictor of s_t and n is the number of periods for which a forecast is generated. Define two dummy variables as:

$$S_t = 1 \quad \text{if } s_t > 0$$

$$S_t = 0 \qquad \text{otherwise,}$$

and

$$X_t = 1 \quad \text{if } x_t > 0$$

$$X_t = 0 \quad \text{otherwise,}$$

Let $P_s = \text{Probability}(s_t > 0)$, $P_x = \text{Probability}(x_t > 0)$ and $\hat{P}$ be the proportion of times that the sign of s_t is predicted correctly. Given that P_s and P_x are not known, under the null hypothesis that s_t and x_t are independently distributed, P_s and P_x, are efficiently estimated by

$$\hat{P}_s = \sum_{t=1}^{n} \frac{S_t}{n} = \bar{S}, \tag{11}$$

$$\hat{P}_x = \sum_{t=1}^{n} \frac{X_t}{n} = \bar{X}, \tag{12}$$

Then, the Pesaran-Timmerman (1992) test statistic formula is

$$S_n = \frac{\hat{P} - \hat{P}_*}{\{v\hat{a}r(\hat{P}) - v\hat{a}r(\hat{P}_*)\}^{\frac{1}{2}}} \overset{a}{\sim} N(0,1) \tag{13}$$

where

$$\hat{P}_* = \hat{P}_s\hat{P}_x + (1-\hat{P}_s)(1-\hat{P}_x), \tag{14}$$

$$v\hat{a}r(\hat{P}) = \frac{1}{n}\hat{P}_*(1-\hat{P}_*), \tag{15}$$

and

$$v\hat{a}r(\hat{P}_*) = \frac{1}{n}(2\hat{P}_s-1)^2\hat{P}_x(1-\hat{P}_x) + \frac{1}{n}(2\hat{P}_x-1)^2\hat{P}_s(1-\hat{P}_s) + \frac{4}{n^2}\hat{P}_s\hat{P}_x(1-\hat{P}_s)(1-\hat{P}_x). \tag{16}$$

The Pesaran and Timmerman (1992) test statistic is used to determine whether the directional accuracy is statistically significant. The null hypothesis of the test is that s_t and x_t are statistically independent.

H_0 : s_t and x_t are stastically independent.

H_1 : s_t and x_t are not stastically independent.

The desired result is to reject this hypothesis, which would imply that the predictor x_t has indeed some power in terms of correctly predicting the sign of changes in the exchange rate.

3.2 Data

The data used in my estimation are at the daily frequency, and the period of observation ranges from March 28, 1996 to February 17, 2017 with 5,451 observations for each exchange rate and for each explanatory variable. The window sizes range from 20% to 50%, which means that the estimation window ranges in size from 1,090 to 2,726 observations. Table 8 summarizes this information. The decision to use data at the daily frequency is explained by Ferraro et al. (2015), who argue that by choosing a different frequency from the usual choice in previous studies, they were able to find a meaningful relationship between commodities prices and movements in the exchange rate.[7] The following variables are included:

- first difference of the logarithm of the bilateral nominal exchange rate between Canada and Japan (YEN-CAD), Mexico (MEX-CAD), Korea (WON-CAD), the US (USD-CAD) and the United Kingdom (GBP-CAD),[8]
- first difference of the logarithm of the West Texas Intermediate crude oil price,[9]
- first difference of the logarithm of the Bloomberg commodity index,[10]
- the Bank of England official interest rate,
- the Bank of Japan basic discount rate,
- the Bank of Korea call rate (overnight all trades),
- the Bank of Mexico 28 days TIIE interest rate,[11]
- the Bank of Canada overnight money market financing interest rate,
- the US three-month Treasury Bill, [12]
- first difference of the logarithm of the S&P GSCI, a commodities index which comprises the principal physical commodities that are traded in active, liquid futures markets,
- first difference of the logarithm of the S&P GSCI non-energy (SPGSNE), similar to the commodities index above, however it excludes all commodities included in the Energy sub-index[13]
- first difference of the logarithm of the gold fixing price, in the London Bullion Market, based in U.S. Dollars,

[7] Ferraro et al. (2015, page 17), state that "Our empirical results greatly differ from the existing literature in two crucial aspects: one is the choice of the economic fundamental (namely, commodity prices) that is very different from those commonly considered in the literature, and the other is the choice of a different data frequency, namely daily versus monthly/quarterly."

[8] Data obtained from Factset, a plataform available at the Financial Research and Learning Lab of Telfer School. Accessed on July 1st, 2017.

[9] West Texas Intermediate (WTI) is a type of crude oil used as a benchmark in oil pricing and the underlying commodity of the New York Mercantile Exchange's oil futures contracts, and it is the main benchmark for crude oil in North America. Data obtained from Federal Reserve Bank of St. Louis (FRED) database. Accessed on July 1st, 2017 `https://fred.stlouisfed.org/series/DCOILWTICO`

[10] The Bloomberg commodity index tracks prices of futures contracts on physical commodities on the commodity markets. Data obtained from Factset. Accessed on July 1st, 2017.

[11] TIIE stands for "The Interbank Equilibrium Interest Rate"

[12] This variable was used in the original paper of Berg et al. (2016). Interest rate data were obtained from the Central Banks of each country. Accessed on July 1st, 2017.

[13] Both S&P commodities index were obtained from Factset. Accessed on July 1st, 2017.

Table 9 presents descriptive statistics for the data used in this study. The selection of countries was made according to a trade criterion; the countries selected are consistently in the top 10 list of Canada's exports. Tables 1, 2, 3, 4, 5 6, and 7 list the major Canadian trade partners in recent years.

The dependent variable in each exchange rate model is the first difference of the logarithm of the nominal exchange rate. I collect the short-term interest rates and then I compute the interest rate differential with Canada, subtracting the daily short-term interest rate of each country from the daily Canadian short-term rate. The Canadian short-term interest rate is the daily overnight money market financing rate obtained from CANSIM, whereas for Canada's trade partners I obtain the overnight interest rate data from their Central Banks. Following the approach of Berg et al. (2016) I use the 3-month Treasury Bill rate for the US. The choice of the observation period is made based on data availability. For most of the countries, the historical short-term interest rate is only available after 1990.

The West Texas Intermediate crude oil price is used as a benchmark in oil pricing in North America. The S&P GSCI is a measure of general price movements and inflation in the world economy. The London Bullion Market Association (LBMA) Gold Price is published twice a day by ICE Benchmark Administration (IBA) and provides a benchmark price that is widely used across the globe by participants such as producers, consumers, investors and central banks.

The S&P GSCI is "calculated primarily on a world production-weighted basis and comprises the principal physical commodities that are the subject of active, liquid futures markets" (S&P GSCI Methodology 2017). I also use the S&P GSCI non-energy index, an alternative version of the S&P GSCI that excludes the commodities included in the energy sub-index.[14] Given that data regarding commodities price indexes are not available for every period of observation, I use unit imputation to fill the missing gaps.[15] These gaps are missing at random, hence, this method should not implicate in any problems in my analysis.

[14] The Energy sub-index consists of Crude Oil (and supporting contracts) and Natural Gas.

[15] Unit imputation is the process of replacing missing data with values. I compute the average of the three pre-gap values.

Figures 1, 2, and 3 show the behavior of commodities prices captured by different indexes. Initially, one can observe the boom of commodities prices in the period between 2000 and 2008. At the end of this period, given the financial crisis, we observe a decrease in commodities prices. In the second period, between 2009 and 2014, we can observe some degree of volatility. However, the changes are not as intense as the changes seen in the first period. The lowest degree of volatility is observed in the final period, between 2014 and the beginning of 2017.

The six macroeconomic fundamentals considered are: Bloomberg commodities index, the gold fixing price index, the West Texas Intermediate (WTI) crude oil price, thr S&P GSCI and the S&P GSCI non-energy index, and the interest rate differential. I intended to use the energy and non-energy commodity price indices from the Bank of Canada as Berg et al. (2016) did in their study. However, given that daily data on these indices are not publicly available, I substitute the S&P GSCI and the S&P GSCI non-energy index for them. Also, following the approach of Ferraro et al. (2015) I use the WTI crude oil price. Additionally, I choose the Bloomberg index given its recognition in financial markets and the gold fixing price because gold is the most popular form of metallic commodity.

4 Results

For each estimation window size, I generate six sets of rolling estimates of equation (4) for each bilateral exchange rate using the OLS method. Then, for each set of estimates, I generate one-step-ahead forecasts of movements in the exchange rate using equation (5). I also produce six sets of rolling estimates of the drift parameter $\hat{\alpha}$ for each exchange rate and estimation window, and the associated one-step-ahead forecasts for the random walk with drift model. These steps are followed by the calculation described in equation (8) of the relative MSPE, which is the MSPE for each set of forecasts based on a macroeconomic fundamental divided by the MSPE of the random walk with drift.

4.1 Point forecasts

I evaluate the predictive power of the macroeconomic factors for the bilateral nominal exchange rate between Canada and its mains trading partners using both point forecasts and directional accuracy criteria. Tables 10, 11, 12, and 13 show the relative mean-squared prediction errors (MSPE) for window sizes between 20% and 50%. A measure lower than 1 implies that the macroeconomic model performs better than the random walk with drift. The bold values in table 10 highlight the cases where the relative MSPE is greater than 1.

Table 10 shows results obtained with an estimation window size of 50%. The random walk model forecasts movements in the Canadian Dollar-Mexican Peso (CAD-MEX) exchange rate better than the structural model for any explanatory variable, except when the gold fixing price is the independent variable. The opposite is observed for the Canadian Dollar-Japanese-Yen exchange rate; when the gold fixing price is the macroeconomic factor, the structural model does not outperform the random walk with the 50% sample size.

Even though the macroeconomic model performance for the MEX-CAD is not great, the model works fine for the other pairs of exchange rates. In particular, for the USD-CAD, the relative MSPE is lower than .92 in all cases, except for the interest rate differential. The Bloomberg index and the two S&P indexes generate the lowest relative MSPE measures for the YEN-CAD and USD-CAD.

The random walk model is systematically outperformed by the macroeconomic model regardless of which macroeconomic factor is used as the explanatory variable when the window size is 20%, 25% or 33%. Notably, the relative MSPE measure is always lowest for the CAD-USD, indicating that the macroeconomic model performs best when applied to this exchange rate. This could be due to the fact that the Canadian and US economies are more closely integrated. However, the ratios are very close to 1 in most other cases. I do not clearly observe a consistent improvement of the model's performance when the window size changes.

The interest rate differential seems to be the worst predictor for any country. The relative MSPE is always close to 1, regardless of the pair of exchange rate and window size. The evidence regarding the interest rate differential provided in tables 10, 11, 12, and 13 is consistent with Berg et al.'s (2016) finding: the interest rate differential generates the worst performance of the macroeconomic model. Additionally, the evidence on tables 10, 11, 12, and 13 suggests that the S&P non-energy index performance is slightly worse than the S&P general index. This is also consistent with Berg et al.'s (2016) analysis, in which the Bank of Canada non-energy commodity price index performs better than the Bank of Canada energy commodity price index.

Next I test the statistical significance of the differences between forecasts using the Diebold and Mariano (DM) test (1995).[16] The decision criterion for the DM test is to reject the null hypothesis:

$$\text{if } dm < -1.96 \quad \text{or} \quad dm > +1.96,$$

In that case, the macroeconomic model forecasts better than the random walk benchmark and the result is statistically significant at the 5 per cent level.

Table 14 shows the DM test statistic for the Canadian-Dollar British-Pound (CAD-GBP). The evidence is favorable for the macroeconomic model when the explanatory variable is the Bloomberg commodities index, the crude oil prices index, or either of the S&P indexes. When the macroeconomic factor is the gold fixing price, the null hypothesis of equal predictive ability cannot be rejected at the 5% significance level for any window size. I also fail to reject the null hypothesis when the interest rate is the explanatory variable for the window sizes of 50%, 33% and 25%. Thus, even though the relative MSPE is always lower than 1 for the Canadian Dollar-British-Pound, the DM test suggests that in the case of gold fixing price and the interest rate differential, the macroeconomic model does not have significantly better predictive ability when compared to the benchmark.

The Canadian Dollar-Japanese-Yen exchange rate has similar performance to that of the CAD-GBP (table 15). I fail to reject the null hypothesis of equal predictive power at the 5% level of significance for any window size when the explanatory variable is the gold fixing price. Again,

[16]The command *dmariano* developed by Christopher F. Baum is used to compute DM test statistics. More information on this test is available at `http://fmwww.bc.edu/repec/bocode/d/dmariano.html`

the performance of the interest rate differential is mixed; I fail to reject the null hypothesis only when the window size is 25%. Moreover, the evidence is favorable to the macroeconomic model using the Bloomberg index, either S&P index or the crude oil price as explanatory variable.

The macroeconomic model also shows statistically significant gains for the case of the Canada's exchange rates with Korea and the United States (tables 16 and 18). However, the interest rate is the only exception in both cases; in the case of the USD-CAD, the null hypothesis of equal predictive power is rejected when the window size is 50% and 25%, and for the WON-CAD, the null hypothesis is rejected only when the window size is 25%.

Finally, the macroeconomic model seems to provide no improvement in terms of predictive power in the case of Mexico (table 17). I fail to reject the null hypothesis of equal predictive power for any combination of window sample and explanatory variable at the 5% level of significance for the Canadian Dollar-Mexican Peso. Perhaps the poor performance of the macroeconomic model is due to the fact that even though Mexico is an OECD country, it is probably the least developed country in this study and this might have an effect on its trade relationship with Canada. The importance of commodities for the Canadian-Mexican trade relationship might be considerably lower than for the other trade relationships. Moreover, given the higher level of uncertainty regarding the Mexican economy, the foreign exchange rate market might depend on other macroeconomic factors (such as productivity or income differential) besides the ones studied in this paper.

4.2 Directional accuracy

In this step, I first calculate success ratios, an indicator of categorical forecast performance. This measure is the proportion of times a model correctly predicts whether the Canadian dollar appreciates or depreciates against Canada's major trade partners. This exercise is important because in exchange rate forecasting one might be more concerned about the direction of changes in the exchange rate, rather then the magnitude of the forecast.

Tables 19, 20, 21, and 22 show the success ratios of the macroeconomic model for all sets of explanatory variables, and for the random walk model. Overall, the macroeconomic model for the CAD-USD exchange rate exhibits the highest success ratios among the pairs of currencies, and also when compared to the random walk's success ratio. Moreover, the Bloomberg index, the crude oil prices, and both S&P indexes generate the highest success ratios, while the interest rate differential and the gold fixing price generate the lowest ratios. The results for the interest rate differential are consistent with the results obtained by Berg et al. (2016), suggesting that the interest rate differential is indeed not a good predictor of movements in the exchange rate.

Figures 8, 7, 6, 4, and 5 allow us to compare the performance of the macroeconomic model for different estimation window sizes for a given exchange rate. The horizontal axis shows the four estimation window sizes, while the vertical axis shows the corresponding success ratio. In the case of Mexico, the success ratio increases with the estimation window size when the explanatory variable is the oil crude price or the S&P non-energy index. On the other hand, the macroeconomic model's performance deteriorates with bigger window sizes when using the gold fixing price, the interest rate differential, and the Bloomberg index.

Next, focusing on figure 5, one can clearly see that the macroeconomic model improves its performance for the CAD-USD exchange rate with bigger estimation window sizes, the exception being the gold fixing price and the interest rate differential models. It is also noticeable that the highest success ratios are obtained for the CAD-USD. The S&P index and the Bloomberg index produce the highest success ratios.

The macroeconomic model shows similar behavior in the case of Japan, reported in figure 7; bigger estimation windows are associated with higher success ratios. The only exceptions are the interest rate differential and the gold fixing price, in which cases, the success ratio decreases when the window size increases.

The macroeconomic model has a mixed performance for Korea and the UK, as we can see in figures 6 and 8. In the first case, there is a mild increase in the success ratio when the estimation window size increases. The macroeconomic model shows the highest success ratios for Korea when the S&P index is used as the explanatory variable. On the other hand, the worst performance is seen with the interest rate differential. Meanwhile, in the case of the UK, the macroeconomic model shows improvement in its performance when the crude oil price, the S&P non-energy, or the Bloomberg index are used. On the other hand, bigger estimation window sizes are associated with lower performance when the explanatory variable is the S&P or the interest rate differential.

Figure 9 shows the performance of the random walk model. There is not much improvement in the performance of the model when the window size changes. In fact, the random walk model shows a lower success ratio when the window size increases in the cases of the UK and the US.

Finally, I use the Pesaran-Timmerman (1992) test statistic to evaluate the statistical significance of the directional forecasts. The decision criterion for this test statistic is to reject the null hypothesis

$$\text{if } S_n < -1.96 \quad \text{or} \quad S_n > +1.96,$$

in which case I would conclude that the structural model has statistically significant directional accuracy power. Table 26 presents the Pesaran-Timmerman test statistic for the window size of 50%. Here, a failure to reject the null hypothesis implies that the forecast signs generated by the macroeconomic model do not have any statistically significant relationship with the signs from the actual data.

Not surprisingly, the evidence is highly unfavorable for the macroeconomic model in the case of the CAD-MEX. In particular, when the forecasts are generated using the interest rate differential, the model was not even capable of discriminating positive and negative changes in the CAD-MEX exchange rate, and so "N/A" is observed in table 26. The macroeconomic model also performs poorly in the cases of the GBP-CAD and the YEN-CAD when the gold fixing price is the explanatory variable. Following the tendency observed in the point forecasts results, the CAD-USD exchange rate statistics are statistically significant at the 5% for all variables, and this is also the case for the WON-CAD exchange rate.

5 Conclusion

This paper's analysis confirms that macroeconomic factors are useful for explaining movements in the bilateral nominal exchange rate. I estimate a macroeconomic model using the OLS method with a rolling in-sample window. The estimation is done for each of six different macroeconomic factors. This procedure allows me to generate one-step-ahead forecasts of movements in the nominal exchange rate. I also estimate a random walk with drift model for the five nominal exchange rates. Then, I compare the performance of the forecasts generated by the macroeconomic model to that of the random walk.

The empirical evidence in this paper is consistent with existing literature (Berg et al. 2016 and Moosa & Burns 2015). Overall, the evidence suggests that macroeconomic models based on the Bloomberg index or the S&P commodities index have the best performance for the USD-CAD exchange rate. One possible explanation for this observation is the fact that the US is by far the most important trade partner of Canada. On the other hand, the macroeconomic model has the worst performance for the Canadian Dollar-Mexican Peso exchange rate, notably when the interest rate differential is the explanatory variable. In fact, the evidence provided in this study suggests that the interest rate differential is the worst predictor for all exchange rates, which is consistent with results obtained by Berg et al. (2016).

This analysis could be extended by testing additional sets of macroeconomics factors such as inflation or productivity. I also would like to analyze in more depth why models for the Canadian Dollar-Mexican Peso have such a bad performance, specially because of the importance of NAFTA for both countries. Furthermore, it would be interesting to test whether there is an optimal window size in terms of point forecasts and directional accuracy.

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7 Figures and Tables

Table 1: **Goods exports 2015**

By region	Value of exports ($B)
United States	403.1
China	19.4
United Kingdom	15.2
Japan	10.7
Mexico	5.5

Source: Global Affairs Canada

Table 2: **Goods exports 2014**

By region	Value of exports ($B)
United States	395.458
EU	39.444
Japan	10.107
China	21.452
India	4.498
Mexico	7.911
South Korea	4.219

Source: Global Affairs Canada

Table 3: **Goods exports 2012**

By region	Value of exports ($B)
United States	338.7
China	19.3
United Kingdom	18.8
Japan	10.4
Mexico	5.4
Netherlands	4.5
South Korea	3.7
Germany	3.6
France	3.2
Brazil	2.6

Source: Global Affairs Canada

Table 4: **Goods exports 2011**

By region	Value of exports ($B)
United States	330.1
United Kingdom	18.8
China	16.8
Japan	10.7
Mexico	5.5
South Korea	5.1
Netherlands	4.8
Germany	4
France	3.1
Hong Kong	3

Source: Global Affairs Canada

Table 5: **Goods exports 2010**

By region	Value of exports ($B)
United States	299.1
United Kingdom	16.4
China	13.2
Japan	9.2
Mexico	5
Germany	3.9
South Korea	3.7
Netherlands	3.2
Brazil	2.6
Norway	2.5

Source: Global Affairs Canada

Table 6: **Goods exports 2009**

By region	Value of exports ($B)
United States	269.8
United Kingdom	12.1
China	11.2
Japan	8.3
Mexico	4.8
Germany	3.7
South Korea	3.5
Netherlands	2.8
France	2.7
India	2.1

Source: Global Affairs Canada

Table 7: **Goods exports 2008**

By region	Value of exports ($B)
United States	376.3
United Kingdom	13.1
Japan	11.1
China	10.4
Mexico	5.8
Germany	4.5
South Korea	3.8
Netherlands	3.7
Belgium	3.4
France	3.2

Source: Global Affairs Canada

Table 8: **Sample size**

Window Size	Estimation observations	Sample	Starting period
20%	4,361	1,090	02-June-2000
25%	4,098	1,362	19-June-2001
33%	3,634	1,817	18-March-2003
50%	2,725	2,726	11-September-2006

Table 9: **Descriptive statistics**

Variable	Mean	Std. Dev.	Min	Max
GBP-CAD	0.0000193	0.0026367	-0.0173428	0.0310383
YEN-CAD	0.00000777	0.0037491	-0.0300992	0.0300312
WON-CAD	0.0000335	0.004191	-0.0859665	0.0585337
MEX-CAD	0.0000826	0.0028876	-0.02983	0.0285645
USD-CAD	0.00000311	0.0023757	-0.0188376	0.0219154
UK interest rate differential	0.8576799	1.222812	-0.5202	7.5
Japan interest rate differential	-2.126733	1.662458	-5.36	0.75
Korea interest rate differential	2.308174	3.495913	-0.76	26.07
Mexico interest rate differential	7.962503	7.221895	1.745	45.55
US interest rate differential	-0.0408797	1.177245	-2.3424	7.8
WTI crude oil	0.0058631	1.386447	-14.76	18.56
Gold fixing price	0.1546964	10.71127	-140.5	77
S&P GS Non energy	0.0174063	2.962791	-23.02995	28.77525
S&P GSCI	0.0361212	6.284266	-50.3609	49.3304
Bloomberg	-0.0041533	6.323398	-125.2387	123.4821

Table 10: **Relative mean-squared prediction errors, window size = 50%**

Macroeconomic factor	UK	Japan	South Korea	Mexico	US
Bloomberg Commodities Index	0.98721	0.91089	0.96189	**1.00083**	0.82366
Interest rate differential	0.99911	0.99973	0.99981	**1.00044**	0.99928
Gold Fixing Price	0.99835	**1.00334**	0.98314	0.99008	0.9183
Crude Oil Prices (WTI)	0.98615	0.93554	0.9737	**1.0006**	0.90387
S&P Non-energy	0.99034	0.92595	0.9695	**1.0003**	0.84945
S&P Commodities index	0.98401	0.90738	0.96463	**1.00065**	0.8549

Relative mean-squared prediction errors (RMSPE) is the ratio between the mean-squared error (MSPE) of the forecasts based on a macroeconomic fundamental and the MSPE of the random walk with drift. If (RMSPE) is lower than 1, then the macroeconomic model outperforms the random walk. Bold values highlight the cases where the random walk model outperforms the macroeconomic model.

Table 11: **Relative mean-squared prediction errors,window size = 33%**

Macroeconomic factor	UK	Japan	South Korea	Mexico	US
Bloomberg Commodities Index	0.98943	0.90991	0.96312	0.99794	0.83985
Interest rate differential	0.99869	0.99925	0.99949	0.99963	0.99928
Gold Fixing Price	0.99721	0.99894	0.9817	0.98034	0.91222
Crude Oil Prices (WTI)	0.98739	0.9295	0.97333	0.99787	0.90637
S&P Non-energy	0.99261	0.92641	0.97128	0.99948	0.8662
S&P Commodities index	0.98608	0.90593	0.96575	0.99792	0.86703

Table 12: **Relative mean-squared prediction errors,window size = 25%**

Macroeconomic factor	UK	Japan	South Korea	Mexico	US
Bloomberg Commodities Index	0.98957	0.91161	0.96367	0.99707	0.84096
Interest rate differential	0.99839	0.99846	0.99873	0.99867	0.9988
Gold Fixing Price	0.9973	0.99328	0.97918	0.98026	0.91549
Crude Oil Prices (WTI)	0.98794	0.92219	0.97209	0.99723	0.90071
S&P Non-energy	0.99267	0.93164	0.97133	0.99855	0.86862
S&P Commodities index	0.98618	0.9034	0.96582	0.99707	0.86453

Table 13: **Relative mean-squared prediction errors,window size = 20%**

Macroeconomic factor	UK	Japan	South Korea	Mexico	US
Bloomberg Commodities Index	0.98984	0.9082	0.96402	0.99627	0.84308
Interest rate differential	0.99808	0.99909	0.99876	0.99824	0.99838
Gold Fixing Price	0.99798	0.98898	0.98171	0.98033	0.91761
Crude Oil Prices (WTI)	0.98808	0.91706	0.97207	0.99674	0.89864
S&P Non-energy	0.99255	0.92832	0.97218	0.99771	0.87032
S&P Commodities index	0.98686	0.89915	0.96595	0.99665	0.86391

Table 14: **Diebold Mariano statistic - UK**

Window Size	50%	33%	25%	20%
Bloomberg Commodities Index	2.802	2.309	2.477	2.42
Interest rate differential	1.363*	1.473*	1.544*	1.978
Gold Fixing Price	0.8457*	0.9473*	1.149*	0.8502*
Crude Oil Prices (WTI)	2.054	1.988	2.071	2.232
S&P Non-energy	2.548	2.215	2.443	2.473
S&P Commodities index	2.9	2.341	2.615	2.305

Cases with * denotes failure to reject H_0 at the 5% level of significance.

Table 15: **Diebold Mariano statistic - Japan**

Window Size	50%	33%	25%	20%
Bloomberg Commodities Index	3.512	2.839	2.685	2.586
Interest rate differential	0.5824*	1.684*	2.462	1.03*
Gold Fixing Price	-1.105*	0.2509*	1.17*	1.751*
Crude Oil Prices (WTI)	3.813	3.099	2.91	2.923
S&P Non-energy	2.661	2.313	2.183	2.094
S&P Commodities index	4.084	3.283	3.079	2.995

Cases with * denotes failure to reject H_0 at the 5% level of significance.

Table 16: **Diebold Mariano statistic - South Korea**

Window Size	50%	33%	25%	20%
Bloomberg Commodities Index	3.433	3.28	3.348	3.227
Interest rate differential	0.7309*	1.418*	2.567	1.908*
Gold Fixing Price	3.524	3.317	3.404	2.986
Crude Oil Prices (WTI)	3.993	3.268	3.213	3.046
S&P Non-energy	2.448	2.46	2.539	2.455
S&P Commodities index	3.788	3.386	3.408	3.189

Cases with * denotes failure to reject H_0 at the 5% level of significance.

Table 17: **Diebold Mariano statistic - Mexico**

Window Size	50%	33%	25%	20%
Bloomberg Commodities Index	-0.2435	0.5877	0.8127	1.189
Interest rate differential	-0.9204	0.4979	1.514	1.795
Gold Fixing Price	0.6214	1.431	1.62	1.763
Crude Oil Prices (WTI)	-0.2751	0.9823	1.032	1.359
S&P Non-energy	-0.1032	0.1825	0.4567	0.7968
S&P Commodities index	-0.2239	0.6945	0.8926	1.133

Table 18: **Diebold Mariano statistic - US**

Window Size	50%	33%	25%	20%
Bloomberg Commodities Index	4.522	4.159	3.948	3.874
Interest rate differential	3.605	1.176*	2.385	1.729*
Gold Fixing Price	3.386	4.014	4.113	4.211
Crude Oil Prices (WTI)	4.494	3.868	3.628	3.575
S&P Non-energy	3.81	3.576	3.453	3.358
S&P Commodities index	4.697	4.172	3.941	3.848

Cases with * denotes failure to reject H_0 at the 5% level of significance.

Table 19: **Success ratio, 20% window size**

Exchange Rate	UK	JAP	KOR	MEX	US
Bloomberg Commodities Index	0.53634	0.5657	0.56615	0.51685	0.60284
Gold Fixing Price	0.51227	0.52947	0.54254	0.53107	0.59963
Oil	0.53657	0.55882	0.55056	0.51089	0.57877
S&P Commidities index	0.53634	0.5634	0.56936	0.51525	0.59482
S&P Non-energy	0.5235	0.55056	0.55285	0.51089	0.59551
Interest rate differential	0.52534	0.51685	0.50952	0.51685	0.51112
Random Walk	0.50332	0.51089	0.50745	0.51525	0.51433

Table 20: **Success ratio, 25% window size**

Exchange Rate	UK	JAP	KOR	MEX	US
Bloomberg Commodities Index	0.53681	0.56224	0.56028	0.52189	0.60724
Gold Fixing Price	0.52115	0.52409	0.5461	0.53485	0.60137
Oil	0.5395	0.56102	0.55172	0.51577	0.58401
S&P Commidities index	0.54292	0.56395	0.56248	0.52018	0.59941
S&P Non-energy	0.52996	0.54903	0.55099	0.51137	0.59966
Interest rate differential	0.51015	0.52262	0.49743	0.51431	0.51846
Random Walk	0.50966	0.50942	0.50061	0.51480	0.50183

Table 21: **Success ratio, 33% window size**

Exchange Rate	UK	JAP	KOR	MEX	US
Bloomberg Commodities Index	0.53605	0.56219	0.56329	0.51706	0.62163
Gold Fixing Price	0.51156	0.51541	0.54458	0.53247	0.6098
Oil	0.5421	0.56577	0.55036	0.52174	0.59906
S&P Commidities index	0.55146	0.5721	0.56577	0.51624	0.6164
S&P Non-energy	0.53082	0.55806	0.55476	0.51266	0.60649
Interest rate differential	0.50908	0.51816	0.50193	0.51156	0.50963
Random Walk	0.50715	0.50881	0.49697	0.50798	0.50413

Table 22: **Success ratio, 50% window size**

Exchange Rate	UK	JAP	KOR	MEX	US
Bloomberg Commodities Index	0.53798	0.57725	0.57138	0.50642	0.62239
Interest rate differential	0.50716	0.52183	0.50606	0.51083	0.50936
Gold Fixing Price	0.50936	0.50275	0.55303	0.51303	0.59193
Crude Oil Prices (WTI)	0.54899	0.58642	0.55633	0.52294	0.60734
S&P Non-energy	0.54495	0.56991	0.5633	0.51376	0.60844
S&P Commodities index	0.53358	0.59083	0.57284	0.52073	0.62459
Random Walk	0.50348	0.51559	0.50715	0.51082	0.49100

Table 23: **Pesaran Timmerman statistic, 20% window size**

Exchange Rate	UK	JAP	KOR	MEX	US
Bloomberg Commodities Index	4.85032	8.35568	8.83178	1.91848*	13.61334
Gold Fixing Price	1.70796*	3.52096	5.68484	3.92309	13.18003
Oil	4.90941	7.62189	6.74179	0.97086*	10.47724
S&P Commidities index	4.84962	8.13025	9.22114	1.65519*	12.56421
S&P Non-energy	3.16437	6.30992	7.05395	1.02789*	12.60338
Interest rate differential	3.33198	1.58424*	1.34455*	1.86984*	1.35046*
Random Walk	0.5579*	0.89097*	1.25483*	1.67879*	2.11424

Cases with * denotes failure to reject H_0 at the 5% level of significance.

Table 24: **Pesaran Timmerman statistic, 25% window size**

Exchange Rate	UK	JAP	KOR	MEX	US
Bloomberg Commodities Index	4.79298	7.71592	7.86778	2.39673	13.75219
Gold Fixing Price	2.86506	2.81811	6.01491	4.21137	13.00619
Oil	5.20544	7.56784	6.72003	1.42633*	10.8443
S&P Commidities index	5.58643	7.97049	8.1181	2.13035	12.77531
S&P Non-energy	3.95462	6.04758	6.63077	0.86462*	12.75188
Interest rate differential	1.22191*	2.34921	-0.06826*	1.07472*	2.26068
Random Walk	1.50734*	0.89769*	0.45467*	1.28135*	0.59112*

Cases with * denotes failure to reject H_0 at the 5% level of significance.

Table 25: **Pesaran Timmerman statistic, 33% window size**

Exchange Rate	UK	JAP	KOR	MEX	US
Bloomberg Commodities Index	4.43304	7.34585	7.75202	1.83267*	14.7303
Gold Fixing Price	1.55412*	1.63811*	5.51496	3.79772	13.33721
Oil	5.22143	7.64245	6.23063	2.64599	12.13881
S&P Commidities index	6.29624	8.51324	8.14296	1.71715*	14.15065
S&P Non-energy	3.82212	6.9172	6.70895	1.18519*	12.88185
Interest rate differential	1.07012*	1.16828*	0.6218*	1.11692*	1.58294*
Random Walk	1.30419*	1.2981*	0.06652*	N/A	1.12047*

Cases with * denotes failure to reject H_0 at the 5% level of significance.

Table 26: **Pesaran Timmerman statistic, 50% window size**

Exchange Rate	UK	JAP	KOR	MEX	US
Bloomberg Commodities Index	4.20324	7.97611	7.56519	0.21867*	13.27284
Interest rate differential	0.67068*	1.70552*	-6.97102	N/A	2.22147
Gold Fixing Price	1.57799*	0.25283*	5.59262	1.26213*	9.88688
Crude Oil Prices (WTI)	5.38349	8.92521	6.10685	2.3057	11.6149
S&P Non-energy	3.69685	7.25558	6.70286	1.07708*	11.64788
S&P Commodities index	4.90673	9.42874	7.75769	1.9927*	13.39474

Cases with * denotes failure to reject H_0 at the 5% level of significance.

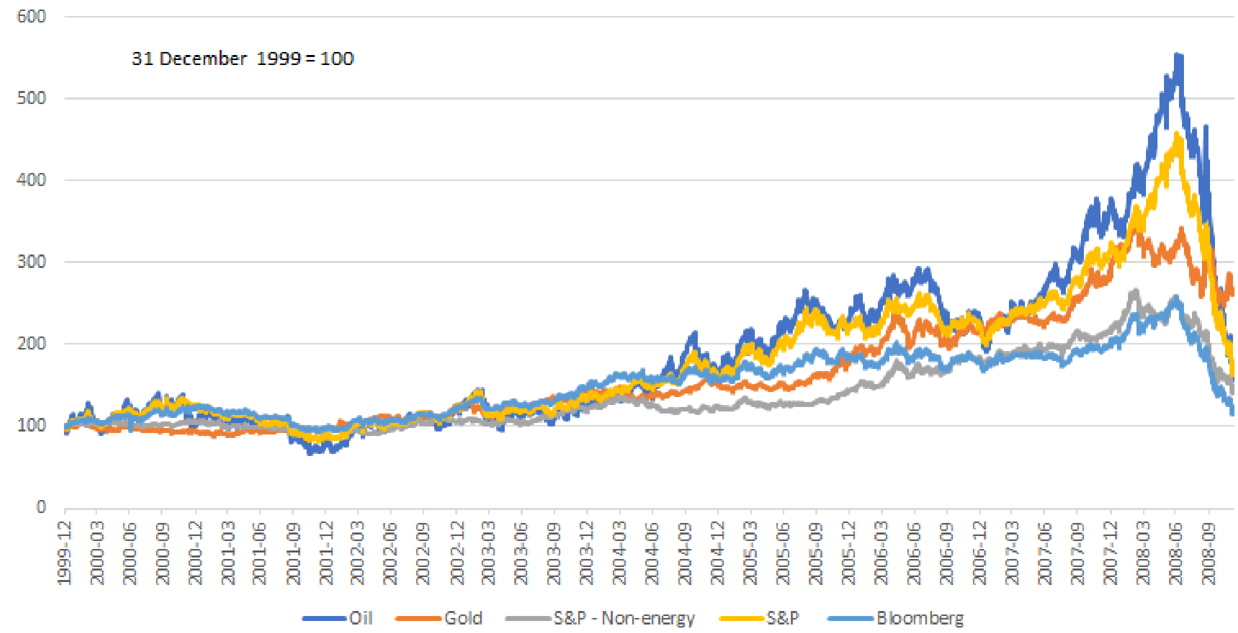

Figure 1: Commodities cycle 2000 - 2008

Source: Factset

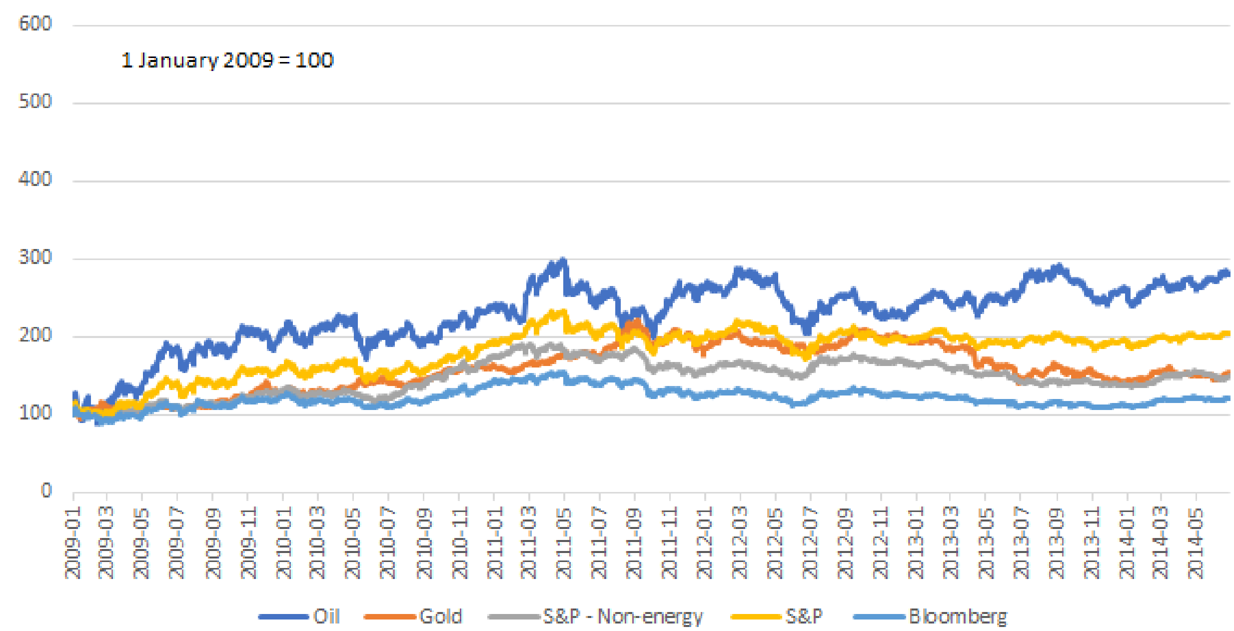

Figure 2: Commodities cycle 2009 - 2014

Source: Factset

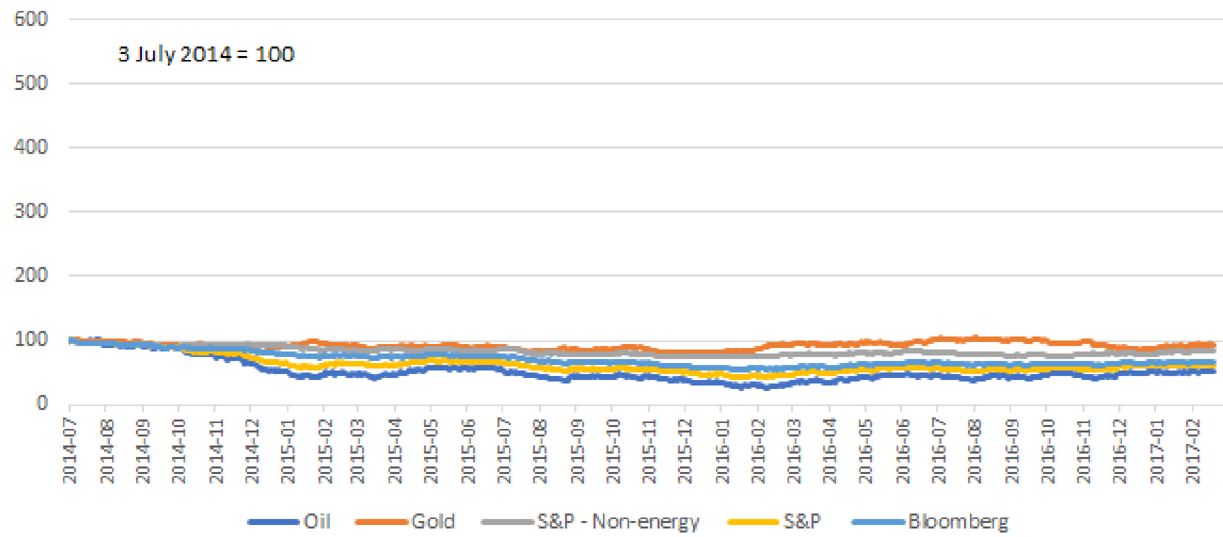

Figure 3: Commodities cycle 2014 - 2017

Source: Factset

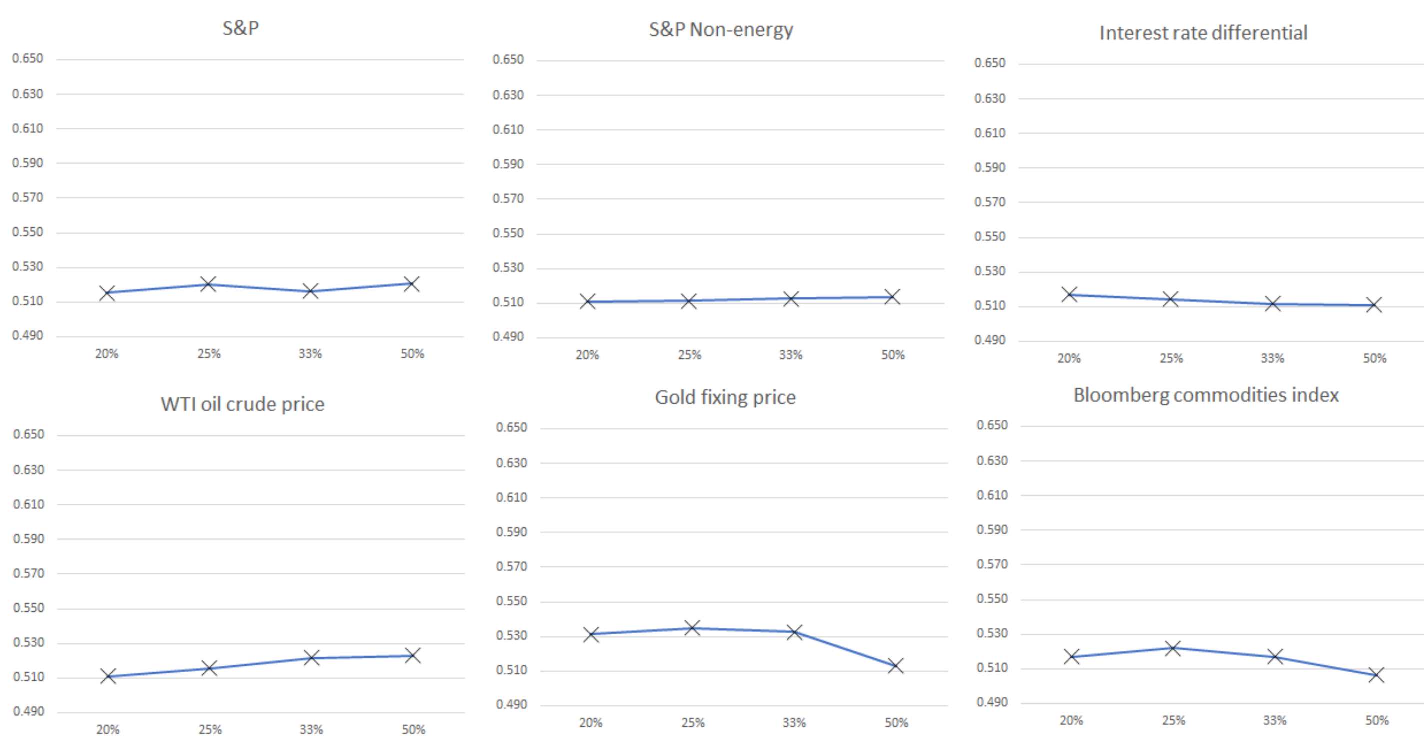

Figure 4: Mexico - success ratio

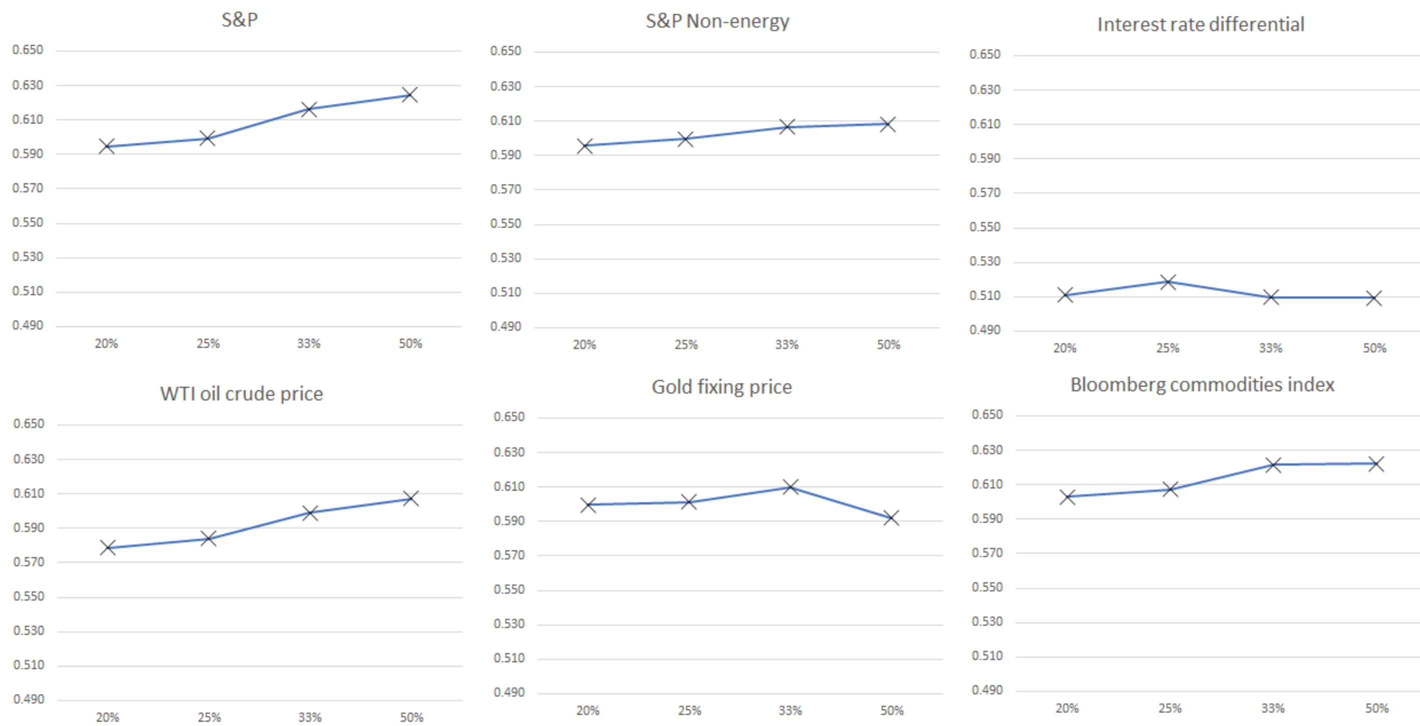

Figure 5: US - success ratio

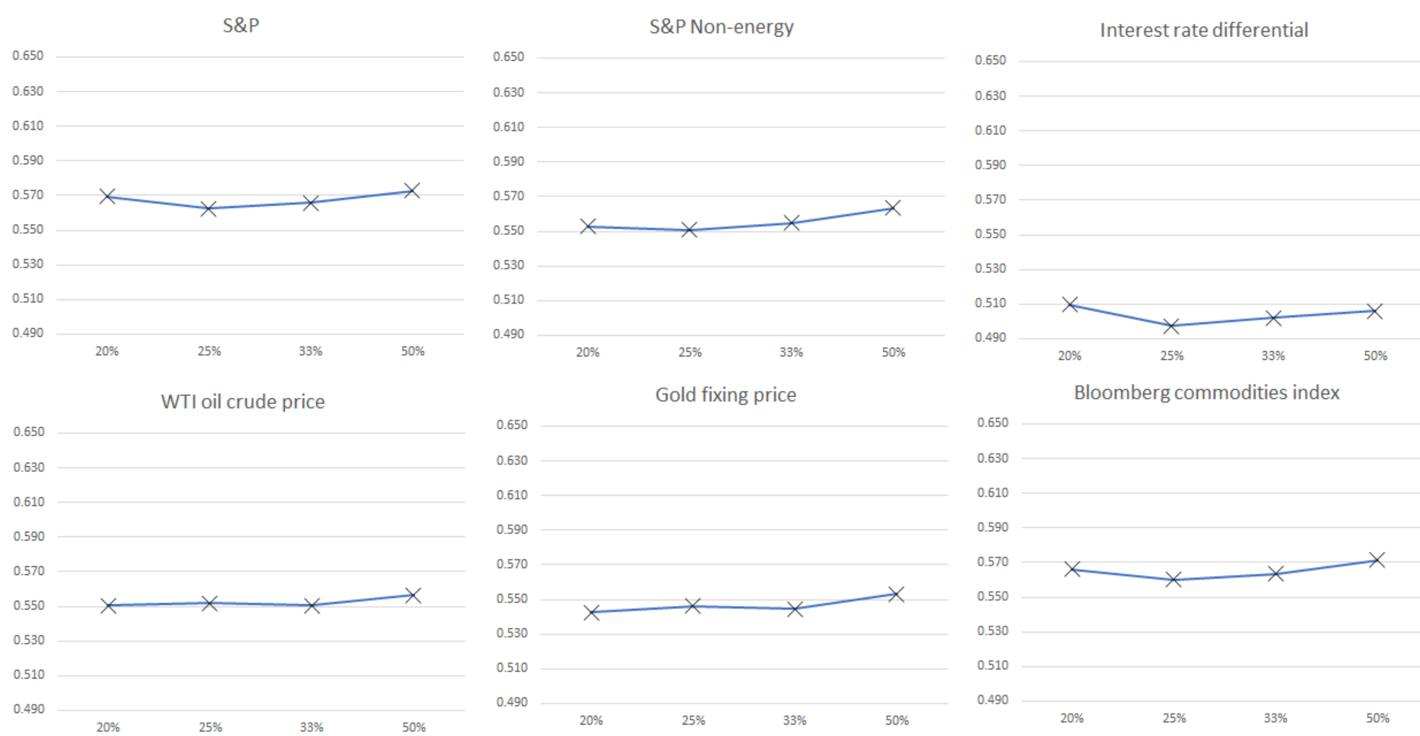

Figure 6: Korea - success ratio

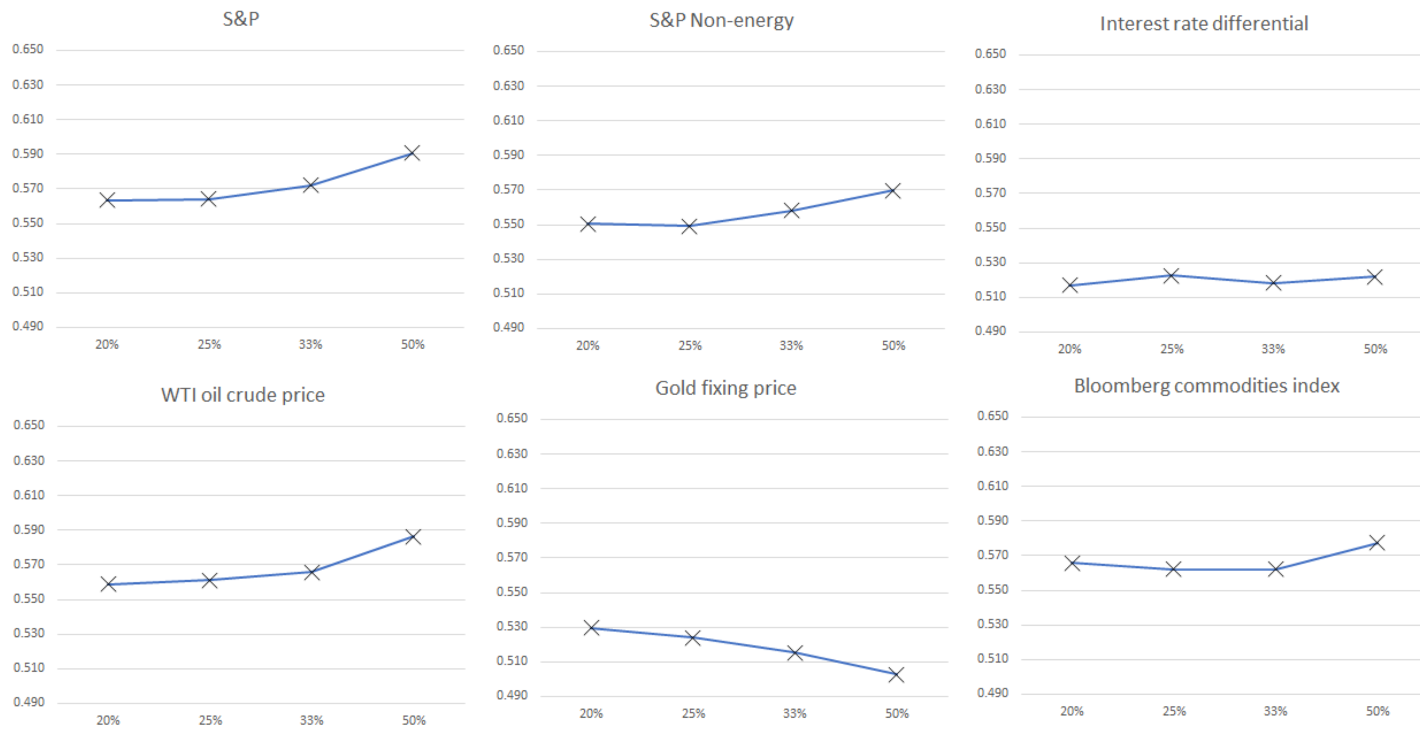

Figure 7: Japan - success ratio

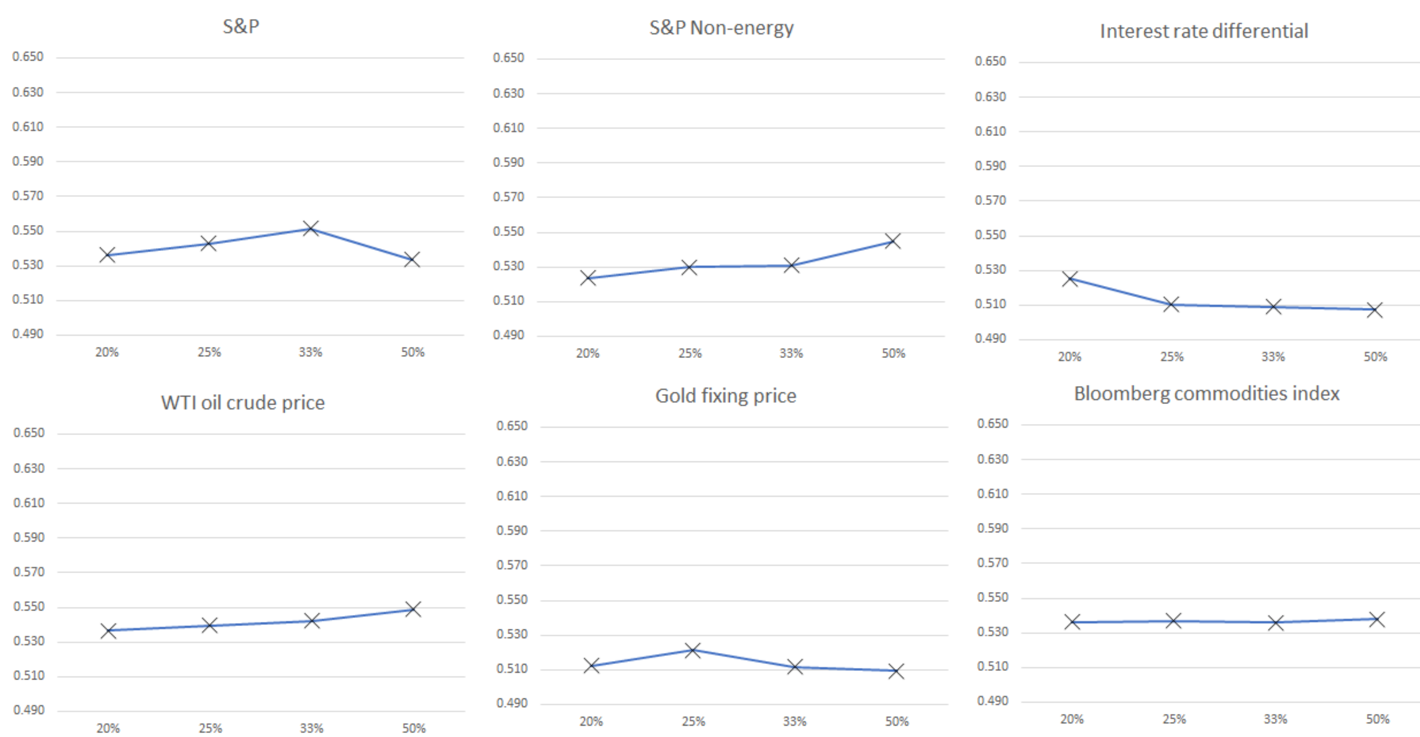

Figure 8: UK - success ratio

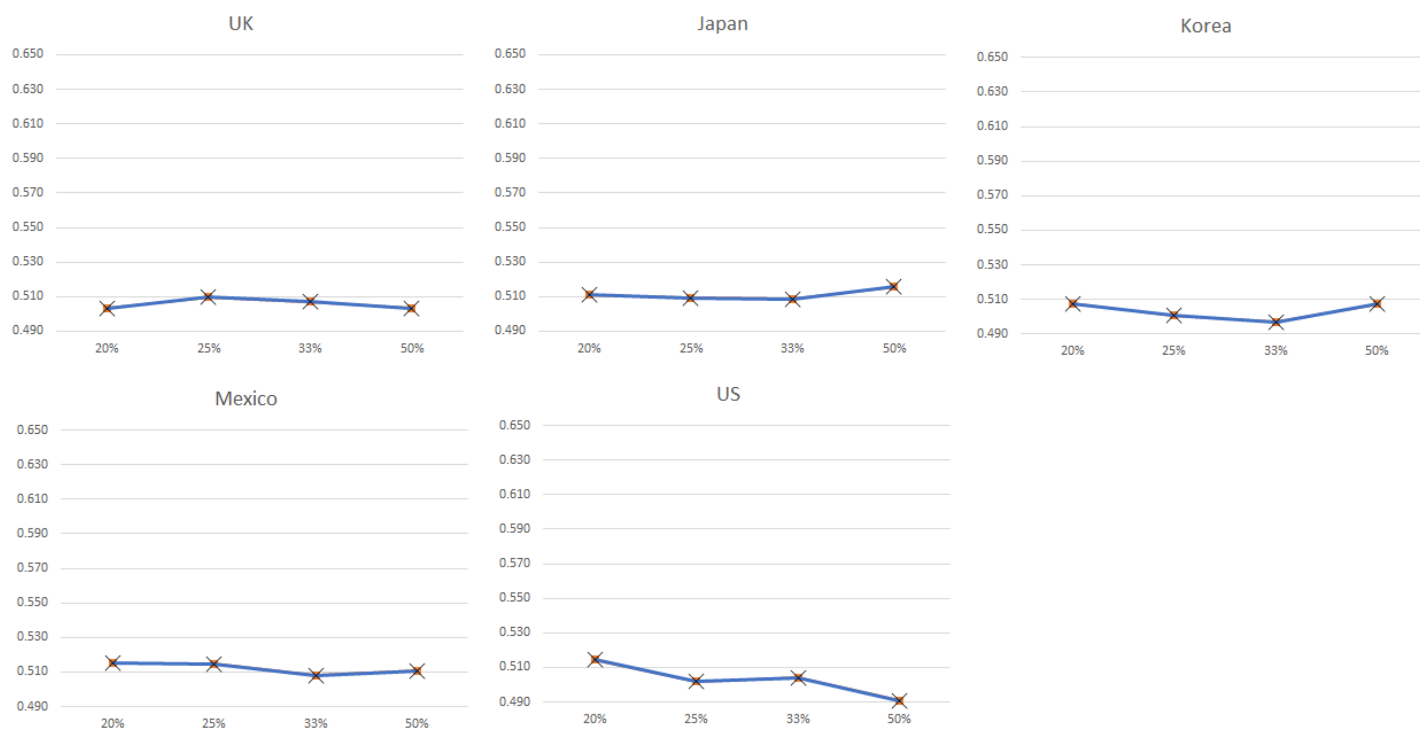

Figure 9: Random walk - success ratio