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The effects of interest, inflation, current account and share prices differentials on the out-of-sample exchange rate predictability.

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Abstract

Previous literature suggested that beating the random walk forecast of the exchange rate is a difficult task to do. The purpose of this study is to test to which extend the bond yield rate, the inflation rate, the current account rate and the share prices differentials affect the out-of-sample predictability of the exchange rate. The effects of these macro-economic variables on seven different exchange rates will be estimated by ARDL-models. In-sample estimations and short-run and long-run out-of-sample forecasts will be computed via these Models. The out-of-sample forecasts will be offset against the random walk.

The results of these forecasts suggest that six out of 14 forecasts of the ARDL-models can beat the random walk, according to the Diebold-Mariano test. Therefore, there can be concluded that the used macro-economic differentials are able to improve the out-of-sample predictability of the exchange rate.

Keywords: Out-of-sample predictability, Exchange rate, ARDL-model, Macro-economics

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Introduction

The exchange rate is one of the main international macro-economic variables. A lot of theory is known about this variable, but building a good and consistent predicting model for the exchange rate behaviour is still a difficult task to do. It has kept policy makers, economists, traders, companies and politicians busy constantly. Kilian and Taylor (2003) emphasize this statement by calling their paper '*Why is it so difficult to beat the random walk forecasts of the exchange rate?*'. An important reason of the difficulty of the task is that the exchange rates are affected by an infinite amount of influences, which are often correlated with each other. Besides that, speculation and bubbles play an important role for the behaviour of the currencies (Meese and Rogoff, 1988). By regressing the effects of the main economic variables on the exchange rates, a broad indication of the origin of exchange rate fluctuations can be indicated.

Lots of research has already been done on the influence of the interest rate on the exchange rate, but research on the effects of the inflation rate is scarce. J. Frankel (1979) implemented the inflation rates, next to the interest differential, into his model. However, he used a time series sample of less than four years. Next to that, he only used one currency: the German Mark/ US dollar rate. Molodtsova and Papell (2009) used Taylor-rule fundamentals to test the exchange rate predictability by using out-of-sample forecasts. By using the Taylor-rule, the interest rates are included in the model. The papers did not find convincing evidence of the out-of-sample predictability. Therefore, it could be scientifically relevant to rebuild the models again, with more and different exchange rates, a bigger sample, different control variables and a different econometric model.

The Auto Regressive Distributed Lag model (ARDL-model), the econometric model that is used, has various advantages compared to other econometric single-equation time series models. Because of the fact that the ARDL-model uses the Error Correction (EC) process, it is useful to forecast and disentangle long-run relationships between macro-economic variables. The model is capable in making a distinction between the short-run and long-run effects of the regressors on the regressand. Due to these characteristics of the model, it will be used to investigate the effects of the interest rate and inflation rate differentials on the exchange rate.

Therefore, the central research question reads as follows:

To which extent do the interest rate, inflation rate, current account and share prices differentials affect the out-of-sample exchange rate predictability?

In this thesis, the effects of the interest rate differentials and the inflation rate differentials on the exchange rates will be tested again. However, this time for a longer time period, namely between the years 1971 and 2019. Next to that, the current account and share prices differentials are added and more currencies are attracted to the model. The currencies that will be discussed are the US Dollar, the British Pound Sterling, the Swiss Franc, the Japanese Yen and the Canadian Dollar. These are currencies of powerful trade nations that have different relationships with each other. These currencies have been chosen, because these currencies are used for single countries. The is also the reason that the currency of the Eurozone has not been used, since the Euro is used in multiple countries. All these countries have different bond yield and inflation rates. This problem does not occur for the currencies that are mentioned before.

To answer the main research question, multiple hypotheses have been set up. These hypotheses will be discussed in the theoretical framework. In that section, a theoretical expectation of the hypotheses will be given too. The data and the methodology of this thesis will be discussed in the next section. Subsequently, the results of the models will be given. The results of the cointegrated relationships, the ARDL-models and the in-sample estimates and out-of-sample forecasts will be reviewed. At the end, based on the results, the hypotheses will be or will not be rejected in the conclusion.

Theoretical framework

Hypothesis 1: To which extent do the interest rate differential and the inflation rate differential influence the exchange rate?

According to Frankel (1979), there are two main approaches to the relationship between the exchange rate and the interest rate. The two approaches have conflicting implications for the relationships between the two variables. The first approach is the so called "Chicago" theory, while the second approach is called the "Keynesian" approach. In this paper the exchange rate is defined as the domestic price of foreign currency. Therefore, a positive (negative) relationship between a variable and the exchange rate will result in a depreciation (appreciation) of the domestic currency when the particular variable increases.

The first approach is called the "Chicago" theory, because it assumes that the prices are fully flexible (Bilson, 1978). The consequence of the flexible-price assumption is that the nominal interest rate will reflect the changes of the expected inflation rate. This comes from the fact that when the domestic interest rate rises relatively to the foreign interest rate, it is a result of the expectation that the currency will lose value, through inflation and depreciation. The demand of the currency of the domestic country will fall relatively to the demand of the foreign currency, which will result in the depreciation of the domestic currency (Frenkel, 1976). So, this approach suggests that there is a positive relationship between the exchange rate and the nominal interest rate.

The Second approach is called the "Keynesian" approach because this approach assumes that the prices are sticky, at least in the short-run (Dornbusch, 1976). The consequence of this assumption is that the movements of the nominal interest rate reflect the changes in tightness of the monetary policy. When there is a contraction in the domestic money supply relative to the demand, without a fall in prices, then this will result in an increase of the domestic interest rate relative to the foreign interest rate. This relative increase of the domestic interest rate attracts capital inflow from foreign countries, which will result in an appreciation of the currency. Therefore, this approach suggests a negative relationship between the exchange rate and the nominal interest rate.

The first approach is a realistic description in cases where the variation in the inflation differential is significantly large. For example, during the German hyperinflation in the 1920s, which Frenkel (1976) used as sample. The second approach is a realistic description in cases where the inflation differential is significantly small. Frankel (1979) developed a model to make realistic descriptions of the exchange rate when the variation of the inflation rate differential is moderate, as the differential was among the major industrialized countries the period before the release date of this paper. The innovation of the model is that it is a combination of the Keynesian assumption of sticky prices and the Chicago assumption of the existence of secular rates of inflation. The model is a version that is based on the role of expectations and quick adjustments in the capital markets.

The outcome of Frankel (1979) is that the exchange rate is negatively related to the nominal interest rate differential, while it is positively related to the expected long-run inflation rate differential. In other words, an increase of the interest rate differential and a decrease of the inflation differential will both result in an appreciation of the domestic currency. The difference between the exchange rate and the equilibrium value of the exchange rate (an "over-shooting" of the exchange rate) is proportional to the real interest rate differential, the nominal interest rate differential minus the inflation rate differential. In periods of tight money, where the interest rate differential is high, the exchange rate will be below the equilibrium value.

The theory of the model exists of two fundamental assumptions. The first assumption is that the interest rate parity holds. It is assumed that there exist efficient financial markets in which the bonds of all different countries are perfect substitutes. The interest rate parity is a no-arbitrage condition. When the parity holds, investors are indifferent between the interest rates of bank accounts in different countries. When there is a difference between the interest rates, exchange rate movements will compensate this difference (Mishkin, 2007). This parity can be mathematically expressed in the following way, where the rate of depreciation of the currency (d_t) equals the interest rate differential between the domestic and foreign country ($r_t - r_t^*$):

$$d_t = r_t - r_t^* \qquad (1)$$

The second assumption is that the rate of depreciation is a function of the difference between the current spot rate and the equilibrium rate ($e_t - \bar{e}$) and the inflation rate differential between the domestic and foreign country ($\pi_t - \pi_t^*$), where θ is a parameter that represents the speed of adjustment:

$$d_t = -\theta(e_t - \bar{e}) + \pi_t - \pi_t^* \qquad (2)$$

Combining equations (1) and (2) will eliminate d_t, and will result in the following equation, where the difference between the current spot rate and the equilibrium rate is expressed in the real interest rate differential:

$$e_t - \bar{e} = -\frac{1}{\theta}[(r_t - \pi_t) - (r_t^* - \pi_t^*)] \qquad (3)$$

To explain the full exchange rate equation, the equilibrium exchange rate ($\bar{e}$) must be explained. The equilibrium exchange rate can be explained based on the purchasing power parity. This parity holds when different baskets of goods have the same real price in every location (the law of one price), in absence of transport costs and tariffs. When there is a price difference between countries, the exchange rate will compensate this difference (Taylor, 2006). So, the equilibrium exchange rate depends on the difference between the equilibrium prices of both countries. The equilibrium prices are the long-run market prices where the quantity of goods demanded equals the quantity of goods supplied. The parity can be mathematically expressed in the following way, where the equilibrium exchange rate equals difference between the domestic and the foreign equilibrium prices ($\bar{p} - \bar{p}^*$):

$$\bar{e} = \bar{p} - \bar{p}^* \qquad (4)$$

The money supply is an important variable that affects the exchange rate. The quantity theory of money has been used to involve the money demand in the exchange rate equation. The quantity theory of money implies that the product of the quantity of money and the velocity of money equals the product of the price level and the number of transactions (Friedman, 2017). By taking logs the following conventional money demand equation arises, where m_t is the log of money supply, p_t is the log of the price level, y_t is the log of output, r_t is the log of the velocity of money, and ϕ and λ are parameters:

$$m_t = p_t + \phi y_t - \lambda r_t \qquad (5)$$

By subtracting the foreign variables from the domestic variables in equation (5), and adding time subscripts, the following equation will arise:

$$m_t - m_t^* = p_t - p_t^* + \phi(y_t - y_t^*) - \lambda(r_t - r_t^*) \qquad (6)$$

By using bars to denote the equilibrium values, and remembering that in the long-run the spot rate equals the equilibrium rate ($e - \bar{e}$) the interest rate differential equals the inflation rate differential ($r_t - r_t^* = \pi_t - \pi_t^*$), by using equation (1) and equation (2), we obtain the following equation:

$$\bar{e} = \bar{p} - \bar{p}^* = \bar{m} - \bar{m}^* - \phi(\bar{y} - \bar{y}^*) + \lambda(\pi_t - \pi_t^*) \qquad (7)$$

Substituting equation (7) into equation (3) and assuming that the current values of the money supply and the output levels equal the expected equilibrium levels, the complete equation of the spot rate determination can be obtained, where $\alpha = -\frac{1}{\theta}$, $\beta = \frac{1}{\theta} + \lambda$ and u_t is the added error term:

$$e_t = m_t - m_t^* - \phi(y_t - y_t^*) + \alpha(r_t - r_t^*) + \beta(\pi_t - \pi_t^*) + u_t \qquad (8)$$

The Real Interest Differential Model of Frankel (1979) proves that $\alpha < 0$ and $\beta > 0$, by using German and US data from July 1974 until February 1978. From these results we can state that a relative higher (lower) interest rate will lead to an appreciation (depreciation) of the domestic currency, while a relative higher (lower) inflation rate will lead to a depreciation (appreciation) of the domestic currency.

Meese and Rogoff (1982a) compares the out-of-sample forecast performance of the Chicago model, the Keynesian model and the model of Hooper and Morton (1982), a study that will be discussed later. The paper of Meese and Rogoff shows that the three models do perform equally well as the random walk model. The paper of Meese and Rogoff (1982b) underlines this conclusion. The study demonstrates that the dismal performance of the short-run to medium-run forecasts is not imputable to the sample distribution of the coefficient estimates.

Meese and Rogoff (1988) presented slightly more favourable results of the forecast performances than their previous studies displayed. The study showed that the real interest rate differential, and thus the nominal interest rate and inflation rate differential, had the theoretical anticipated sign. However, it could not detect evidence for a statistically significant relationships between the exchange rate and the other variables.

Based on Meese and Rogoff (1982a), Molodtsova and Papell (2009) studied the performances of empirical exchange rate models. As the previous papers did not find evidence of out-of-sample exchange rate predictability, a model that incorporated the Taylor rule fundamentals has been tested. The paper examined the linkage between the exchange rate volatility and the set of fundamentals that arise when the central bank adjusts the interest rate according to the Taylor rule of Taylor (1993). The Taylor rule can be displayed in the following way, where $\ddot{i}_t$ is the target interest rate, π_t is the actual inflation rate, $\ddot{\pi}_t$ is the target level of the inflation rate, $(y_t$-$\bar{y}_t)$ represents the output gab and $\ddot{r}_t$ is the equilibrium level of the interest rate:

$$\ddot{i}_t = \pi_t + \alpha(\pi_t - \ddot{\pi}_t) + \beta(y_t - \bar{y}_t) + \ddot{r}_t \qquad (9)$$

Molodtsova and Papell (2009) combined the interest rate parity, the purchasing power parity and the monetary fundamentals with the Taylor rule equation. This combination resulted in an exchange rate forecast equation that exists of the nominal exchange rate (e_t), the domestic (d) and foreign (f) inflation and (lagged) interest rates, the real exchange rate (q_t) and an error term (η_t):

$$\Delta e_t = \omega - \omega_{d\pi}\pi_t + \omega_{f\pi}\pi_t^* - \omega_{dy}y_t + \omega_{fy}y_t^* + \omega_q q_t - \omega_{di}i_{t-1} + \omega_{fi}i_{t-1}^* + \eta_t \qquad (10)$$

From estimating this model, the paper proved that there was very strong evidence of exchange rate predictability by including the Taylor rule fundamentals in the exchange rate equation. The models containing the Taylor rule significantly outperform the random walk models in several occasions.

The theory does agree on several terms. It states that the interest rate and inflation rate differentials are vital variables for forecasting the exchange rate. It is expected that an increase of the interest rate differential will lead to an appreciation of the currency, while it is expected that an increase of the inflation rate differential will result in a depreciation of the currency. Therefore, the first hypothesis states the following: *An increase of the interest rate differential will lead to an appreciation of the domestic currency, while an increase of the inflation rate differential will result in a depreciation of the domestic currency*.

Hypothesis 2: To which extent does the current account differential influence the exchange?

Exchange rate movements will result in changes in the balance of payments of countries. When the domestic currency appreciates, it will be relatively more expensive for foreign consumers to import the goods form the domestic country, while it will be relatively less expensive for domestic consumers to import foreign goods. Thus, an appreciation of the currency will lead to higher imports and lower exports, while a depreciation will lead to lower imports and higher exports. Lower imports and higher exports will result in an improved trade balance, and thus will an appreciation (depreciation) of the home currency lead to a worsened (improved) current account. By following the reasoning, it is expected that the currency and the current account are negatively correlated (Roomer, 2000).

Hooper and Morton (1982) extended the model of Frankel (1979) by adding the current account and risk premium dynamics. The current account is added to the model, because the study assumes that the unexpected changes in the current account can provide information about shifts in underlying determinants that necessitate compensating shifts in the exchange rate in order to maintain the equilibrium of the current account in the long-run.

The equilibrium of the exchange rate is in the paper defined as the exchange rate that equilibrates the current account in the long-run. The long-run equilibrium value of the current account is determined by the rate where foreign and domestic investors wish to accumulate (or decumulate) domestic-currency-dominated assets after deducting the foreign-currency-based assets. The relationship between the exchange rate and the current account can be calculated by the following current account equation, where $\bar{C}$, the long-run current account balance, is a function of the equilibrium value of the exchange rate ($\bar{s}$) and a vector of other variables that affect the current account ($f_1(X)$):

$$\bar{C} = \gamma\bar{s} + f_1(X) \qquad (11)$$

The coefficient γ represents the long-run response of the current account to the exchange rate. When assuming the Marshall-Lerner condition does hold, coefficient γ is expected to be positive. By assuming that $E\Delta(\bar{s}) = 0$, equation (11) can be rewritten as:

$$f_1(X)_t - f_1(X)_{t-1} = C_t - E_{t-1}(C_t) - \bar{C} \qquad (12)$$

By converting equation (11) and equation (12), equation (8) can be extended in the following way, where η is the speed of adjustment between the actual current account and the expected current account, i is the lag number and λ is a parameter that represents the fraction of the gap between the actual value and the equilibrium value of the current account, that is expected to be eliminated in the next period:

$$e_t = m_t - m_t^* - \phi(y_t - y_t^*) + \alpha(r_t - r_t^*) + \beta(\pi_t - \pi_t^*) + \frac{1-\eta}{\gamma}\lambda\bar{C} * t - \frac{1-\eta}{\gamma}\sum_i[\,C_{-i} - (1-\lambda)C_{-i-t}] + u_t \quad (13)$$

Equation (13) tells us that the exchange rate reacts on the cumulative movements of the current account and a time trend. Positive (negative) cumulative movements will result in an appreciation (depreciation) of the currency, while the trend has a downward effect on the value of the currency. The results of the paper show that all coefficients have the expected sign as in equation (13), and are significant (Hooper and Morton, 1982). Next to that, the study shows that the current account is a good indicator for the unexpected shocks in the real exchange rate. The results of the paper reflect that well over half of the movements in the exchange rate are caused by shifts in the current account and the real interest rate differential. Therefore, the current account is an important variable in the exchange rate model.

The paper of Lee and Chinn (2006) tests open-economy macro models by using structural vector auto regression analyses of the G7 countries. The paper states that temporary shocks have no long-run impact on the real exchange rate. The temporary shocks will affect the current account, and thus the current account will capture the temporary shocks in the model, as said in Hooper and Morton (1982). Shifts in the real exchange rate are caused by permanent shocks. Obstfeld and Rogoff (2005) come to the same conclusion, by using US data. The paper of Lee and Chinn (2006) also states that global shocks do not have effects on the exchange rate or the current account. Only country specific shocks have an effect on these two variables. The variables are only affected if the situation between the countries itself change.

In Kim and Roubini (2008) the effects of the fiscal policy on the current account and the real exchange rate are tested. Previous empirical evidences suggested that there exists “twin divergence”; the fiscal and current account move in opposite directions. When the fiscal account improves, the current account worsens, and vice versa. The paper studied US data between the first quarter of 1973 and the fourth quarter of 2004.

The empirical results of the study suggested that government deficit shocks improve the current account, and depreciate the real exchange rate in the short-run. The findings are robust under many different specifications. So according to the paper there exists a negative correlation between the current account and the real exchange rate. Detailed empirical analysis shows that the depreciation of the real exchange rate was mainly the result of a depreciation of the nominal exchange rate.

A previous empirical analysis of the US current account deficit showed the same results. Blanchard and Giavazzi (2005) tested two main forces behind the large current account deficits of the Unites States. First, the US demand for foreign goods had increased and, secondly, the foreign demand for US assets had increased. These forces resulted in a steadily increasing current account deficit since the mid-1990s. The paper showed that this steadily increasing current account deficit was accompanied by accompanied by a real exchange rate depreciation of the US dollar, the same results as the paper of Kim and Roubini (2008). The depreciation of the US dollar has accelerated since 2002. By developing a simple portfolio model, the paper of Blanchard and Giavazzi (2005) concluded that this acceleration of the depreciation of the US dollar will continue in the near future, surely against the Japanese Yen and the Chinese Renminbi.

The theory does agree on several terms. The exchange rate and current account are expected to be negatively correlated; an increase in the current account will result in an appreciation of the currency. Next to that, the current account could be seen as an important variable in capturing unexpected shocks. Therefore, the second hypothesis states the following: *An increase of the current account, divided by GDP, differential will lead to a depreciation of the domestic currency.*

Hypothesis 3: To which extent does the difference between the growth rates of the share prices influence the exchange rate?

Ajayi and Mougouè (1996) studied the relationship between the exchange rate and the stock prices for eight advanced economies, using daily data from 1985 to 1991. An error correction model has been used to estimate the short-run and long-run dynamics of both variables. The results of this model show that an increase in the aggregate domestic stock prices results in a depreciation of the domestic currency. Their explanation of this result is that an increase in the domestic stock prices indicates an expanding economy, which is related to higher inflation expectation. Foreign investors are less likely to invest in countries where the (expected) inflation is relatively high. Therefore, the money demand from foreign investors will decrease, which will lead to a lower valuation of the home currency.

Ajayi, Friedman and Mehdian (1998) investigated the causal relationships between the share prices differentials and the changes in the exchange rates, using daily data from 1987 to 1991. The share prices differential consisted of the difference between the stock returns of the United States and multiple advanced and emerging countries from Asia. The results of the paper provide evidence to indicate unidirectional causal relationships, in the Granger sense, between the share prices differentials and the change in exchange rates for the advanced countries. The stock market influences the exchange rate, and not the other way around. No consistent causal relationships have been found for the emerging countries. A possible reason for this last result is that emerging countries do not have developed financial markets. Therefore, activities in these undeveloped markets do not result in significant changes of the exchange rates. The results of this paper suggest that the exchange rate and the share prices are closely related, and thus the share prices differential could be a good variable to add to the model for predicting exchange rate movements.

Granger, Huang and Yang (2000) extended the previous paper. The paper investigates the relationships between movements in the stock market and the changes in the exchange rate for nine Southeast Asian countries. The results suggest the same outcome, where there exists a non-consistent unidirectional relationship between the share prices and the exchange rate. The share prices are leading the exchange rate with a negative correlation. The results could not determine dual causality between the two variables.

Next to that, did the studies on all different Asian countries show diversified results. A possible reason for this finding is that there are differences between the countries in terms of capital mobility and trade volume. This thesis will capture these effects by adding the current account to the model. Pan et al. (2007) confirms the previous mentioned results of Granger, Huang and Yang (2000). The paper comes to the same results by examining data of seven East Asian countries over the period between 1988 and 1998. Doong et al. (2005) strengthens these results even more. By investigating the dynamic relationship between the exchange rates and stock prices of six emerging Asians countries for a slightly different sample, 1989 to 2003, the paper shows results that are similar as the papers before; unidirectional negative causality between the stock prices and the exchange rate.

Aydemir and Demirhan (2009) tested the causal relationship between the exchange rate and the stock prices too, using Turkey's data from 23 February 2001 until 11 January 2008. This period has been chosen, because during this period the Turkish exchange rate regime was determined as floating. The results of this study show that there exists a bidirectional causal relationship between the exchange rates and the used stock prices indices. Most stock prices are negatively correlated with the exchange rate.

On the other hand, Nieh and Lee (2001) came to different conclusions. The study examined the relationship between the exchange rates and the share prices for G7 countries. The sample existed of daily data from 1993 until 1996. The results of the paper suggested that there is no long-run equilibrium relationship between the two variables. The given explanation stated that the exchange rate and the share prices are more dependent on each country's differences in their economic stage, government policy and expectation pattern than on each other. Ozair (2006) came to the same result by examining the causal relationship between both variables, using quarterly US data from 1960 to 2004. The results show that there is no causal linkage, and no cointegration, between the exchange rate and the share prices.

So, one can conclude that the papers are far from a consensus. The only similarity between the papers is that when a relationship between the exchange rates and the share prices has been proved, the two variables are likely to be negatively correlated. Therefore, the third hypothesis states the following: *An increase of the share prices differential will lead to a depreciation of the domestic currency.*

Data

Exchange rates

Seven different exchange rates have been used: the British Pound/US Dollar rate, the Swiss Franc/US Dollar rate, the Swiss Franc/British Pound rate, the Japanese Yen/US Dollar rate, the Japanese Yen/British Pound rate, the Canadian Dollar/US Dollar rate and the Canadian Dollar/British Pound rate. The exchange rates are in the form of foreign currency/home currency. As there are seven exchange rates, seven models have emerged. These exchange rates are chosen, because these are part of the most commonly traded currencies in the world. The Euro is not selected, because the Euro is used in multiple countries, with different bond yields and inflation rates. All nominal exchange rates are retrieved from the FRED database. The FRED database contains economic data released by the Federal Reserve Bank of St. Louis. The quarterly data captures the exchange rates between the first quarter of 1971 and the fourth quarter of 2018. The data is not seasonally adjusted.

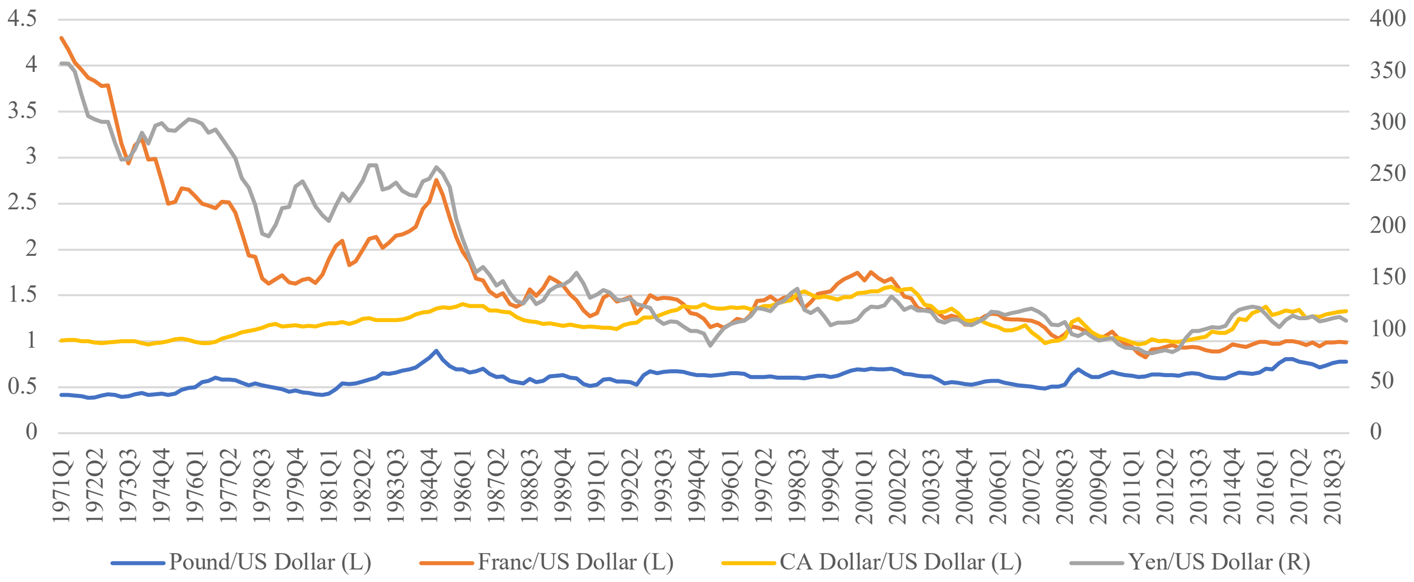

Figure 1: The British, Swiss and Japanese currencies compared to the US Dollar.

Figure 1 shows the movements of the British Pound, the Swiss Franc, the Canadian Dollar and the Japanese Yen, compared to the US Dollar. The figure shows a downward sloping line for the Japanese Yen and Swiss Franc. This implies that the US Dollar has appreciated compared to these exchange rates between 1971 and 2018, while the valuation of the US Dollar did not change significantly compared to the British Pound and the Canadian Dollar.

The left vertical axis shows the values for the exchange rates of the Pound, the Franc and the Canadian Dollar, compared to the US Dollar. The right vertical axis shows the values for the exchange rate of the Yen, compared to the US Dollar. Table 1 contains the descriptive statistics of all exchange rates used in this thesis.

Table 1:
Descriptive statistics exchange rates

Descriptive statistic	CA Dollar/ Pound	CA Dollar/ US Dollar	Yen/Pound	Yen/US Dollar	Franc/Pound	Franc/US Dollar	Pound/US Dollar
Mean	2.081403	1.220177	291.2150	160.2666	3.013499	1.661188	0.595452
Median	2.095732	1.211567	209.0028	122.4695	2.427527	1.468974	0.611462
Maximum	2.824230	1.594600	864.4666	357.6946	10.38338	4.301227	0.896902
Minimum	1.509901	0.965433	121.5679	77.33306	1.242809	0.826040	0.385022
Std. Dev.	0.294452	0.165099	183.9066	73.15278	1.945750	0.731257	0.099064
Skewness	-0.006816	0.230390	1.473070	0.976822	2.228683	1.584894	-0.102735
Kurtosis	2.292267	2.169162	4.175953	2.592753	7.720272	5.347286	2.940887

The nominal exchange rates are converted into quarterly growth rates. The logarithm of the current exchange rate is subtracted by the logarithm of the first lag of the exchange rate. The data is multiplied by 100 to get easy interpretable results. After these adjustments, the exchange rate variable will now be expressed in percentages.

Interest rates

The long-term (10 years) government bond yield rates are used as the interest rate variable. This variable is chosen, because this is the main government bond variable that represents the consumption and investment climate of a country. This variable is retrieved from the FRED database. The data is monthly available from January 1971 until December 2018. The variable is expressed in percentages. The data is not seasonally adjusted. Table 2 contains the descriptive statistics of the government bond yield rates of all five countries.

Table 2:
Descriptive statistics bond yield rate (%)

Descriptive statistics	Canada	Japan	Switzerland	United Kingdom	United States
Mean	5.022390	2.124161	2.840691	5.224587	4.721139
Median	4.721748	1.445667	2.864500	4.786850	4.615000
Maximum	11.14067	7.474667	6.812731	12.31667	9.206667
Minimum	1.059973	-0.145000	-0.509000	0.841100	1.563333
Std. Dev.	2.634528	1.876971	1.929034	2.819435	2.002800
Skewness	0.489819	1.172326	0.163766	0.548233	0.287085
Kurtosis	2.298750	3.375479	2.313622	2.533655	2.104802

Inflation rates

The annual growth rate of the consumer price index (CPI) per month is used as the inflation variable. The CPI is calculated as the per period change of a fixed set of consumer goods and services of constant quantity and various characteristics. The CPI is measured in a weighted average of a wide range of different indices. This variable is retrieved from the database of The Organization for Economic Co-operation and Development (OECD). The Data is monthly available from January 1971 until December 2018 and expressed in percentages. Table 3 provides the descriptive statistics of the inflation rates of the five countries.

Table 3:
Descriptive statistics inflation rate (%)

Descriptive statistics	Canada	Japan	Switzerland	United Kingdom	United States
Mean	4.034058	2.540760	2.319402	5.530418	3.995072
Median	2.653580	1.000000	1.360750	2.966667	3.147571
Maximum	12.69604	23.43333	10.75337	26.56568	14.50699
Minimum	-0.864304	-2.200000	-1.374020	0.333333	-1.622572
Std. Dev.	3.272364	4.410602	2.613812	5.390071	2.976584
Skewness	1.097695	2.680338	1.153318	1.760870	1.505694
Kurtosis	3.095114	11.61142	3.663661	5.713310	5.067578

Current account

This variable indicates the international economic position of a country. A positive current account reflects that a country is a net lender, while a negative current account reflects that a country is a net borrower. So, this variable captures a big part of the excess supply or excess demand of a currency. This variable is divided by GDP to create a ratio of the variable. According to Hooper and Morton (1982), this is one of the main variables that could describe the (real) exchange rate. This variable is partly derived from the FRED database and partly from the database of OECD.org. The data is quarterly available and expressed in percentages.

Table 4:
Descriptive statistics current account/GDP (%)

Descriptive statistics	Canada	Japan	Switzerland	United Kingdom	United States
Mean	-0.903131	2.750567	9.575517	-2.759456	-3.143805
Median	-1.366231	2.826641	9.569696	-2.827288	-2.638142
Maximum	3.626427	4.808359	18.41547	0.810210	-1.191212
Minimum	-4.850955	-0.739004	-2.762278	-6.731844	-6.299311
Std. Dev.	2.218931	1.107920	3.806261	1.646750	1.343821
Skewness	0.225612	-0.446648	-0.301525	-0.063237	-0.677422
Kurtosis	1.664416	2.932661	3.537047	2.575843	2.315686

Share prices

The growth rate of the share prices is added to the model to capture the wealth effects and the investment climate of the countries. The variable captures the weighted total share prices for all shares in the particular country. This variable is retrieved from the database of the FRED. The data is quarterly available from the first quarter of 1971 until the fourth quarter of 2018. The data is not seasonally adjusted. This variable is also expressed in percentages. Table 5 shows the descriptive statistics of the growth rate of the share prices of all five countries.

Table 5:
Descriptive statistics growth rate share prices (%)

Descriptive statistics	Canada	Japan	Switzerland	United Kingdom	United States
Mean	1.704045	1.589302	1.521932	2.007679	1.882986
Median	2.120056	1.770900	1.642293	1.805044	2.057346
Maximum	20.86433	25.16372	17.58942	42.21344	20.51986
Minimum	-31.09456	-29.88815	-28.66807	-23.73120	-30.43515
Std. Dev.	7.064949	8.341021	7.003999	8.002871	6.292797
Skewness	-0.630617	0.021109	-0.612079	0.458564	-0.892745
Kurtosis	5.484258	3.755131	4.591662	7.763777	6.869894

Methodology

ARDL-model and F-Bounds Test

In this thesis, the ARDL-model is used to model the relationships between the exchange rates and the other mentioned macro-economic variables. This model is used in the past decades to model various relationships between economic variables in time series setups. The ARDL-model contains lagged values of the dependent variable, and the current and lagged values of the independent variables. The model will automatically select the optimal number of lags for the dependent and independent variables individually (Pesaran and Shin, 1998). This will be done by using the values of an information criteria. The Aike Information Criteria (AIC) has been used to select the optimal number of lags in the ARDL-model.

The popularity of these models come due the fact that the models have some benefits. The model can be used if the variables are integrated of different orders, as long as the variables are not integrated of order two. So, the model can be used if the data is a combination of variables that are integrated of order zero or one, $I(0)$ or $I(1)$, respectively. Another reason for the popularity of the ARDL-model is that the model has a reparameterization in error correction form. This is useful in this thesis, because cointegration of different non-stationary variables are equivalent to the EC process (Hassler and Wolters, 2006).

Equation 14 is a generalized mathematical representation for the short-run ARDL (p, q) model. In an ARDL-model it is assumed that $p \geq 1$ and $q \geq 0$. Next to that, for simplicity it assumed that the lag order q is the same for all variables in the $K \times 1$ vector $\boldsymbol{X}_t$. In reality, the model could contain a different number of lags for all independent variables. The parameter γ_o represents the constant term, while ε_t is the error term and i denotes the lag number.

$$\mathrm{Y}_t = \gamma_o + \sum_{i=1}^{p} \delta_i \, Y_{t-i} + \sum_{i=0}^{q} \beta'_i \, \boldsymbol{X}_{t-i} + \varepsilon_t \tag{14}$$

Next to the short-run model, the ARDL-model can also test for the existence of a long-run relationship between the variables. The model is useful for forecasting and to calculate the long-run relationships from the short-run dynamics, because some time series are interconnected due to equilibrium forces.

Based on the EC representation of the ARDL-model, the cointegrating relationships between the variables can be tested. This can be done by using the F-Bounds test (Pesaran, Shin and Smith, 2001). The Bounds test will conclude whether the long-run model is useful or not. The following hypotheses will be tested:

$$H_0: (\lambda = 0) \cap (\textstyle\sum_{i=0}^{q} \beta_i = 0) \tag{15}$$

$$H_a: (\lambda \neq 0) \cup (\textstyle\sum_{i=0}^{q} \beta_i \neq 0) \tag{16}$$

Where the coefficient λ is the speed-of-adjustment parameter. This parameter measures to which extend the dependent variable will react to a deviation from the equilibrium relationship, and how fast this distortion of the equilibrium will be corrected. In other words, it shows that there is convergence in the long-run. The parameter should always have a negative sign. If not, the model will be explosive, and there will be no convergence (Pesaran and Shin, 1998). The speed-of adjustment parameter can be calculated in the following way:

$$\lambda = \left(1 - \textstyle\sum_{i=1}^{p} \delta_i\right) < 0 \tag{17}$$

There will be statistical evidence for the existence of a long-run relationship if the null hypothesis is rejected. If so, the long-run ARDL-model can be used. A generalized long-run ARDL(p, q, r)-model can be set up like the following equation:

$$\mathrm{Y}_t = c_o + \varphi_{1i}(p, q)X_{t-i} + \varphi_{2i}(p, r)Z_{t-i} + \varepsilon_{it} \tag{18}$$

Stationarity and Augmented Dickey-Fuller test

All variables that are included in estimated equations must be stationary. If the equation includes non-stationary variables, the estimated coefficients could be spurious and meaningless. A variable is stationary when it moves towards a mean, or a deterministic trend. The movements that diverges the variable from their constant mean, will be caused by random shocks. When the shock is faded away, the variable will move back to the mean. A non-stationary variable contains a unit root. Consider the following AR(1) equation:

$$Y_t = \alpha Y_{t-1} + c + u_t \tag{19}$$

Where Y_t is a particular variable, α is a persistence parameter, c is the constant term and u_t is the white noise ($E_t[u_{t+i}] = 0$). The variable Y_t will converge toward the mean $\frac{c}{1-\alpha}$ if $-1 < \alpha < 1$. Equation (20) could be written as follows, where both sides are subtracted by Y_{t-1} (where $\rho = \alpha - 1$):

$$\Delta Y_t = \rho Y_{t-1} + c + u_t \tag{20}$$

Stationarity of the variable requires that ρ has a value close to zero (Nelson and Plosser, 1982). In this case, the equation will be a random walk. This can be tested with the Augmented Dickey-Fuller test. In this thesis, the optimal lag length is automatically selected based on the Schwarz Info Criterion. The null and the alternative hypotheses of the Augmented Dickey-Fuller test could be written in the following way (Harris, 1992):

$$H_0: \rho = 0 \tag{21}$$

$$H_a: \rho < 0 \tag{22}$$

When it has been found that the particular variable is non-stationary, the null hypothesis will be rejected. Converting the non-stationary variables from a level estimation into a first difference estimation, is one way to solve the problem for unit roots (Dickey and Fuller, 1979). As an example, equation 23 will be converted from a level estimation into a first difference estimation, equation 24:

$$Y_t = \alpha Y_{t-1} + \beta X_t + \gamma Z_t + \varepsilon_t \tag{23}$$

$$\Delta Y_t = \alpha \Delta Y_{t-1} + \beta \Delta X_t + \gamma \Delta Z_t + u_t \tag{24}$$

Adding this all together, the six different ARDL models could be created. The government bond yield rate models (A-models) have the following equation:

$$Growth\ rate\ exchange\ rate_t = c_{oA} + \sum_{i=1}^{p} \varphi_{0\text{A}i}\, Growth\ rate\ exchange\ rate_{t-i} + \sum_{i=1}^{q} \varphi_{1\text{A}i}\, \Delta Bond\ yield\ differential_{t-\text{a}-i} + \varepsilon_{iAt} \tag{25}$$

The inflation rate models (B-models) have the following equation:

$$Growth\ rate\ exchange\ rate_t = c_{oB} + \sum_{i=1}^{p} \varphi_{0\mathrm{B}i}\ Growth\ rate\ exchange\ rate_{t-i} + \sum_{i=0}^{r} \varphi_{2\mathrm{B}i}\ \Delta Inflation\ differential_{t-\mathrm{b}-i} + \varepsilon_{iBt} \quad (26)$$

The current account models (C-models) have the following equation:

$$Growth\ rate\ exchange\ rate_t = c_{oC} + \sum_{i=1}^{p} \varphi_{0\mathrm{C}i}\ Growth\ rate\ exchange\ rate_{t-i} + \sum_{i=0}^{s} \varphi_{3\mathrm{C}i}\ \Delta Current\ account\ differential_{t-c-i} + \varepsilon_{iCt} \quad (27)$$

The share prices models (D-models) have the following equation:

$$Growth\ rate\ exchange\ rate_t = c_{oD} + \sum_{i=1}^{p} \varphi_{0\mathrm{D}i}\ Growth\ rate\ exchange\ rate_{t-i} + \sum_{i=0}^{v} \varphi_{4\mathrm{D}i}\ Growth\ rate\ share\ prices\ differential_{t-\mathrm{d}-i} + \varepsilon_{iDt} \quad (28)$$

The combination models (E-models) have the following equation:

$$Growth\ rate\ exchange\ rate_t = c_{oE} + \sum_{i=1}^{p} \varphi_{0\mathrm{E}i}\ Growth\ rate\ exchange\ rate_{t-i} + \sum_{i=0}^{q} \varphi_{1\mathrm{E}i}\ \Delta Bond\ yield\ differential_{t-\mathrm{a}-i} + \sum_{i=0}^{r} \varphi_{2\mathrm{E}i}\ \Delta Inflation\ differential_{t-\mathrm{b}-i} + \sum_{i=0}^{s} \varphi_{3\mathrm{E}i}\ \Delta Current\ account\ differential_{t-c-i} + \sum_{i=0}^{v} \varphi_{4\mathrm{E}i}\ Growth\ rate\ share\ prices\ differential_{t-\mathrm{d}-i} + \varepsilon_{iEt} \quad (29)$$

The long-run models (F-models) have the following equation:

$$Growth\ rate\ exchange\ rate_t = c_{oF} + \varphi_{1\mathrm{F}i} \Delta Bond\ yield\ differential_{t-\mathrm{a}} + \varphi_{2\mathrm{F}i} \Delta Inflation\ differential_{t-\mathrm{b}} + \varphi_{3\mathrm{F}i} \Delta Current\ account\ differential_{t-c} + \varphi_{4\mathrm{F}i} Growth\ rate\ share\ prices\ differential_{t-\mathrm{d}} + \varepsilon_{iFt} \quad (30)$$

Where the long-run coefficients are calculated in the following way:

$$\varphi_{\mathrm{XF}i} = \frac{\sum_{i=0}^{Y} \varphi_{\mathrm{XE}i}}{1 - \sum_{i=1}^{p} \varphi_{0\mathrm{E}i}} \quad (31)$$

In the long-run form, only the current variables, and thus no lags, are used. Hereby, it will show how much an increase of a variable in a particular point in time, will affect the exchange rate variable in the long-run.

Cointegration and Johansen Cointegration test

Since the research of Engle and Granger (1987) and Granger (1986), there arose increased interest in cointegration analyses of possible long-run equilibrium relationships between non-stationary variables. The papers concluded that a linear combination of multiple non-stationary variables may be stationary. If this stationary linear combination arises, the non-stationary variables are cointegrated. The stationary linear combination will result in the cointegrating equation. This equation can be interpreted as the long-run equilibrium between the variables. Consider the following first order dynamic equation:

$$y_t = \theta y_{t-1} + \phi x_t + \varepsilon_t \tag{32}$$

In this equation, y_t is explained by its lagged value, and an exogenous explanatory variable that follows a random walk, where u_t is the white noise ($E_t[u_{t+i}] = 0$).

$$x_t = x_{t-1} + u_t \tag{33}$$

We can rewrite formula (32) in the following way, by deducting from both sides the lagged dependent variable, and adding and deducting the lagged explanatory variable on the right side:

$$\Delta y_t = \phi \Delta x_t - (1-\theta)\left[y_{t-1} - \frac{\phi}{1-\theta} x_{t-1}\right] + \varepsilon_t \tag{34}$$

The expression within the square brackets is the error correction term. This term will adjust y_t downwards if its past value is above $\frac{\phi}{1-\theta} x_{t-1}$, and the other way around. The error correction term will keep the non-stationary variables together. The short-run disturbances will come due to the fact of changes in Δx_t and the error term ε_t.

Johansen (1991, 1995) presented new results on maximum likelihood estimators and likelihood ratio tests for cointegration, by using Gaussian Vector Auto Regressive (VAR) models. All series are required to be integrated of order 1, but the test will be performed on the level form of the variables (Cheung and Lai, 1993). Consider the following VAR-model of order p:

$$Y_t = A_1 Y_{t-1} + \cdots + A_p Y_{t-p} + BX_t + \epsilon_t \tag{35}$$

In this equation, Y_t is a k-vector of non-stationary variables, X_t is a d-vector of deterministic variables and ϵ_t is the vector of errors. Equation (35) can be rewritten in the following way:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-1} + BX_t + \epsilon_t, \tag{36}$$

where:

$$\Pi = \sum_{i=1}^{P} A_i - I_i \tag{37}$$

$$\Gamma_i = -\sum_{j=i+1}^{P} A_j \tag{38}$$

Granger's representation theorem says that if the coefficient matrix Π has a reduced rank of $r < k$ (where r is the number of cointegrating relationships), then $r * k$ matrices α and β exist, such that $\Pi = \alpha\beta'$ and $\beta' Y_t$ is stationary (I(0)). The approach of the Johansen Cointegration Test is to estimate the coefficient matrix Π from an unrestricted VAR. By using this VAR, it will be tested if the restrictions implied by the reduced rank of Π could be rejected.

The null and alternative hypotheses of the Johansen Cointegration test are stated as follows:

$$H_0: There\ exists\ no\ cointegrating\ equation \tag{39}$$

$$H_a: There\ exists\ a\ cointegrating\ equation \tag{40}$$

The null hypothesis will be rejected if the value of the trace statistics is higher than the critical value, using a 5% significance value. If not, the test has failed to reject the null hypothesis. In this thesis, EViews allowed for linear deterministic trends in the data, but the cointegrating equations are only allowed to have intercepts. The lag interval from 1 lag to 4 lags has been used. For all tests and models, the 5% significance level is used.

Forecast methods

The performance of the models will be compared by their predictable power. Two types of forecast methods have been used: the dynamic and static forecast methods. The dynamic forecast method includes multi-step forecasts, starting from the first observation of the forecast sample. This forecast method is only possible when the estimated equation contains at least one lag of the dependent variable. The previously estimated values of the dependent variable will be used for the lags of this variable. The first estimation will use actual values of the independent variable, as there are no previously estimated values. A simplified estimation of a dynamic forecast will be estimated in the following way, where $\hat{y}_{t+k}^{d}$ is the estimated dependent variable, x_{t+k} is an independent variable, and α, β and θ are coefficients:

$$\hat{y}_{t+k}^{d} = \alpha x_{t+k} + \beta \hat{y}_{t+k-1}^{d} + \theta \hat{y}_{t+k-2}^{d} \tag{41}$$

The static forecast method includes one-step ahead forecasts. The actual values of the dependent variable will be used for the lags of the dependent variable. So, previous estimations will not affect next estimations. A simplified estimation of a static forecast will be estimated in the following way:

$$\hat{y}_{t+k}^{s} = \alpha x_{t+k} + \beta y_{t+k-1} + \theta y_{t+k-2} \quad (42)$$

Both forecast methods will be used for the out-of-sample forecasts, to produce two different forecasts per exchange rate. The in-sample estimations will be computed by using the dynamic forecast method. The predictive power of the out-of-sample forecasts will be offset to the random walk in both timeframes. The (one-step ahead) random walks of the static forecasts can be described in the following way, where e_t is the growth rate of the exchange rate and u_t is the white noise (t represents the last observation before the first observation of the forecast sample):

$$e_{t+1} = e_t + u_{t+1} \quad (43)$$

As $E_t[u_{t+1}] = 0$, equation (43) can be rewritten in the following way:

$$e_t - e_{t-1} = \Delta e_t = 0 \quad (44)$$

Therefore, it is expected that the next observation of e_t has the same value as the current value of the variable. The random walks of the one-step ahead forecasts will be estimated in the following way:

$$e_{t+1} = e_t \quad (45)$$

The (multi-step ahead) random walks for the dynamic forecasts are computed in a different way. As it is expected that the change of e_{t+i} is zero, the long-term random walk can be described in the following way:

$$e_{t+n} = e_t + u_{t+1} + u_{t+2} + \cdots + u_{t+n} \quad (46)$$

As $E_t[\sum_{i=1}^{n} u_{t+i}] = 0$, rewriting equation (46) will results in the same equation as equation (44). Therefore, it is expected that every future value of e_t has the same value as the current value of the variable, for this timeframe. The random walks of the multi-step ahead forecasts will be estimated in the following way:

$$e_{t+n} = e_t \quad (47)$$

RMSE and Diebold-Mariano test

The Root Mean Squared Error (RMSE) is used as the forecast evaluation criterium. By using this criterium it is possible to compare different forecasts, it is a measure of accuracy of the forecasts. The RMSE is the squared root of the average of the squared difference between the actual and forecasted output. The lower the value of the measure, the better the forecast. Suppose the forecast sample has a value of $j = T + 1, T + 2, \dots, T + h$, and the actual and forecasted values are denoted as Y_t and $\widehat{Y_t}$, respectively.

The RMSE is applicable to compare different forecasts within the same dataset and not between different datasets, it is scale-dependent (Hyndman and Koehler, 2006). Therefore, it is possible to compare the different forecasts for every different exchange rate, and thus be able to conclude which model does estimate the individual exchange rates the best. The forecast evaluation measure is defined in the following way:

$$RMSE = \sqrt{\frac{\sum_{t=T+1}^{T+h}(\hat{Y}_t - Y_t)^2}{h}} \qquad (48)$$

While there could be a difference between the RMSE's, the forecasts won't always be statistically different. The Diebold-Mariano test (DM-test) has been used to test the statistical significance of the difference between two forecasts (Diebold and Mariano, 2002). So, it will test if the two forecasts have the same predictive power. This will be tested by calculating loss differential (L_t), which consists of the difference between the squared errors of the two forecasts. Y_t represents the actual values of the exchange rate, while $\hat{Y}_{1t}$ and $\hat{Y}_{2t}$ represent the forecasted values of the two different models. The loss differential will be calculated in the following way:

$$L_t = (\hat{Y}_{1t} - Y_t)^2 - (\hat{Y}_{2t} - Y_t)^2 \qquad (49)$$

The DM-test will test if the expected loss differentials are equal or not, for any given time period. The null hypothesis states that the two forecasts have the same accuracy, while the alternative hypothesis states that two forecasts have different levels of accuracy. The two hypotheses could be written in the following way:

$$H_0: E[L_t] = 0 \; \forall t \qquad (50)$$

$$H_a: E[L_t] \neq 0 \qquad (51)$$

The null hypothesis will be rejected if the p-value is lower than 0.05. If not, the test has failed to reject the null hypothesis, which means that the forecasts are not statistically different. The DM-test will only be done on the out-of-sample forecasts.

Results

Stationarity

Tables 18 until 22, in the appendix, describe the results of the Augmented Dickey-Fuller tests. As the null-hypothesis states that there exists a unit root, the t-statistic has to be smaller (more negative) than the critical value to be rejected. The results show that the growth rates of the exchange rates and the share prices differentials are stationary. The differentials of the government bond yield rates, the inflation rates and the current accounts tend to have a unit root. Therefore, these variables are converted into first differences and tested again. The results show that these variables are first difference stationary.

Results Johansen Cointegration test

Table 6 shows the results of the Johansen Cointegration test. The results of the table describe that there exist cointegrated relationships between the exchange rates and the independent variables. The relationship is very strong between the growth rate of the exchange rates and share prices growth rate differentials. The table suggests that there exist cointegrated relationships between the growth rate of the exchange rates and the other differentials too, but these results are ambiguous. The critical value of all tests is 15.495, using the five percent significance level.

Table 6:
Cointegrated relationships between the exchange rates and the independent variables

Exchange rates	Bond yield rate differential	Inflation rate differential	Current account differential	Share prices growth rate differential
British Pound/US Dollar	19.354**	17.482**	17.140**	65.680***
Swiss Franc/US Dollar	18.261**	15.097*	17.386**	47.531***
Swiss Franc/British Pound	23.037***	18.138**	13.248	57.063***
Japanese Yen/US Dollar	7.983	17.216**	21.505***	39.998***
Japanese Yen/British Pound	15.815**	23.054***	15.183*	49.941***
Canadian Dollar/US Dollar	56.577***	50.706***	30.616***	83.824***
Canadian Dollar/British Pound	13.741*	17.821**	14.156*	62.671***

* P<0.10, ** P<0.05, *** P<0.01

Results ARDL-models

All seven exchange rates are separately tested. Therefore, seven different time series models have been emerged. The models have different samples, because the availability of certain data differ between the countries. The sample sizes are cut in half. The first half of the samples are used to compute the models, where the second half of the samples are used to perform the out-of-sample forecasts.

The in-sample period for the British Pound/US Dollar model is between 1972Q3 and 1995Q3, for the Swiss Franc/US Dollar model between 1980Q2 and 1999Q3 and for the Swiss Franc/British Pound between 1982Q1 and 1999Q4. The Japanese Yen/US Dollar and Japanese Yen/British Pound models have an in-sample period between 1994Q2 and 2006Q3, while the in-sample periods of the Canadian Dollar/US Dollar and Canadian Dollar/British Pound models are between 1981Q2 and 1999Q4. The out-of-sample periods are between the next observation of the last of in-sample observation and 2018Q4. Table 23, in the appendix, shows all samples and sample sizes in an organized way.

The exchange rate is expressed in the foreign price of the home currency; an increase of the exchange rate means an appreciation of the home currency. The A-models are the government bond yield rate models. The B-models are the inflation rate models. The C-models are the current account models and the D-models are the share prices models. These models do only include the optimal number of lags of the exchange rate and the current and lagged values of the variables that are stated in their name. The E-models are a combination of those four models. These E-models do include all four variables. The F-models are the long-run models. These models contain all long-run equilibrium coefficients, which are extracted from the E-models. The results of the E-models will be described. The results of all other models could be interpreted in the same way.

Table 24, in the appendix, shows the results of the F-Bounds tests. The results of these tests show that for all E-Models the null-hypotheses will be rejected, the values of the test statistics are larger than both critical values. Therefore, it can be stated that the F-models, the long-run models, are useful.

Exchange rate British Pound/US Dollar

Table 7:
ARDL-models British Pound/US Dollar exchange rate (%)

Variables	Model A1	Model B1	Model C1	Model D1	Model E1	Model F1
Growth rate Pound/US Dollar (-1)	0.192* (0.105)	0.166* (0.100)	0.206** (0.102)	0.206** (0.102)	0.172* (0.102)	
ΔBond yield rate differential (-1)	1.291** (0.648)				1.361** (0.631)	5.015*** (1.787)
ΔBond yield rate differential (-2)	0.771 (0.643)				1.042* (0.622)	
ΔBond yield rate differential (-3)	1.052* (0.639)				0.656 (0.640)	
ΔBond yield rate differential (-4)	-0.016 (0.643)				-0.456 (0.642)	
ΔBond yield rate differential (-5)	1.433** (0.634)				1.551*** (0.608)	
ΔInflation rate differential (-5)		-0.853*** (0.325)			-1.007*** (0.359)	-1.217*** (0.445)
ΔCurrent account differential			0.757 (0.530)		0.643 (0.525)	0.777 (0.646)
Growth rate share prices differential				-0.012 (0.073)	-0.096 (0.073)	-0.116 (0.089)
Constant	0.420 (0.525)	0.485 (0.539)	0.423 (0.541)	0.343 (0.542)	0.400 (0.517)	0.483 (0.621)
RMSE estimation	4.971	5.058	5.220	5.271	4.621	n/a
R-squared	0.156	0.101	0.061	0.043	0.257	n/a
AIC	6.144	6.121	6.164	6.171	6.107	n/a
DW	1.892	1.991	1.987	1.975	1.990	n/a

* P<0.10, ** P<0.05, *** P<0.01 Sample: 1972Q3-1995Q3 (94 included observations), (Standard Errors in parentheses)

If the first lag of the growth rate of the exchange rate between the US dollar and the British pound increases by one percentage point, then the value of the US dollar is expected to appreciate by 0.172% compared to the value of the British pound. Although, this variable has an insignificant coefficient, using the 5% significance level.

When the first and fifth lag of the bond yield rate of the United States increase by one percentage point more than the government bond yield of the United Kingdom, then the value of the US Dollar, compared to the value of the British Pound, is expected to appreciate by 1.361% and 1.551%, respectively. The coefficients of the second, third and the fourth lag of the bond yield rate differential are insignificant. Therefore, the effects of these variables on the exchange rate are expected to be zero.

If the fifth lag of the inflation rate of the United States increases by one percentage point more than the inflation rate of the United Kingdom, then the value of the US Dollar is expected to depreciate by 1.007% compared to the value of the British Pound. When the current account, divided by the GDP, of the United States increases by one percentage point more than the current account, divided by the GDP, of the United Kingdom, then the value of the US Dollar is expected to appreciate by 0.643% compared to the value of the British Pound. However, the coefficient of this variable is insignificant.

If the growth rate of the share prices of the United States increases by one percentage point more than the growth rate of the share prices of the United Kingdom, then the value of the US Dollar is expected to depreciate by 0.096% compared to the value of the British Pound. The coefficient is statistically and economically insignificant.

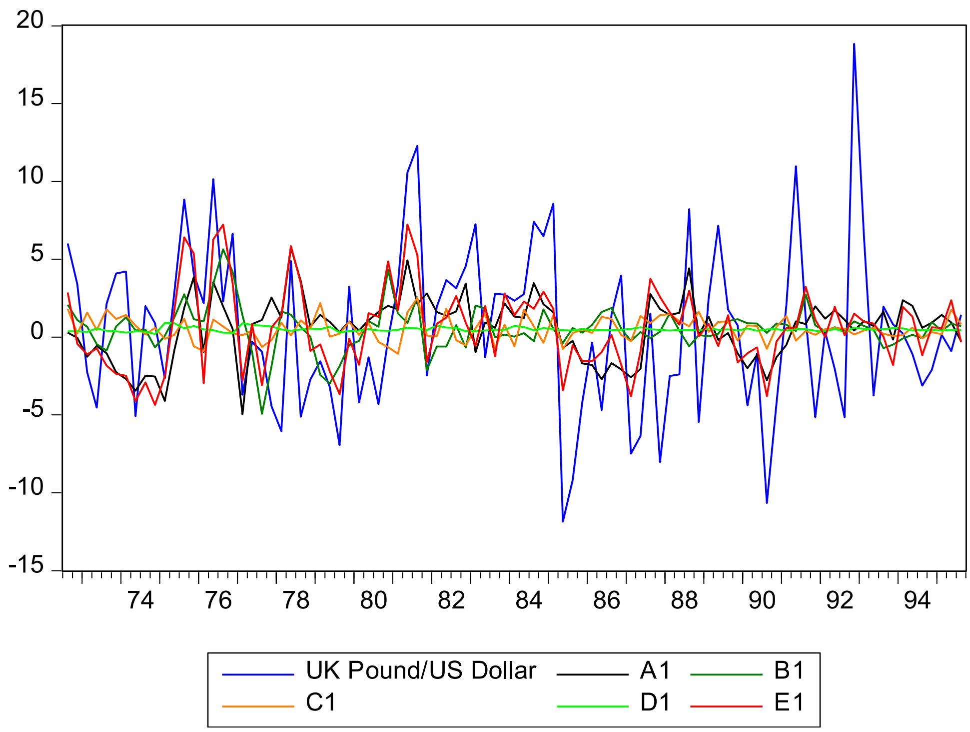

Figure 2: In-sample estimations British Pound/US Dollar (%).

Figure 2 shows the in-sample estimations of the five British Pound/US Dollar models. The red line (Model E1; the combination model) follows the actual exchange rate the – blue line – the best, especially in the period between 1975 and 1984. Most movements of the red line are caused by the bond yield rate differential. The black line (Model A1; the bond yield rate model) follows most of the movements of the red line. Therefore, it could be said that the bond yield rate differential is the most important variable in estimating the exchange rate, according to these estimations.

The same holds for the green line (Model B1; the inflation rate model), during the period between 1975 and 1984. The peaks are captured by both the red and green line. Some peaks are not estimated in full extend. Possibly, the speculation is the source of these big peaks, that could be started by a change of the included variables.

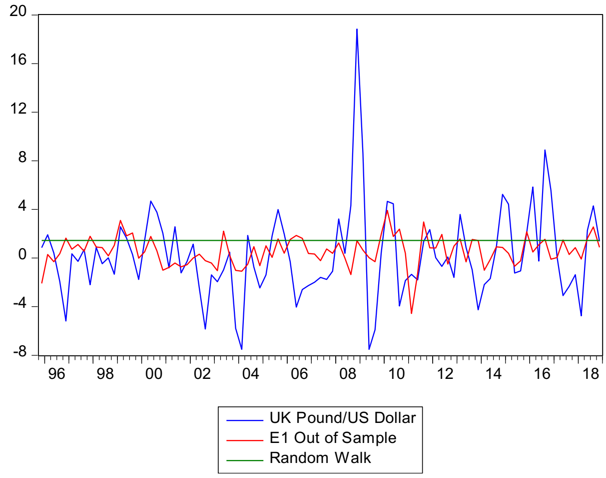

Figure 3: Out-of-Sample (dynamic) forecasts British Pound/US Dollar (%).

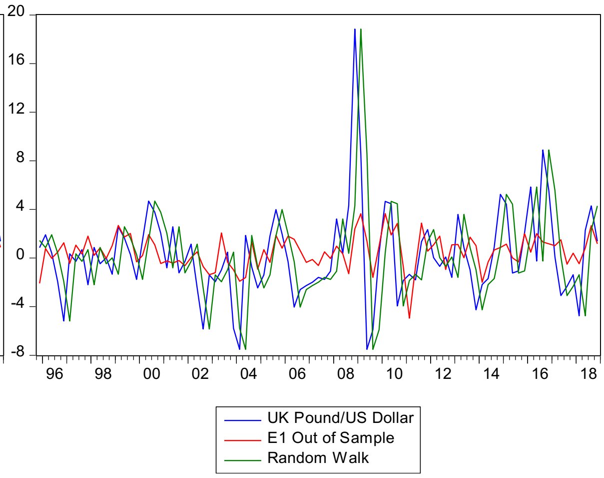

Figure 4: Out-of-Sample (one-step ahead) forecasts British Pound/US Dollar (%).

Figure 3 shows the out-of-sample multi-step ahead forecasts of the E1 model and the random walk. The out-of-sample forecast does follow some of the movements of the actual exchange rate, but not in full extend. The same holds for Figure 4, which shows the out-of-sample one-step ahead forecast of the E1 model and the one-step ahead random walk. In this figure does the E1 model capture the peaks better, but still not in full extend. As mentioned before, speculation could be the source of these extreme peaks. But according to the models, the differentials are likely to have predictable power and they are able to describe some movements of the exchange rate in the out-of-sample forecast.

Exchange rate Swiss Franc/US Dollar

Table 8:
ARDL-models Swiss Franc/US Dollar exchange rate (%)

Variables	Model A2	Model B2	Model C2	Model D2	Model E2	Model F2
Growth rate Franc/US Dollar (-1)	0.247** (0.110)	0.193* (0.113)	0.230** (0.112)	0.229** (0.110)	0.172 (0.112)	
ΔBond yield rate differential	2.285** (1.027)				2.494** (1.096)	6.346*** (2.155)
ΔBond yield rate differential (-1)	1.744* (1.043)				1.503 (1.040)	
ΔBond yield rate differential (-2)	-0.852 (1.010)				-0.999 (1.013)	
ΔBond yield rate differential (-3)	2.596*** (0.985)				2.256** (1.034)	
ΔInflation rate differential		-1.912** (0.926)			-1.841** (0.868)	-2.224** (1.033)
ΔCurrent account differential			-0.735 (0.5704)		-0.380 (0.565)	-0.459 (0.680)
Growth rate share prices differential				-0.201** (0.099)	-0.163* (0.090)	-0.200* (0.120)
Constant	-0.223 (0.590)	-0.255 (0.645)	-0.222 (0.642)	-0.045 (0.627)	-0.122 (0.596)	-0.148 (0.720)
RMSE estimation	5.094	5.539	5.619	5.652	4.832	n/a
R-squared	0.251	0.115	0.083	0.101	0.333	n/a
AIC	6.192	6.307	6.319	6.298	6.169	n/a
DW	1.958	1.906	2.004	1.850	1.856	n/a

* P<0.10, ** P<0.05, *** P<0.01 Sample: 1980Q2-1999Q3 (78 included observations), (Standard Errors in parentheses)

The results of model E2 can be interpreted in the following way. When the first lag of growth rate of the exchange rate between the US Dollar and the Swiss Franc will increase by one percentage point, then the current growth rate of the exchange rate is expected to increase insignificantly by 0.172 percentage point.

An increase of one percentage point of the current value and the third lag of the change of the bond yield rate differential is expected to result in appreciation of the US Dollar, compared to the value of the Swiss Franc, by 2.494% and 2.246%, respectively. So, this model does also suggest that a higher domestic bond yield rate will result in a clear appreciation of the domestic currency. The coefficients of the first and second lag of the bond yield rate differential are insignificant.

If the inflation rate in the United States increases by one percentage point more than the Swiss inflation rate, then the value of the US Dollar is expected to depreciate by 1.841%, compared to the value of the Swiss Franc. When the current account, devided by GDP, of the United States increases by one percentage point more than the one of Switserland, then it is expected that the value of the US Dollar, compared to the value of the Swiss Franc, will depreciate by 0.380%. However, this coefficient is statistically insignificant.

The growth rate of the share prices differential is negativelly correlated with the growth rate of the exchange rate; when the growth rate of the share prices differential will increase by one percentage point, then it is expected that the value of the US Dollar, compared to the value of the Swiss Franc, will insignificantly depreciate by 0.163%.

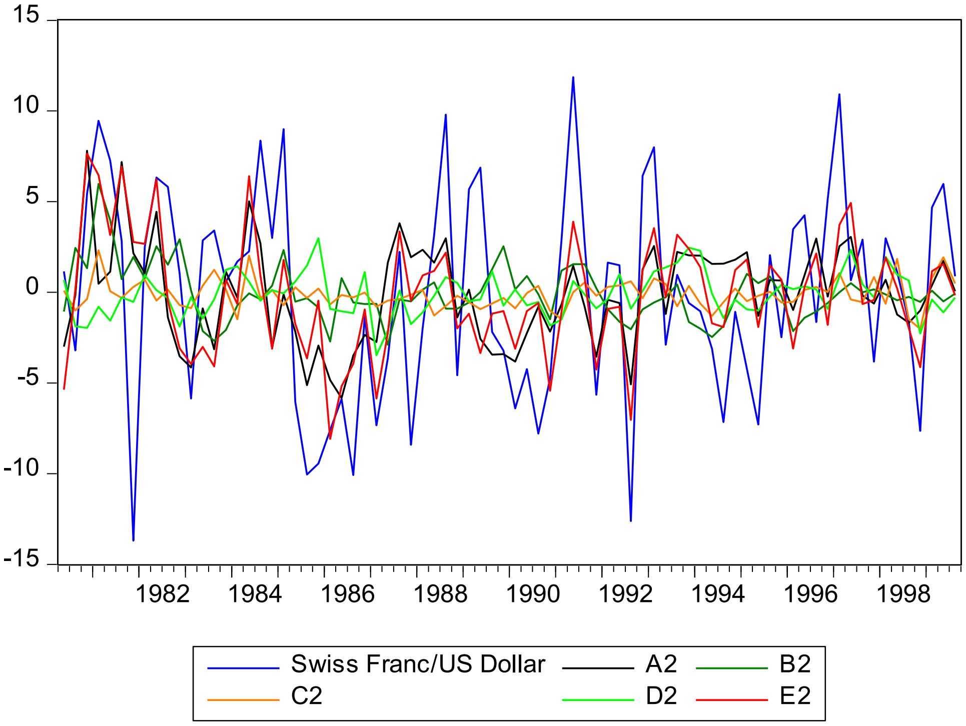

Figure 5: In-sample estimations Swiss Franc/US Dollar (%).

Figure 5 shows the in-sample estimations of the five Swiss Franc/US Dollar models. The red line (Model E2; the combination model) does follow the actual exchange rate relatively well. Some of the peaks are captured in full extend. This figure does also suggest that the bond yield rate differential is the most important variable in estimating the exchange rate. The black line (Model A2; the bond yield rate model) reflects the same movements as the red line. The estimation of the red line is more accurate than the black line, because Model E2 does also contain the inflation rate and share prices differentials.

The dark green line (Model B2; the inflation rate model) and the light green line (Model D2; the share prices model) show some correct estimations of the movements of the exchange rate. Therefore, the figures suggest that adding these variables into the E-models will help the models in estimating the exchange rate more accurate. As expected, the orange line (Model C2; the current account model) does not estimate the movements of the exchange rate well. The coefficient of the current account differential is insignificant.

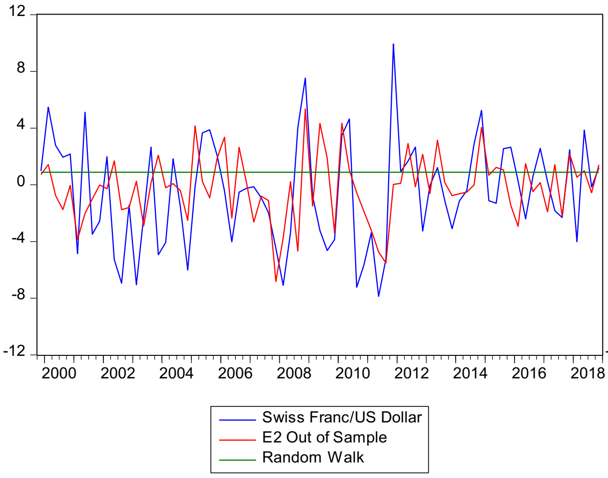

Figure 6: Out-of-Sample (dynamic) forecasts Swiss Franc/US Dollar (%).

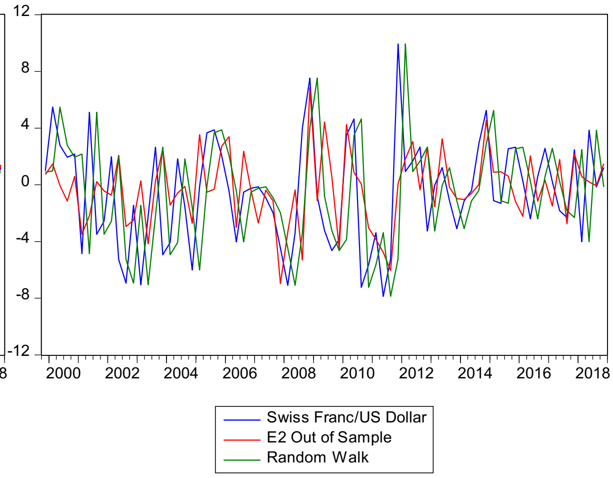

Figure 7: Out-of-Sample (one-step ahead) forecasts Swiss Franc/US Dollar (%).

Figure 6 shows the out-of-sample multi-step ahead forecasts of Model E2 and the random walk. Model E2 does forecast the exchange rate relatively well, especially in the period between 2004 and 2014. Most peaks are captured by the model. The same holds for Figure 7, the out-of-sample one-step ahead forecast of Model E2. The model does predict most of the movements of the exchange rate in the out-of-sample period. The last two figures do suggest that this model is capable in forecasting the Swiss Franc/US Dollar exchange rate, in some extend.

Exchange rate Swiss Franc/British Pound

Table 9:
ARDL-models British Swiss Franc/British Pound exchange rate (%)

Variables	Model A3	Model B3	Model C3	Model D3	Model E3	Model F3
Growth rate Franc/Pound (-1)	0.306*** (0.114)	0.300** (0.123)	0.232** (0.111)	0.252** (0.118)	0.285** (0.118)	
Growth rate Franc/Pound (-2)		-0.162 (0.115)				
ΔBond yield rate differential (-1)	1.987** (0.967)				2.027** (0.968)	5.375*** (2.070)
ΔBond yield rate differential (-2)	1.588* (0.892)				1.815** (0.903)	
ΔInflation rate differential		-0.148 (0.629)			-0.181 (0.609)	-0.254 (0.849)
ΔCurrent account differential			-0.698** (0.327)		-0.677** (0.312)	-1.775** (0.758)
ΔCurrent account differential (-1)			-0.658** (0.322)		-0.593** (0.281)	
Growth rate share prices differential				0.027 (0.089)	-0.020 (0.092)	-0.028 (0.127)
Constant	0.076 (0.498)	-0.431 (0.500)	-0.525 (0.492)	-0.320 (0.497)	-0.083 (0.488)	-0.115 (0.680)
RMSE estimation	4.022	4.195	4.025	4.224	3.819	n/a
R2	0.156	0.091	0.148	0.065	0.241	n/a
AIC	5.648	5.722	5.672	5.722	5.646	n/a
DW	1.972	1.913	1.857	1.869	1.951	n/a

* P<0.10, ** P<0.05, *** P<0.01 Sample: 1982Q1-1999Q4 (72 included observations), (Standard Errors in parentheses)

The results of model E3 can be interpreted in the following way. When the first lag of growth rate of the exchange rate between the British Pound and the Swiss Franc will increase by one percentage point, then the current growth rate of the exchange rate is expected to increase by 0.285 percentage point.

When the previous bond yield rate of the United Kingdom increases by one percentage point more than the bond yield rate of Switserland, then the value of the British Pound, compared to the value of the Swiss Franc, is expected to appreciate by by 2.027%. An increase of one percentage point of the second lag of the bond yield differential is expected to result in an appreciation of the British pound by 1.815%.

If the inflation rate in the United Kingdom increases by one percentage point more than the Swiss inflation rate, then the value of the British Pound is expected to depreciate by 0.181%, compared to the value of the Swiss Franc. However, the coefficient is insignificant, using a 5% significance level.

When the current value and the first lag of the current account, divided by GDP, of the United Kingdom increase by one percentage point more than the one of Switserland, then it is expected that the value of the British Pound, compared to the value of the Swiss Franc, will depreciate by by 0.677% and 0.593%, respectively.

The growth rate of the share prices differential is negatively correlated with the growth rate of the exchange rate; an increase of the growth rate of the share prices differential of one percentage point is expected to result in a depreciation of the British Pound, compared to the Swiss Franc by 0.020%. The coefficient is statistically and economically insignificant.

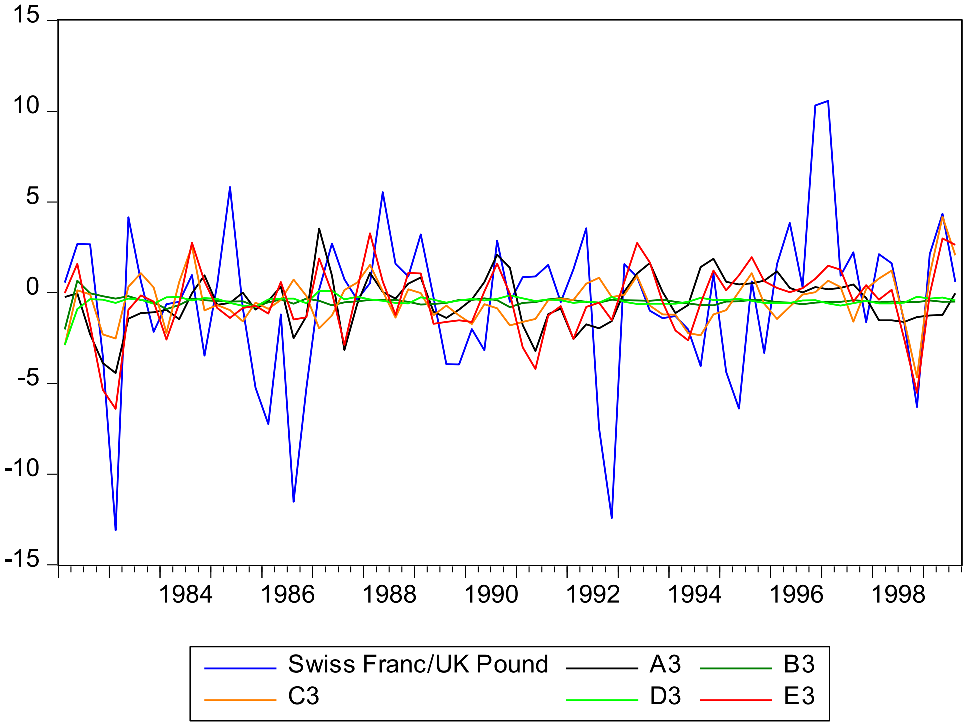

Figure 8: In-sample estimations Swiss Franc/British Pound (%).

Figure 8 shows the in-sample estimations of the five Swiss Franc/British Pound models. The red line (Model E3; the combination model) estimates the movements of the exchange rate the best of all Swiss Franc/British Pound models. The big peaks are not captured by the model, but most of the small movements are estimated. Speculation and sentiment could be the source of the big peaks in the movements of the exchange rate.

As the previous in-sample estimation suggested is the bond yield rate differential the most important variable in estimating the movements of the exchange rate. The black line (Model A3; the bond yield rate model) and the orange line (Model C3; the current account model) estimate the movements of the exchange rate well too. These two differentials are the most important variables in Model E3. The combination of the variables gives the best fitting estimation.

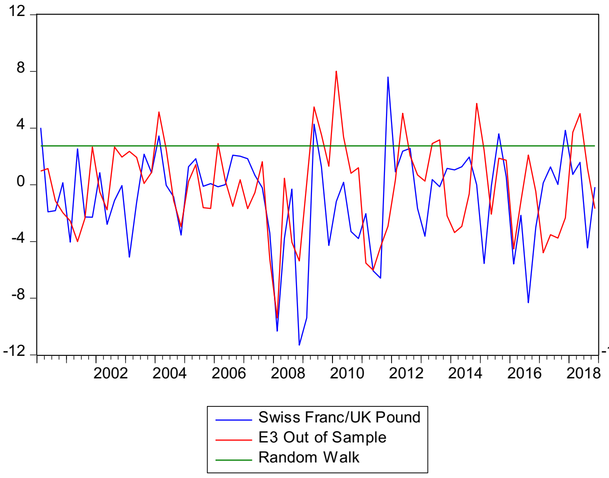

Figure 9: Out-of-Sample (dynamic) forecasts Swiss Franc/British Pound (%).

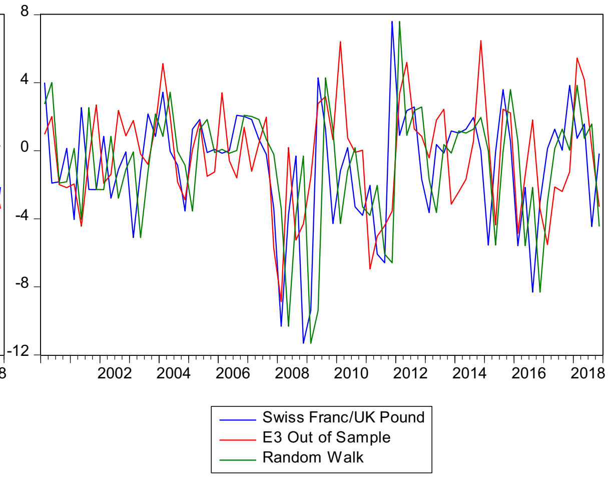

Figure 10: Out-of-Sample (one-step ahead) forecasts Swiss Franc/British Pound (%).

Figure 9 shows the out-of-sample multi-step ahead forecasts of Model E3 and the random walk. The forecast of Model E3 follows most trends and captures most of the big peaks of the actual exchange rate. The same holds for Figure 10, the out-of-sample one-step ahead of Model E3 and the random walk. This figure is a little more accurate than the previous figure. The forecasts suggest that Model E3 has some predictable power of the movements of the exchange rate, even out-of-sample. The out-of-sample forecasts of Model E2, the combination model of the Swiss Franc/US Dollar, was relatively accurate too. These results suggest that forecasting the Swiss Frans is relatively accurate forecastable by using the ARDL-models.

Exchange rate Japanese Yen/US Dollar

Table 10:
ARDL-models Japanese Yen/US Dollar exchange rate (%)

Variables	Model A4	Model B4	Model C4	Model D4	Model E4	Model F4
Growth rate Yen/US Dollar (-1)	0.381*** (0.137)	0.139 (0.139)	0.166 (0.159)	0.198 (0.144)	0.273** (0.125)	
Growth rate Yen/US Dollar (-2)	-0.397*** (0.141)	-0.225* (0.125)	-0.292*** (0.100)	-0.295** (0.144)	-0.415*** (0.145)	
Growth rate Yen/US Dollar (-3)	0.350** (0.134)			0.270** (0.121)		
ΔBond yield rate differential (-3)	3.287* (1.950)				6.119*** (2.190)	7.970** (3.524)
ΔBond yield rate differential (-4)	-2.559 (1.950)				-2.246 (2.055)	
ΔBond yield rate differential (-5)	5.567*** (1.977)				5.223** (1.971)	
ΔInflation rate differential (-2)		-1.866* (1.065)			-0.653 (1.033)	-3.790** (1.794)
ΔInflation rate differential (-3)					-2.213** (1.077)	
ΔInflation rate differential (-4)					-1.459 (1.125)	
ΔCurrent account differential					0.659 (1.469)	9.351*** (3.115)
ΔCurrent account differential (-1)			3.531*** (1.309)		4.638*** (1.533)	
ΔCurrent account differential (-2)			0.311 (1.607)		0.609 (1.570)	
ΔCurrent account differential (-3)			0.475 (1.461)		1.344 (1.436)	
ΔCurrent account differential (-4)			3.599* (2.086)		3.422** (1.515)	
Growth rate share prices differential				0.046 (0.090)	-0.066 (0.087)	-0.058 (0.078)
Constant	-0.041 (0.629)	0.290 (0.698)	1.309 (0.900)	0.062 (0.719)	1.952** (0.832)	1.710** (0.730)
RMSE estimation	4.754	4.831	4.689	5.014	3.630	n/a
R-squared	0.351	0.127	0.250	0.142	0.578	n/a
AIC	5.921	6.097	6.133	6.119	5.906	n/a
DW	1.951	1.974	1.769	1.982	1.981	n/a

* P<0.10, ** P<0.05, *** P<0.01 Sample: 1994Q2-2006Q3 (50 included observations), (Standard Errors in parentheses)

The results of model E4 can be interpreted in the following way. When the first lag of the growth rate of the exchange rate between the US Dollar and the Japanese Yen increases by one percentage point, then the current growth rate of the exchange rate is expected to increase by 0.273 percentage point. An increase of one percentage point of the second lag of the exchange rate is expected to result in an insignficant decrease of 0.415 percentage point of the current growth rate of the exchange rate.

When the third and the fifth lag of the bond yield rate of the United States increase by one percentage point more than the third lag of the bond yield rate of Japan, then the value of the US Dollar, compared to the value of the Japanese Yen, is expected to appreciate by 6.119% and 5.223%, respectively. The coefficient of the fourth lag is negative, but also statistically insignificant.

If the second lag of the inflation rate of the United States increases by one percentage point more than the second lag of the inflation rate of Japan, then the value of the US Dollar is expected to depreciate by 2.213% compared to the value of the Japanese Yen. The coefficients of the second and fourth lag of the inflation rate are insignificant.

When the first and fourth lag of the current account, divided by the GDP, of the United States increase by one percentage point more than the current account ratio of Japan, then the value of the US Dollar, compared to the value of the Japanese Yen, is expected to appreciate by 4.638% and 3.422%, respectively. The coefficients of the current value, the second lag and third lag of the current account differential are insignificant.

If the growth rate of the share prices of the United States increases by one percentage point more than the growth rate of the share prices of Japan, then the value of the US Dollar is expected to depreciate by 0.066%, compared to the value of the Japanese Yen. The coefficient is statistically and economically insignificant.

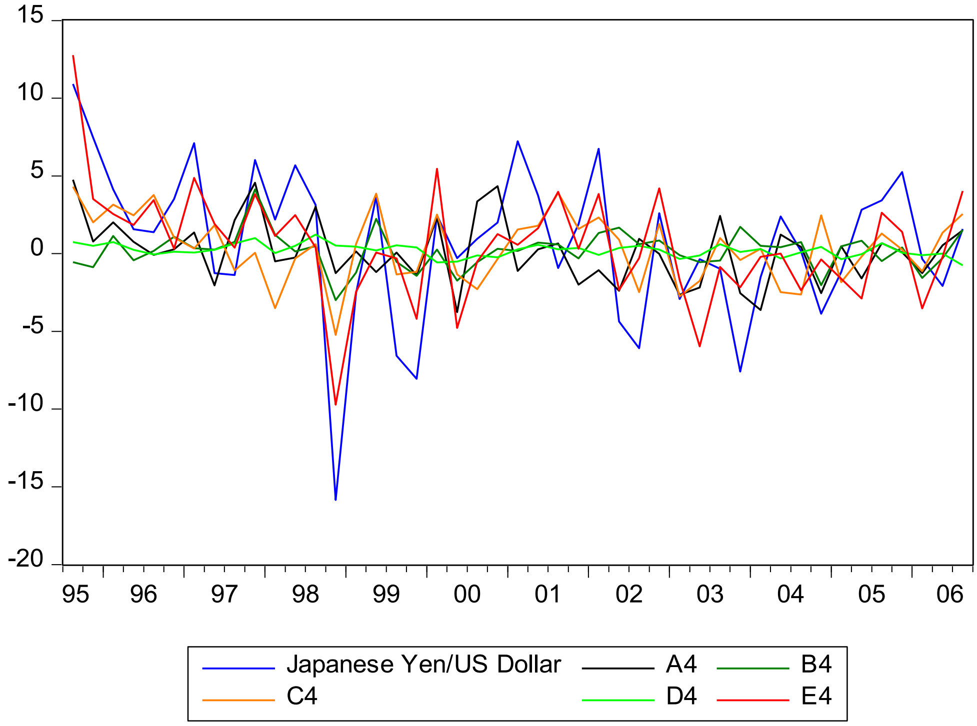

Figure 11: In-sample estimations Japanese Yen/US Dollar (%).

Figure 11 shows the in-sample estimations of the five Japanese Yen/US Dollar models. The estimation of Model E4 (the combination model), the red line, follows most of the movements of the actual exchange rate, the blue line, relatively well. Most of all trends are captured, while some of the peaks are completely estimated. The black line (Model A4; the bond yield rate model) suggests that the bond yield rate differential is the most important variable in estimating the exchange rate, as the previous in-sample figures suggested. The black line follows the red and blue line in most movements.

The dark green line (Model B4; the inflation rate model) and the orange line (Model C4; the current account model) suggest that the inflation rate differential and the current account rate differential are also important in estimating the movements of the exchange rate. The light green line (Model D4; the share prices model) shows that the share prices differential has no impact, which is not unexpected as the coefficient of the variable is economically and statistically insignificant in models D4 and E4.

This model suggests the advantages of the ARDL-model. As a variety of different lags of all variables result in a quite well-fitting estimation of the actuals. Relationships between variables are pointed out by the automatic selection of the optimum number of lags of all variables.

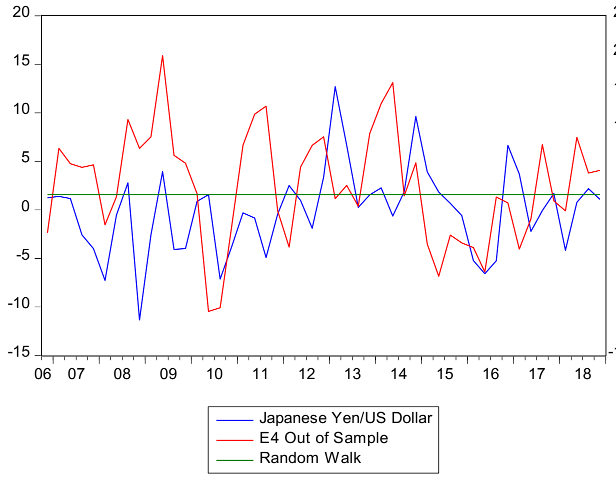

Figure 12: Out-of-Sample (dynamic) forecasts Japanese Yen/US Dollar (%).

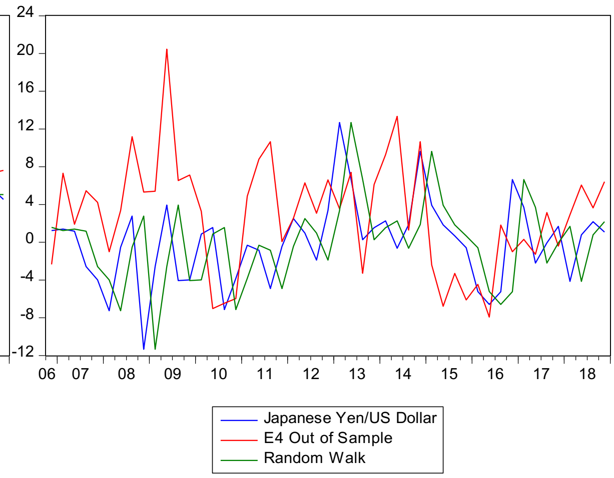

Figure 13: Out-of-Sample (one-step ahead) forecasts Japanese Yen/US Dollar (%).

Figure 12 shows the out-of-sample multi-step ahead forecasts of Model E4 and the random walk. The forecast is relatively inaccurate. Some of the trends are captured, but the forecast of Model E4 overshoots most of the peaks. The same holds for Figure 13, the out-of-sample one-step ahead forecast of Model E4. The forecast is a little more accurate, but the peaks are still overshot. These forecasts suggest the possible downside of the ARDL-model. The ARDL-model can explain (unexpected) relationships between variables for the given sample, but the relevance and existence of these relationships are questionable for the out-of-sample period.

Exchange rate Japanese Yen/British Pound

Table 11:
ARDL-models Japanese Yen/British Pound exchange rate (%)

Variables	Model A5	Model B5	Model C5	Model D5	Model E5	Model F5
Growth rate Yen/Pound (-1)	0.083 (0.135)	0.163 (0.138)	0.202 (0.146)	0.209 (0.148)	-0.047 (0.150)	
Growth rate Yen/Pound (-2)	-0.308** (0.131)		-0.220 (0.144)	-0.222 (0.143)	-0.301** (0.137)	
Growth rate Yen/Pound (-3)	0.303** (0.126)		0.276** (0.138)	0.277** (0.131)	0.278** (0.128)	
ΔBond yield rate differential	4.579*** (1.615)				5.892*** (1.576)	21.634*** (0.943)
ΔBond yield rate differential (-1)	3.840** (1.697)				5.247*** (1.796)	
ΔBond yield rate differential (-2)	5.943*** (1.655)				9.001*** (1.778)	
ΔBond yield rate differential (-3)					3.004 (1.881)	
ΔInflation rate differential (-2)		-2.565** (1.098)			-2.226** (0.930)	-4.178** (1.654)
ΔInflation rate differential (-3)					-0.657* (0.948)	
ΔInflation rate differential (-4)					-1.586 (0.952)	
ΔCurrent account differential			0.083 (0.700)		-0.792 (0.690)	-3.905** (1.817)
ΔCurrent account differential (-1)					-0.981 (0.642)	
ΔCurrent account differential (-2)					-1.304** (0.634)	
ΔCurrent account differential (-3)					-1.099* (0.638)	
Growth rate share prices differential				-0.009 (0.083)	-0.162** (0.074)	-0.152* (0.081)
Constant	0.724 (0.550)	0.609 (0.648)	0.523 (0.667)	0.524 (0.669)	0.723 (0.560)	0.675 (0.489)
RMSE estimation	3.815	4.436	4.653	4.659	3.180	n/a
R-squared	0.433	0.120	0.126	0.126	0.652	n/a
AIC	5.647	5.926	5.999	5.999	5.606	n/a
DW	2.035	2.023	2.034	2.032	1.979	n/a

* P<0.10, ** P<0.05, *** P<0.01 Sample: 1994Q2-2006Q3 (50 included observations), (Standard Errors in parentheses)

The results of model E5 can be interpreted in the following way. When the second lag of growth rate of the exchange rate between the British Pound and the Japanese yen will increase by one percentage point, then the current growth rate of the exchange rate is expected to decrease by 0.301 percentage point. An increase of one percentage point of the third lag of the exchange rate is expected to result in a increase of 0.278 percentage point of the current growth rate of the exchange rate between the two countries. The first lag of the growth rate of the exchange rate is insignificant.

When the current value, the first lag and the second lag of the bond yield rate of the United Kingdom increase by one percentage point more than the bond yield rate of Japan, then the value of the British Pound, compared to the value of the Japanese yen, is expected to appreciate by 5.892%, 5.247% and 9.001%, respectively. These numbers are quite high, and possibly unrealistic. The coefficient of the third lag of the bond yield rate differential is insignificant.

If the second lag of the inflation rate of the United Kingdom increases by one percentage point more than the second lag of the inflation rate of Japan, then the value of the British Pound is expected to depreciate by 2.226% compared to the value of the Japanese Yen. The coefficients of the third and fourth lag of the inflation rate differential are insignificant, using the 5% significance level.

When the second lag of current account, divided by the GDP, of the United Kingdom increases by one percentage point more than the current account ratio of Japan, then the value of the British Pound is expected to depreciate by 1.304% compared to the value of the Japanese Yen. The coefficients of the current value, the first lag and the third lag of the current account differential are insignificant.

If the growth rate of the share prices of the United Kingdom increases by one percentage point more than the growth rate of the share prices of Japan, then the value of the British pound is expected to depreciate by 0.162% compared to the value of the Japanese Yen.

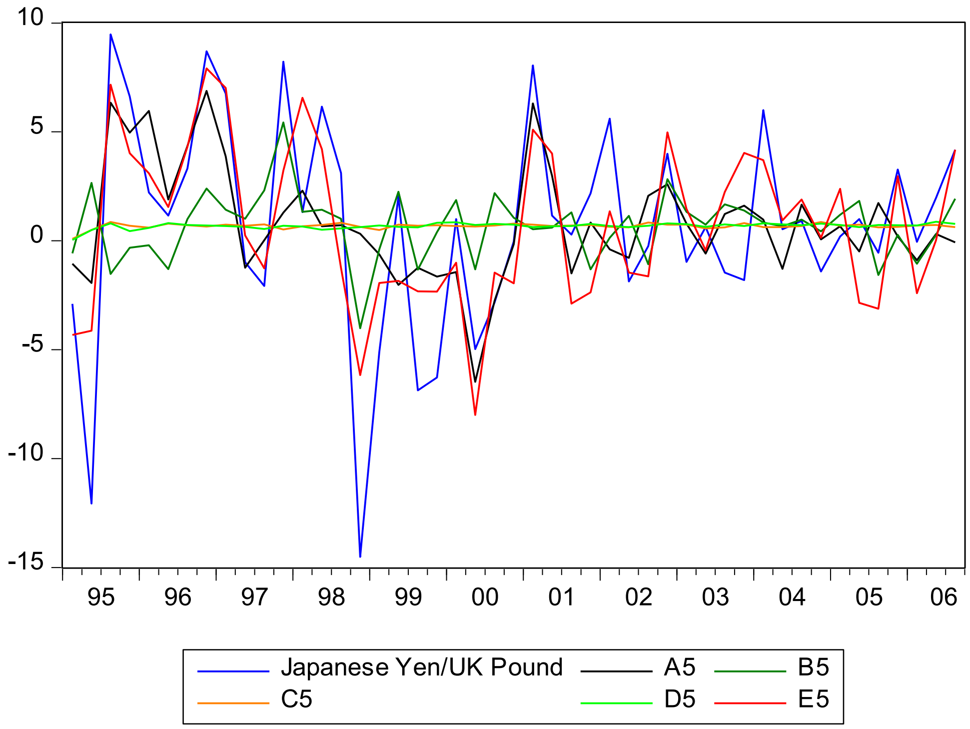

Figure 14: In-sample estimations Japanese Yen/British Pound (%).

Figure 14 shows the in-sample estimations of the five Japanese Yen/British Pound models. The red line (Model E5; the combination model) follows most of the movements of the actual exchange rate, the blue line. Almost all peaks are captured by the estimation of Model E5, while some are estimated in full extend. As the previous Japanese Yen mode, the ARDL-model selected a lot of lags for the combination model, which resulted in a relatively accurate in-sample estimation of the movements of the exchange rate.

The black line (Model A5; the bond yield rate model) and the green line (Model B5; the inflation rate model) suggest that movements in the bond yield rate differential and the inflation rate differential are the origin of most of the movements of the red line. Model C5 (the current account model) and Model D5 (the share prices model) have insignificant coefficients for the current account differential and share prices differential, respectively. Combining these variables with the bond yield rate and inflation rate differential leads to significant coefficients of these variables, and subsequently to a more accurate estimation of the movements of the exchange rate.

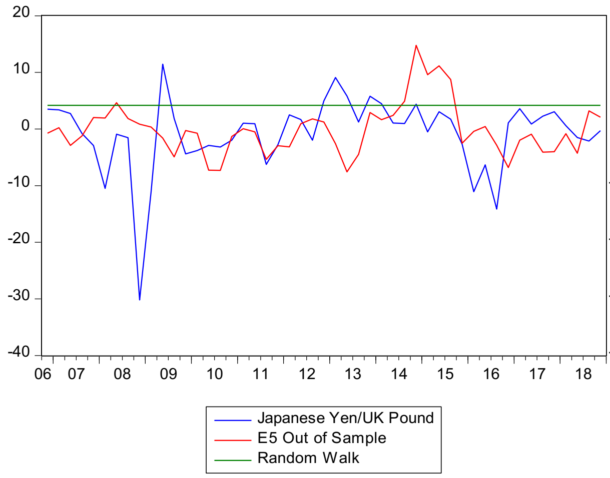

Figure 15: Out-of-Sample (dynamic) forecasts Japanese Yen/British Pound (%).

Figure 16: Out-of-Sample (one-step ahead) forecasts Japanese Yen/British Pound (%).

Figure 15 shows the out-of-sample multi-step ahead forecasts of Model E5 and the random walk. Although some of the trends of the actual exchange rate are captured, Model E5 does forecast the movements of the exchange rate relatively inaccurate. The multi-step ahead forecast overshoots some peaks, while some peaks are not forecasted at all. The one-step ahead forecast of Model E5 in figure 16 shows a more accurate forecast of the movements of the exchange rate. Trends are captured relatively better, but the model does still overshoot most of the peaks.

Exchange rate Canadian Dollar/US Dollar

Table 12:
ARDL-models Canadian Dollar/US Dollar exchange rate (%)

Variables	Model A6	Model B6	Model C6	Model D6	Model E6	Model F6
Growth rate exchange rate (-1)	0.307*** (0.106)	0.285*** (0.107)	0.245** (0.109)	0.253** (0.107)	0.404*** (0.106)	
Growth rate exchange rate (-2)	-0.026 (0.109)	-0.110 (0.109)	-0.095 (0.113)	-0.105 (0.110)	-0.105 (0.108)	
Growth rate exchange rate (-3)	0.378*** (0.106)	0.429*** (0.107)	0.409*** (0.110)	0.410*** (0.108)	0.397*** (0.100)	
ΔBond yield rate differential (-1)	1.499*** (0.539)				1.916*** (0.538)	6.298 (3.839)
ΔInflation rate differential (-1)		-0.448** (0.214)			-0.564*** (0.209)	-0.771 (0.909)
ΔInflation rate differential (-2)		0.417* (0.210)			0.330 (0.220)	
ΔCurrent account differential			-0.134 (0.199)		-0.181 (0.190)	-0.596 (0.654)
Growth rate share prices differential (-4)				-0.083* (0.046)	-0.106** (0.042)	-0.349* (0.199)
Constant	0.052 (0.177)	0.080 (0.180)	0.083 (0.186)	0.203 (0.191)	0.132 (0.177)	0.434 (0.560)
RMSE estimation	1.560	1.671	1.688	1.676	1.509	n/a
R-squared	0.295	0.283	0.222	0.253	0.408	n/a
AIC	3.672	3.716	3.771	3.730	3.604	n/a
DW	1.901	1.887	1.916	1.924	1.973	n/a

* P<0.10, ** P<0.05, *** P<0.01 Sample: 1981Q2-1999Q4 (75 included observations), (Standard Errors in parentheses)

The results of model E6 can be interpreted in the following way. When the first and third lag of growth rate of the exchange rate between the US Dollar and the Canadian Dollar will increase by one percentage point, then the current growth rate of the exchange rate is expected to increase by 0.404 and 0.397 percentage point. The second lag of the growth rate of the exchange rate is insignificant.

When the first lag of the bond yield rate of the United States increases by one percentage point more than the bond yield rate of Canada, then the value of the US Dollar is expected to appreciate by 1.916% compared to the value of the Canadian Dollar. The coefficients of the bond yield rate differentials are significant in the E-model, while the coefficient of this variable is insignificant in the long-run model (Model F6). A reason for the low significance of the long-run coefficient of the government bond yield differential could be the low difference between the government bond yields of the United States and Canada.

Figure 17 shows that this government bond yield differential, the blue line, is always relatively close to zero, especially for the in-sample period. For comparison, the bond yield rate differentials between the United Kingdom and the two countries are added. These two differentials show relatively higher values and relatively more movements over time.

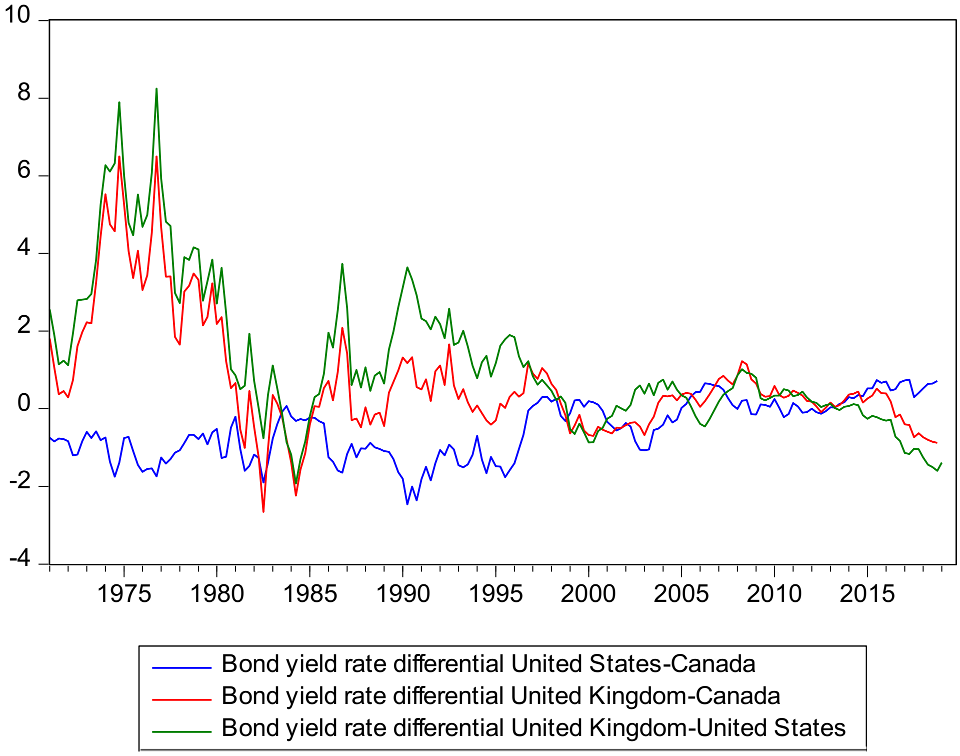

Figure 17: Government bond yield rate differentials (%).

Next to that, table 13 shows that this differential has a lower standard deviation, a smaller difference between the maximum and minimum values, and a mean closer to zero compared to the other two government bond yield differentials, the United Kingdom compared to the United States and Canada. This result could suggest that currency will only be exchanged if the interest rate benefits are big enough, the expected benefit of exchanging currency should surpass the possible switching costs (Huchzermeier and Cohen, 1996). So, small interest rate changes are not likely to lead to currency exchanges in the long-run.

Table 13:
Descriptive statistics bond yield rate differentials for the US, the UK and Canada (%)

Descriptive statistics	US/Canada bond yield rate differential	UK/Canada bond yield rate differential	US/UK bond yield rate differential
Mean	-0.543239	0.695912	1.239152
Median	-0.516891	0.349911	0.646450
Maximum	0.750311	6.503333	8.243333
Minimum	-2.464000	-2.660333	-1.926667
Std. Dev.	0.751227	1.500184	1.877742

If the first lag of the inflation rate of the United States increases by one percentage point more than the inflation rate of Canada, then the value of the US Dollar is expected to depreciate by 0.564% compared to the value of the Canadian Dollar. The second lag of the inflation differential is positive and statistically insignificant.

When the current account, divided by the GDP, of the United States increases by one percentage point more than the current account ratio of Canada, then the value of the US Dollar is expected to depreciate by 0.181% compared to the value of the Canadian Dollar. However, the coefficient of this variable is insignificant.

If the growth rate of the share prices of the United States increases by one percentage point more than the growth rate of the share prices of Canada, then the value of the US Dollar is expected to depreciate by 0.106% compared to the value of the Canadian Dollar.

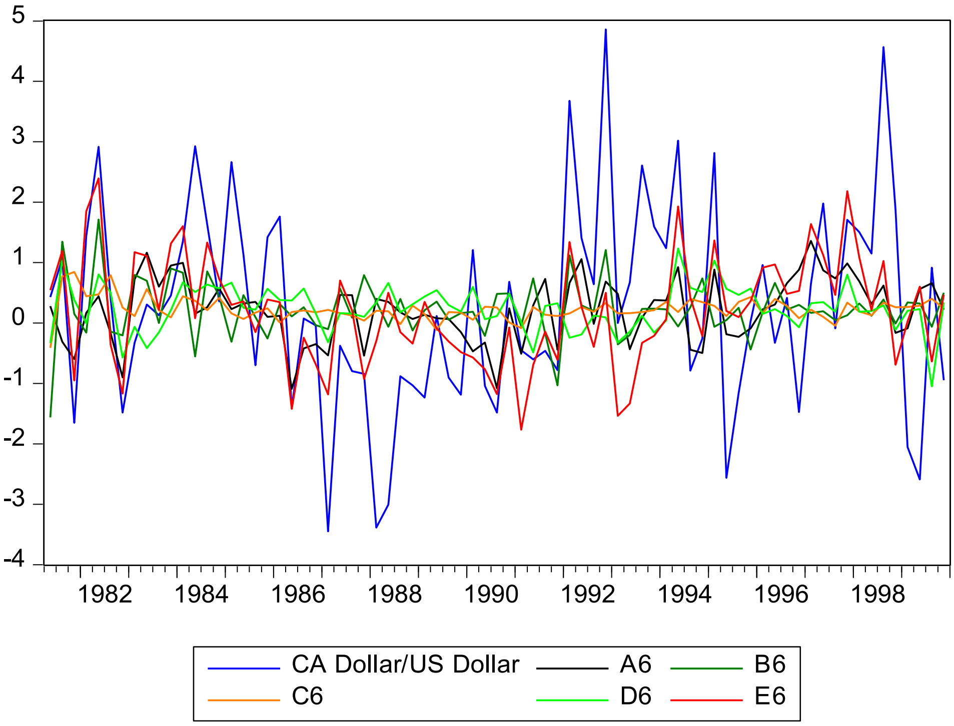

Figure 18: In-sample estimations Canadian Dollar/US Dollar (%).

Figure 18 shows the in-sample estimations of the five Canadian Dollar/US Dollar models. The figure suggests that the red line (Model E6; the combination model) is the most accurate estimation of the actual exchange rate. Most of the trends are captured, but most of the peaks are not estimated. This figure does also suggest that the bond yield rate differential is the most important variable for estimating the movements of the exchange rate. The black line (Model A6; the bond yield rate model) estimates most movements of the exchange rate the best of all other individual models.

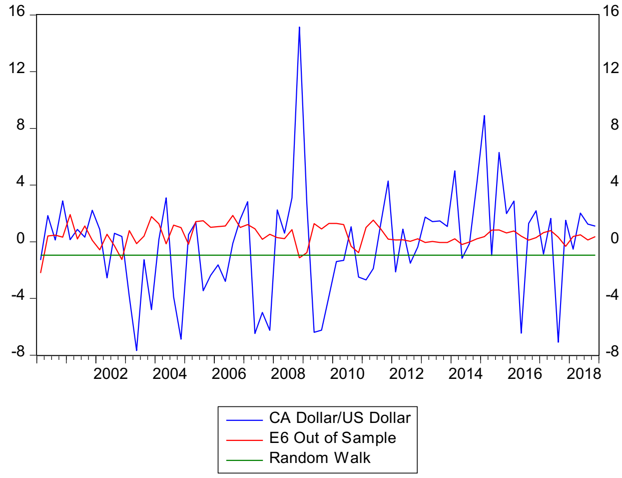

Figure 19: Out-of-Sample (dynamic) forecasts Canadian Dollar/US Dollar (%).

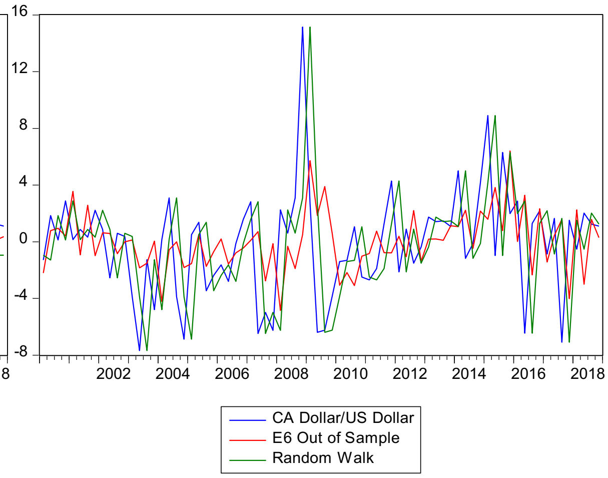

Figure 20: Out-of-Sample (one-step ahead) forecasts Canadian Dollar/US Dollar (%).

Figure 19 shows the out-of-sample multi-step ahead forecasts of Model E6 and the random walk. The multi-step forecast of Model E6 is really inaccurate, since it does not capture any trends or peaks. The out-of-sample one-step ahead forecast of Model E6 of Figure 20 is a lot more accurate. The one-step ahead forecast of the model captured most of the trends and forecasted most of the peaks of the actual exchange rate.

A possible reason for this result is the difference between the significance of the short-run and long-run coefficients of the bond yield rate differential. The coefficients of the short-run model (Model E6) are significant, while the coefficient of the long-run model (Model F6) are not. This could be an explanation for the result that the multi-step ahead forecast is really inaccurate, while the one-step ahead does forecast most movements of the exchange rate relatively accurate.

Exchange rate Canadian Dollar/British Pound

Table 14:
ARDL-models Canadian Dollar/British Pound exchange rate (%)

Variables	Model A7	Model B7	Model C7	Model D7	Model E7	Model F7
Growth rate exchange rate (-1)	0.252**	0.267**	0.231**	0.275**	0.108	
	0.117	0.113	0.110	0.107	(0.115)	
Growth rate exchange rate (-2)	-0.234**					
	0.117					
ΔBond yield rate differential (-3)	2.193**				1.639**	4.211**
	0.878				(0.802)	(1.791)
ΔBond yield rate differential (-4)	0.104				0.272	
	0.885				(0.859)	
ΔBond yield rate differential (-5)	1.863**				1.845**	
	0.877				(0.886)	
ΔInflation rate differential (-4)		-0.413			-1.579***	-1.771***
		0.450			(0.559)	(0.634)
ΔCurrent account differential			0.251		0.336	0.377
			0.440		(0.435)	(0.479)
ΔCurrent account differential (-1)			0.857**			
			0.421			
Growth rate share prices differential				-0.173**	-0.167**	-0.188*
				0.086	(0.083)	(0.102)
Constant	-0.006	-0.172	0.157	0.173	0.364	0.408
	0.535	0.560	0.549	0.528	(0.528)	(0.594)
RMSE Returns forecast	4.601	4.873	4.582	4.836	4.154	n/a
R-squared	0.195	0.080	0.115	0.114	0.228	n/a
AIC	5.969	6.023	5.969	5.937	5.880	n/a
DW	2.058	1.944	2.031	1.891	1.861	n/a

* P<0.10, ** P<0.05, *** P<0.01 Sample: 1981Q2-1999Q4 (75 included observations), (Standard Errors in parentheses)

The results of model E7 can be interpreted in the following way. When the first lag of growth rate of the exchange rate between the British Pound and the Canadian Dollar is expected to increase by one percentage point, then the current growth rate of the exchange rate will increase by 0.108 percentage point. The coefficient of this variable is insignificant.

When the third and the fifth lag of the bond yield rate of the United Kingdom increase by one percentage point more than the bond yield rate of Canada, then the value of the British Pound, compared to the value of the Canadian Dollar, is expected to appreciate by 1.639% and 1.845%, respectively. The fourth lag of the bond yield rate differential is insignificant.

If the fourth lag of the inflation rate of the United Kingdom increases by one percentage point more than the inflation rate of Canada, then the value of the British Pound is expected to depreciate by 1.579% compared to the value of the Canadian Dollar. When the current account, divided by the GDP, of the United Kingdom increases by one percentage point more than the current account ratio of Canada, then the value of the British Pound is expected to insignificantly appreciate by 0.336%, compared to the value of the Canadian Dollar.

When the growth rate of the share prices of the United Kingdom increases by one percentage point more than the growth rate of the share prices of Canada, then the value of the British Pound is expected to depreciate by 0.167% compared to the value of the Canadian Dollar.

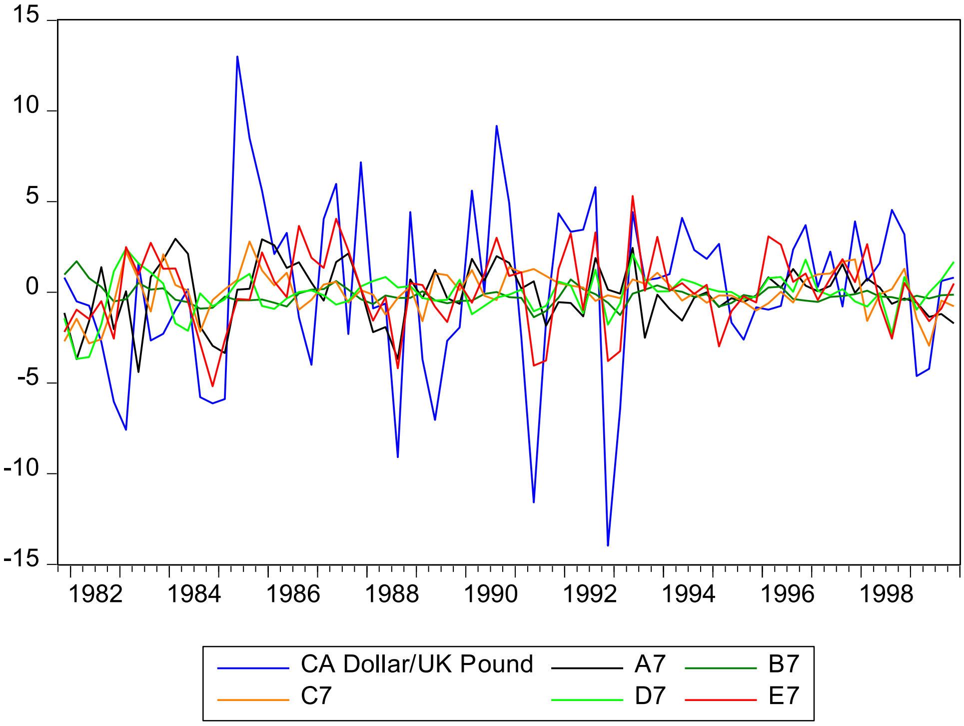

Figure 21: In-sample estimations Canadian Dollar/British Pound (%).

Figure 21 shows the in-sample estimations of the five Canadian Dollar/British Pound models. As all previous in-sample figures suggested, the red line (Model E7; the combination model) is the most accurate estimation of the movements of the exchange rate. The accuracy of the estimation of Model E7 is debatable. Some trends and peaks are captured, but some of them are not estimated at all. This figure does also suggest that the bond yield rate differential is the most important variable in forecasting the exchange rate.

The black line (Model A7; the bond yield rate model) has the same movements as the red line. The orange line (Model C7; the current account model) shows that the current account has some impact in estimating the movements of the exchange rate, as the line moves in several cases parallel to the red line.

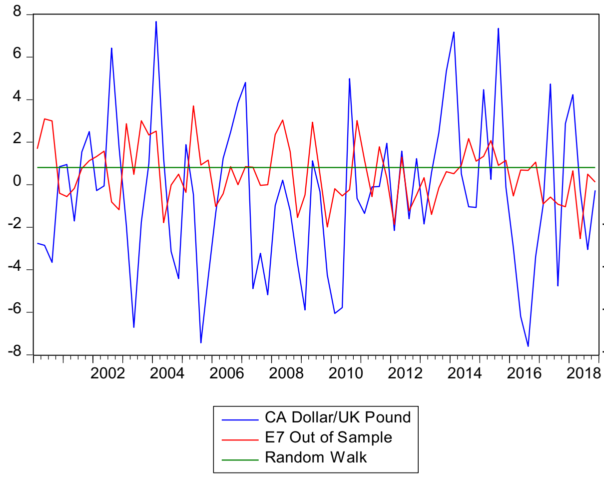

Figure 22: Out-of-Sample (dynamic) forecasts Canadian Dollar/British Pound (%).

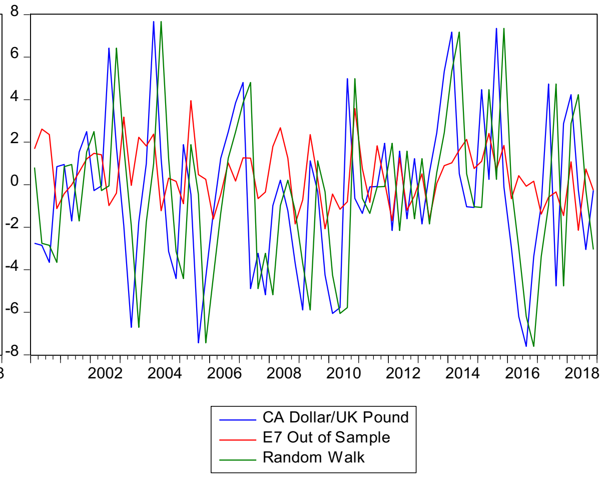

Figure 23: Out-of-Sample (one-step ahead) forecasts Canadian Dollar/British Pound (%).

Figure 22 shows the out-of-sample multi-step ahead forecast of Model E7 and the random walk. The forecast follows some trends, but does not capture most of the peaks. This figure suggests that the predictable power of Model E7 is questionable for the long-term. The one-step ahead forecast of E7 in Figure 23 comes a little closer to the actual movements of the growth rate of the exchange rate. Some trend are captured, but not in full extend. A reason for the lack of predictable power of the peaks could be the influence of speculation on the exchange rate, which is hard to include in a model.

Long-run forms

Table 15 shows the coefficients of all long-run forms, the F-models, as in tables 7 until 12 and Table 14. The table shows some clear results. In the long-run, the growth rate of the exchange rate and the bond yield are positively correlated. A relatively higher bond yield rate in the domestic country is expected to result in an appreciation of the home currency. The coefficients of the bond yield rate differential are relatively high. This means that per percentage point change the bond yield rate has a relatively big effect on the exchange rate, compared to the other independent variables.

The change of the inflation rate differential and the growth rate of the exchange rate are negatively correlated in the long-run. A relatively higher inflation rate in the domestic country is expected to result in a depreciation of the home currency. The same holds for the growth rate of share prices differential. The long-run coefficients of the share prices differential have a clear negative sign too, although the coefficients are insignificant in all models.

The change of the current account, divided by GDP, differential has an ambiguous correlated relationship with the growth rate of the exchange rate. The coefficient of the variable has no clear sign. The coefficients are significant in only three of the seven models, using the 5% significance level. However, adding the current account to the models has the possible benefit of capturing unexpected economic shocks.

Table 15:
Results long-run forms (%)

Exchange rate	ΔBond yield rate differential	ΔInflation rate differential	ΔCurrent account differential	Growth rate share prices differential	Constant
British Pound/US Dollar	5.015***	-1.217***	0.777	-0.116	0.483
Swiss Franc/US Dollar	6.346***	-2.224**	-0.459	-0.200*	-0.148
Swiss Franc/British Pound	5.375***	-0.254	-1.775**	-0.028	-0.115
Japanese Yen/US Dollar	7.970**	-3.790**	9.351***	-0.058	1.710**
Japanese Yen/British Pound	21.634***	-4.178**	-3.905**	-0.152*	0.675
Canadian Dollar/US Dollar	6.298	-0.771	-0.596	-0.349*	0.434
Canadian Dollar/British Pound	4.211**	-1.771***	0.377	-0.188*	0.408

* P<0.10, ** P<0.05, *** P<0.01

Forecasts evaluations

The RMSE has been used as the criterium to evaluate the forecasts. Table 16 shows the RMSE's of all in-sample estimations. The greener the cell of the value, the lower the RMSE, and thus the better the forecast. For all exchange rates do the E-models (the combination models) predict the growth rate of the exchange rate the best. The A-models (the bond yield rate models) are the best predicting models of all single variable models. This is in line with the previous results of the graphs of the in-sample estimations, which suggested that most movements of the E-models are caused by the movements of the bond yield rate differentials. The table does also suggest that the inflation rate differential and the current account differential estimations have a relatively low RMSE. The estimations of the share prices differential models have the highest RMSE for every exchange rate, which is in line with the previous results. The figures suggested that the predictive power of the share prices differentials was negligible.

Table 16:
RMSEs in-sample estimations

Exchange rate	A-Models	B-Models	C-Models	D-Models	E-Models
British Pound/US Dollar	4.971	5.058	5.220	5.271	4.621
Swiss Franc/US Dollar	5.094	5.539	5.619	5.652	4.832
Swiss Franc/British Pound	4.022	4.195	4.025	4.224	3.819
Japanese Yen/US Dollar	4.754	4.831	4.689	5.014	3.630
Japanese Yen/British Pound	3.815	4.436	4.653	4.659	3.180
Canadian Dollar/US Dollar	1.560	1.671	1.688	1.676	1.509
Canadian Dollar/British Pound	4.601	4.873	4.582	4.836	4.154

Table 17 shows the RMSEs and the results of the DM-tests of the out-of-sample forecasts, both the E-models and the random walk. The out-of-sample forecasts are only estimated for the E-models, as the regression tables and Table 16 suggest that these models are the most accurate models in predicting the movements of the exchange rate. These models have the biggest chance of beating the random walk.

For every model two horizons are used: one-step ahead and multi-step ahead forecasts. These two horizons have been chosen, because they reflect the predictive power of the E-models in the short-run and the relatively long-run. The predictive power of the models is offset to the random walks in both timeframes. The values of the RMSE's will suggest which forecasts is better, while the DM-test will calculate if the difference between the forecasts is statistically significant. When the difference between the forecasts is statistically significant, then it is possible to say that the one forecast is beating the other.

The results of Table 17 suggest that some E-models have more predictive power compared to the random walk, in multiple timeframes. The null-hypothesis of no difference between the accuracy of the forecasts will be rejected if the computed DM-statistic falls outside the range of -1.960 and 1.960, and then the p-value will be lower than 0.05.

The forecasts of the E-models of the British Pound/US Dollar rate and the Swiss Franc/US Dollar rate have more predictable power than the random walk for both timeframes. The one-step ahead forecast of the E-model of the Canadian Dollar/British Pound rate is beating the random walk, while the long-run forecast of the E-model of the Swiss Franc/British Pound does beat the random walk too. The forecasts of the E-model of the Japanese Yen/US Dollar rate are beaten by the random walk. The DM-test suggested that the differences between these forecasts are significantly different from the random walk, as the p-value is smaller than 0.05.

The forecasts of the E-model of the Japanese Yen/British Pound rate are not statistically different from the forecasts of the random walk. The same holds for the one-step ahead forecast of the E-model of the Swiss Franc/British Pound rate, both forecasts of the E-model of the Canadian Dollar/US Dollar rate and the long-run forecast of the E-model of the Canadian Dollar/British Pound rate. These forecasts have the same predictable power as the forecasts of the random walk. The differences between the forecasts are not statistically significant, the p-value of the DM-test is bigger than 0.05. The forecasts of these E-models have the same level of accuracy as the random walk. So, six out of the 14 E-models are beating the random walk, while two E-models are beaten by the random walk. Six forecasts are not statistically different.

Table 17:
Evaluation out-of-sample forecasts

Exchange rate	Horizon	RMSE		DM-test	
		E-Models	Random walk	DM-stat.	P-value
British Pound/US Dollar	1 quarter	3.398	4.072	-1.997	0.049**
	93 quarters	3.581	3.860	-2.184	0.029**
Swiss Franc/US Dollar	1 quarter	3.561	4.664	-2.925	0.003***
	77 quarters	3.562	4.248	-2.004	0.048**
Swiss Franc/British Pound	1 quarter	3.799	4.226	-1.044	0.296
	76 quarters	3.946	4.964	-1.994	0.046**
Japanese Yen/US Dollar	1 quarter	7.050	5.015	2.915	0.004***
	49 quarters	7.248	4.599	3.697	0.000***
Japanese Yen/British Pound	1 quarter	7.543	7.457	0.664	0.507
	49 quarters	7.750	8.176	-0.534	0.593
Canadian Dollar/US Dollar	1 quarter	4.006	4.561	-1.786	0.074*
	76 quarters	4.163	3.774	0.969	0.333
Canadian Dollar/British Pound	1 quarter	3.748	4.171	-3.161	0.002***
	76 quarters	3.879	3.751	0.822	0.411

* P<0.10, ** P<0.05, *** P<0.01

Conclusion

Forecasting the exchange rate is one of the most difficult puzzles in economic theory. Knowing the effect of the main economic variables on the exchange rate is the beginning of solving the puzzle. Therefore, the effects of the interest rate, inflation rate, current account and share prices differentials on the exchange rate have been investigated in this thesis. This has been done by using ARDL-models. These models can select the optimal number of lags of both the independent and dependent variable, and can make distinguish between the short-run and long-run effects of the independent variables.

The data has been checked for stationarity by using the Augmented Dickey-Fuller test. The results show that the exchange rates and the bond yield rate, the inflation rate and the current account rate differentials are first difference stationary. The Johansen Cointegration test has been used to check if there exist long-run relationships between the exchange rates and the differentials. The results of the test confirmed that there exist long-run relationships between the exchange rate and all differentials.

The models indicate that there exists a clear positive relationship between the exchange rates and the bond yield differentials. The models do also show that there exists a clear negative relationship between the exchange rates and the inflation differentials. A relatively higher domestic bond yield rate is expected to result in an appreciation of the domestic currency, while a relatively higher inflation rate is expected to result in a depreciation of de domestic currency. This is in line with the theory of Frankel (1979) and its extensions. Therefore, the first hypothesis, which states that an increase of the interest rate differential leads to an appreciation of the domestic currency and an increase of the inflation rate differential leads to a depreciation of the domestic currency, cannot be rejected.

The second hypothesis states that an increase of the domestic current account will lead to an appreciation of the domestic currency. This hypothesis will be rejected, because the models in this thesis indicate that there exists no ambiguous and/or statistically significant relationship between the exchange rate and the current account. Besides that, the theory stated that the current account could capture random economic shocks in the model, and could therefore still be useful in exchange rate models.

The third hypothesis stated that an increase of the share prices differential leads to a depreciation of the domestic currency. The models suggest that this negative relationship exists. Relatively higher share prices in the domestic country will lead to an appreciation of the home currency. However, the coefficient of the variable was most of the times statistically and economically insignificant. The third hypothesis cannot be rejected.

The long-run forms suggested the same results as described above. A clear positive relationship between the exchange rate and the bond yield rate differentials, and a clear negative relationship between the exchange rate and the inflation rate and share prices differentials. The relationship between the exchange rate and the current account differential was ambiguous in the long-run too.

The in-sample estimations suggested that the combination models (E-models) did have the most predictable power of all models. The RMSE's of the combination models did have the lowest values compared to the other models. The models did also suggest that the bond yield rate differential is the most important variable for estimating the movements of the exchange rate. The combination models did significantly depend on the movements of the bond yield rate differentials, and the bond yield rate models did generally have the second lowest RMSE. The E-models did estimate most of the exchange rate movements, but most of the times not in full extend. Possibly, speculation could be a possible source of the big peaks, that could be started by a change in the variables that are used in the models.

Out-of-sample forecasts have been made to test the predictable power of the E-models. This has been done for two different horizons; a one quarter and a multi-step horizon. These results have been offset to the random walk in both timeframes. The results suggest that six out of the 14 E-models could beat the random walk in predicting the exchange rate. Although most forecasts of the E-models did have a lower RMSE than the forecast of the random walk, the DM-test suggested that these forecasts are not statistically different.

So, an answer to the central research question can be formulated. There can be concluded that the used macro-economic differentials are able to improve the out-of-sample predictability of the exchange rate to some extent, where the bond yield rate differential is the most important variable.

Economic variables do affect most of all other economic variables. Therefore, it is really likely that regressing these variables will lead to biased coefficients. As most economic variables are correlated with each other, it is really likely that there exists multicollinearity in the models. Next to that, there will be missing variables in the models that are used in this thesis. Future research could investigate which variables are missing, and which effect these variables could have on the exchange rate predictability. Adjusting the sample is another possible extension of this thesis. Quarterly data has been used in this thesis, and could possibly be adjusted to monthly or even daily data, when there is access to these resources.

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Appendix

US: United States
UK: United Kingdom
SZ: Switzerland
JP: Japan
CA: Canada

Table 18:
Augmented Dickey-Fuller test statistic growth rate exchange rates

	t-statistic	Critical value		
		1% level	5% level	10% level
UK/US	-8.824454***	-3.473967	-2.880591	-2.577008
SZ/US	-9.821273***	-3.473967	-2.880591	-2.577008
SZ/UK	-9.40382***	-3.473967	-2.880591	-2.577008
JP/US	-5.353575***	-3.473967	-2.880591	-2.577008
JP/UK	-5.4882***	-3.473967	-2.880591	-2.577008
CA/US	-9.537282***	-3.473967	-2.880591	-2.577008
CA/UK	-9.19818***	-3.473967	-2.880591	-2.577008

* P<0.10, ** P<0.05, *** P<0.01

Table 19:
Augmented Dickey-Fuller test statistic bond yield rate differentials

Differential	t-statistic	Critical value		
		1% level	5% level	10% level
US-UK	-2.203619	-3.473967	-2.880591	-2.577008
1st difference	-11.25129***			
US-SZ	-2.487847	-3.473967	-2.880591	-2.577008
1st difference	-10.15775***			
UK-SZ	-2.414814	-3.473967	-2.880591	-2.577008
1st difference	-11.10824***			
US-JP	-2.39716	-3.486064	-2.885863	-2.579818
1st difference	-10.84154***			
UK-JP	-1.602933	-3.486064	-2.885863	-2.579818
1st difference	-12.06987***			
US-CA	-1.829894	-3.473967	-2.880591	-2.577008
1st difference	-11.21109***			
UK-CA	-2.185395	-3.473967	-2.880591	-2.577008
1st difference	-10.57846***			

* P<0.10, ** P<0.05, *** P<0.01

Table 20:
Augmented Dickey-Fuller test statistic inflation rate differentials

Differential	t-statistic	Critical value		
		1% level	5% level	10% level
US-UK	-2.607555*	-3.473967	-2.880591	-2.577008
1st difference	-5.626885***			
US-SZ	-2.63646*	-3.473967	-2.880591	-2.577008
1st difference	-4.118149***			
UK-SZ	-1.936472	-3.473967	-2.880591	-2.577008
1st difference	-4.99816***			
US-JP	-2.475106	-3.473967	-2.880591	-2.577008
1st difference	-5.679382***			
UK-JP	-2.069526	-3.473967	-2.880591	-2.577008
1st difference	-4.777307***			
US-CA	-1.886899	-3.473967	-2.880591	-2.577008
1st difference	-7.645221***			
UK-CA	-2.821326*	-3.473967	-2.880591	-2.577008
1st difference	-6.0497***			

* P<0.10, ** P<0.05, *** P<0.01

Table 21:
Augmented Dickey-Fuller test statistic current account differentials

Differential	t-statistic	Critical value		
		1% level	5% level	10% level
US-UK	-2.032757	-3.473967	-2.880591	-2.577008
1st difference	-13.43921***	-3.473967	-2.880591	-2.577008
US-SZ	2.841081*	-3.473967	-2.880591	-2.577008
1st difference	-18.88972***	-3.473967	-2.880591	-2.577008
UK-SZ	-2.200823	-3.473967	-2.880591	-2.577008
1st difference	-19.7822***	-3.473967	-2.880591	-2.577008
US-JP	-1.512078	-3.497727	-2.890926	-2.582514
1st difference	-5.232623***	-3.499167	-2.89155	-2.582846
UK-JP	-2.718072*	-3.497727	-2.890926	-2.582514
1st difference	-12.83874***	-3.498439	-2.891234	-2.582678
US-CA	-2.121716	-3.473967	-2.880591	-2.577008
1st difference	-12.19215***	-3.474265	-2.880722	-2.577077
UK-CA	-2.008275	-3.473967	-2.880591	-2.577008
1st difference	-10.94161***	-3.474567	-2.880853	-2.577147

* P<0.10, ** P<0.05, *** P<0.01

Table 22:
Augmented Dickey-Fuller test statistic growth rate share prices differentials

Differential	t-statistic	Critical value		
		1% level	5% level	10% level
US-UK	-11.92136***	-3.473967	-2.880591	-2.577008
US-SZ	-10.18403***	-3.473967	-2.880591	-2.577008
UK-SZ	-9.599808***	-3.473967	-2.880591	-2.577008
US-JP	-9.340866***	-3.473967	-2.880591	-2.577008
UK-JP	-9.913983***	-3.473967	-2.880591	-2.577008
US-CA	-9.766658***	-3.473967	-2.880591	-2.577008
UK-CA	-9.964851***	-3.473967	-2.880591	-2.577008

* P<0.10, ** P<0.05, *** P<0.01

Table 23:
Samples (sample size)

Exchange rate	In-Sample	Out-of-Sample
British Pound/US Dollar	1972Q3-1995Q3 (94)	1995Q4-2018Q4 (93)
Swiss Franc/US Dollar	1980Q2-1999Q3 (78)	1999Q4-2018Q4 (77)
Swiss Franc/British Pound	1982Q1-1999Q4 (72)	2000Q1-2018Q4 (76)
Japanese Yen/US Dollar	1994Q2-2006Q3 (50)	2006Q4-2018Q4 (49)
Japanese Yen/British Pound	1994Q2-2006Q3 (50)	2006Q4-2018Q4 (49)
Canadian Dollar/US Dollar	1981Q2-1999Q4 (75)	2000Q1-2018Q4 (76)
Canadian Dollar/British Pound	1981Q2-1999Q4 (75)	2000Q1-2018Q4 (76)

Table 24:
Results F-Bounds Test

Model	Test statistic value	Critical value (1%)	
		I(0)	*I*(1)
E1	13.124	3.29	4.37
E2	9.872	3.29	4.37
E3	13.428	3.29	4.37
E4	7.585	3.29	4.37
E5	6.608	3.29	4.37
E6	4.754	3.29	4.37
E7	11.375	3.29	4.37