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An Empirical Analysis of the Effect of Key Policy Rate Changes on the Unbiasedness Hypothesis

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Abstract

Interest rate parity is one of the most important theory in international finance which determines the relationship between the exchange rate and interest rates of two countries. However, there are many empirical findings showing that interest rate parity condition does not hold. A phenomenon called the forward premium puzzle commonly exists in the currency markets. It refers to the situation that the high-interest country’s currency tends to appreciate with respect to the low-interest country’s currency which contradicts the interest rate parity theory. Intrigued by this fascinating puzzle, we want to explore the causes of this puzzle, especially how the central bank announcements might affect the foreign exchange market.

This thesis focuses on uncovering whether a country's central bank announcements of changes in the key policy rate would affect how the unbiasedness hypothesis holds. Using daily observations of spot exchange rates and 1-month and 3-month forward exchange rates enables us to remove the days of change from the dataset. This thesis distinguishes itself from the literature by its research question and methodology.

Empirical literature usually find evidence against the unbiasedness hypothesis. This thesis on the other hand, finds some evidence supporting that unbiasedness hypothesis holds for the six currency pairs: CAD/USD, EUR/USD, JPY/USD, NOK/USD, CHF/USD and GBP/USD in the period 01/01/2002 to 19/10/2018.

In order to solve econometric issues like serial correlation incurred by using daily observations of regression variables, necessary adjustments are made to correct for them. By comparing the regression results of different models, we can see the effect of removing days of key policy rate changes on the unbiasedness hypothesis. The main results from the empirical analysis show that removing the days surrounding changes in the key policy rate does not affect the regression results notably, except in the case of removing seven days for the CHF/USD.

Preface

Interest rate parity got our attention through the International Finance course, in which the idea of writing a thesis within this area came to our minds. We learned about interest rate parity and were fascinated by the controversies surrounding the foreign exchange market, the world's largest and allegedly the most efficient financial market. Many researchers find empirical evidence showing that uncovered interest rate parity does not hold in reality. Through discussion with our professor, we decided to write an empirical thesis to explore if removing the days that central bank changes the key policy rate can impact on the validity of the unbiasedness hypothesis.

During the process of writing the thesis, we gained significant and valuable insight into the foreign exchange market and how interest rates affect foreign exchange rates. We have also acquired a more profound understanding of how to write a thesis, and how to apply econometric techniques to empirical analysis. It has been challenging and demanding, especially the econometric part of the thesis, but it is fulfilling for us to complete this thesis.

To our supervisor Michael Kisser, we want to extend our sincere gratitude. Michael has provided us with constructive criticism and valuable suggestions for our thesis throughout the semester. We also extend our gratitude to everyone who has helped us in the process of writing the thesis.

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Content

1. Introduction

The failure of interest rate parity and existence of forward premium puzzle have attracted many researchers' attention. It has been a popular topic for decades because if we can figure out what leads to the puzzle and explain the real mechanism of how interest rates affect the exchange rate, it would have significant impact on international finance. Central banks and governments can make better monetary and fiscal policy to maintain their interest rate or exchange rate. Market participants can also improve their decisions as they are better informed. Due to this noble objective, numerous researches have been done to answer why interest rate parity fails. This thesis provides a new perspective to answer the question.

The primary objective of this thesis is to analyze if a country's central bank's change in the key policy interest rate can impact the unbiasedness hypothesis. The currencies chosen for this thesis are among the most influential and liquid currencies in the world. These currencies are well known and commonly used in empirical literature which also investigate interest rate parity.

The thesis is split into three parts. First, we test if the covered interest rate parity holds for the data used in this thesis. Second, we conduct a replication of how empirical literature typically tests the unbiasedness hypothesis. Lastly, we conduct our regression test of the unbiasedness hypothesis. In our test, we remove zero, one, three and seven days from the dataset, when one or both of the countries in a currency pair change their key policy rate.

Before conducting the tests, a thorough explanation of related theory is given. After that, we derive the econometric regression for the tests and explain all the included data.

2. Theory and Literature Review

2.1 The Foreign Exchange Market

The foreign exchange (FX) market consists of several different segments with the Spot market together with the Forward and the Futures market as the main segments. In the spot market, currencies are traded with immediate delivery which means typically within two business days. The spot rate is decided by demand and supply. Whereas, banks usually determine the forward rate based on the interest rate parity and no-arbitrage arguments.

The currency exchange rate is the price of one currency measured in another currency, and it can be given in two different ways. In this thesis, the notation of how many domestic units which buys one foreign unit will be used. The spot rate is then the domestic price of foreign currencies with immediate delivery, and the forward rate is the price of foreign currency at a given time in the future. If the exchange rate increases, it means that additional domestic currency is needed to buy one unit of foreign currency. The price of forward contracts can vary based on the spot exchange rate, domestic interest rate, foreign interest rate, and contract length. A forward premium for the foreign currency exists when the forward rate is higher than the spot rate. A forward discount for the foreign currency exists when the forward rate is lower than the spot rate (Bekaert & Hodrick, 2014, pp 62-67).

The FX market has become more relevant to our everyday life in the past decades as international economies become increasingly integrated by globalization. Huge trade volume and heightened capital flow increased the demand for foreign exchange. The turnover of the FX market is more than $5 trillion a day. The FX market is the largest and most liquid financial market in the world (BIS, 2016, pp 3). In the background of globalization, companies expand their businesses to other countries, which increases the demand for foreign currencies. If an exporter awaits payment in a foreign currency, their income in local currency will fluctuate if the exchange rate changes and they are prone to foreign exchange risk. If the exporter decides to enter into a forward contract, the future exchange rate will be agreed today, and the exporter eliminates the foreign exchange risk. This operation is called hedging with a forward contract.

Nevertheless, it is also possible to make a profit in the FX market by speculation. Speculators usually do speculation in the belief of them having profound knowledge about the market, and that this knowledge can lead to a profit from a shift in the exchange rates. Furthermore, if someone tries to exploit interest rate differentials between countries and uses forward contracts to secure his investment or loans against currency risk, the riskless profit he can earn is called arbitrage.

2.2 Forward and Futures

Forward and Futures have mainly the same purpose, which is to offer firms, institutions, and investors the opportunity to buy or sell, in the case of this thesis: currencies, at an agreed price and time in the future. However, forward and futures differ in some crucial aspects.

Forward contracts are non-standardized contracts that cannot be traded in a centralized exchange. Forward contracts are over-the-counter instruments which makes them not as readily available as futures contracts. Forward contracts are tailored among parties to buy or sell currency on a future date at an agreed price. Forward contracts have multiple purposes like hedging foreign exchange risk or speculation. Counterparty default risk exists in forward contracts since it is an over-the-counter instrument.

Nonetheless, futures contracts are highly standardized contracts available at exchanges. Highly standardized contract means that the contracts have a given form, typically they have fixed maturities of different lengths. Moreover, they lack the flexibility and require the investor to deposit a margin while forwards do not require any payments before maturity. Finally, the marking-to-market characteristics of futures contracts obliterate the counterparty default risk. Hence, the futures and forward rates are not automatically equal at all time. Furthermore, futures contracts are more liquid than forward. Investors can sell futures contracts in a secondary market which is not applicable to the forward contracts.

2.3 Interest Rate Parity

Interest Rate Parity (IRP) is one of the most profound international finance theories and has been discussed as far back as 1889 by the German economist Walther Lotz (1889). IRP states that the interest rate differential among two countries equals the differential among the forward and spot exchange rate, which is the forward premium or discount. When the interest differential equals the forward premium, it represents a no-arbitrage equilibrium among domestic and foreign money market, presuming free capital mobility and perfect asset substitutability. IRP is a no-arbitrage equilibrium where the investors will be indifferent to the interest denoted in the same currency which can be earned by depositing money in two countries. Furthermore, IRP can be divided into Covered Interest Rate Parity (CIP) and Uncovered Interest Rate Parity (UIP).

CIP is based on a no-arbitrage condition and states that it should not be possible to profit on the interest rate differential when accounting for both the spot and the forward exchange rate. Covered means that the investment is not exposed to transaction foreign exchange risk (Bekaert & Hodrick, 2014, pp 189). In advance agreement on the future exchange rate is precisely how CIP differs from UIP. At the same time, it opens for arbitrageurs to gain risk-free profit when CIP does not hold. Profit can be achieved by going long in the high-interest rate currency and short in the low-interest rate currency and use the mispriced forward contract to gain profit.

Typically there will not be deviations from CIP since the foreign exchange market is highly efficient. A highly efficient market can be shown through small transaction costs where market operators in a normal market situation should quickly arbitrage away any CIP deviations. The deviations will dissolve quickly since once there is a possibility for arbitrage profit, investors will start to exploit the arbitrage opportunity and it dissolves. However, research done on CIP deviations tell us that short-lived CIP deviations exist (Akram et al, 2008, pp 1 and Baba & Packer, 2008, pp 1) in conjunction with the 2007-2009 financial crisis. Here the deviations and arbitrage opportunities are shown to increase with the market volatility. However, in a normal market situation CIP is expected to hold.

For many years studies showed that the UIP theory did not hold, either in the way of the currency not moving as much as expected or even in the opposite direction. The notion that UIP does not hold is not a big surprise since it is based on risk premiums, rather than the no-arbitrage condition. That UIP does not hold is thoroughly shown in the literature by researchers like Fama (1984, pp 319), Engel (1996, pp 123) and Lustig & Verdelhan (2007, pp 89). If UIP holds, one is indifferent between using a forward contract now to exchange currencies on a future date or to exchange at the spot exchange rate on the same date in the future. The change in the exchange rate will dissolve a potential profit from taking advantage of interest rate differential, i.e., the currency of a country with low interest rates will appreciate compared to the currency of a country with high interest rates. However, CIP states that the forward exchange rate should be such that the return of investing in the high-interest rate currency and the return of investing in the low interest is the same when using a forward contract to cover the FX risk.

Interest rates can be divided into short-term and long-term interest rates. The central bank could control the short-term interest rates if they chose to exercise their power. Moreover, for the long-term interest rates, it is unclear if it is the central bank or the market power that influence these rates (Fama. 2013, pp 2-5). This thesis will not go into any further discussion regarding how the short-term and long-term interest rates are decided. Different central banks normally set the key policy rate either so that the country's currency exchange rates keep stable or to maintain the inflation within a given range. It works through several channels when the central bank changes the interest rate to control the economy: (Figure 1. Bank of England, Monetary Policy Committee. 1999).

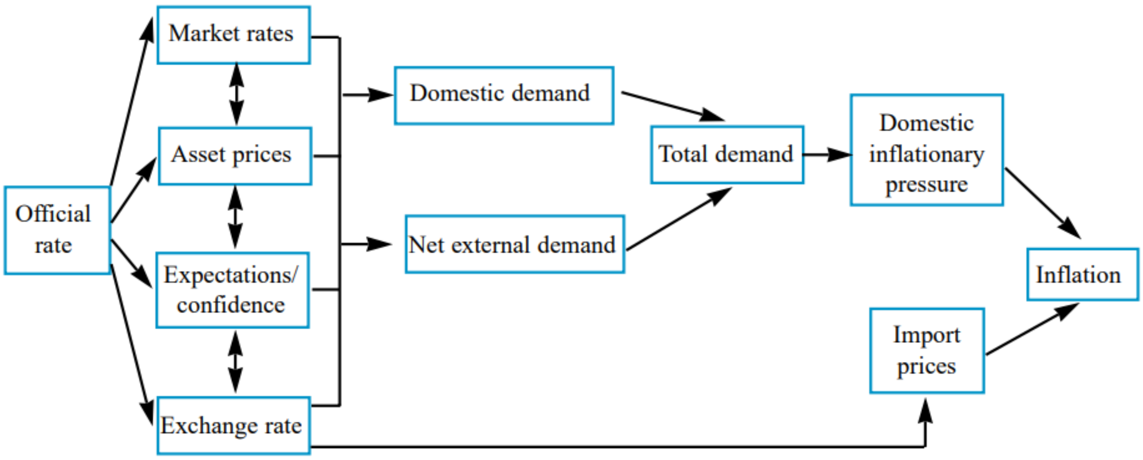

Fig 1 - Monetary Transmission Mechanism

Following the model from the Bank of England, it is possible to observe that changes in the interest rate can lead to changes in the exchange rate between two countries. Increased interest rates make it more appealing for an investor to invest in the country, which leads to an appreciation of the currency exchange rate through increased demand, but this increase in interest rate also reduced domestic consumption which theoretically is negative for the exchange rate. It is also important to note that there is a delay between changes in the key rate and when it affects consumption, savings, and lending. The Bank of England paper (Bank of England, Monetary Policy Committee, 1999) calculations show that it takes up to two years before the maximum effect from key rate changes shows in the inflation. The inflation target is also a common part of the monetary policy of many countries today. If a country's inflation is negative, then the consumers are better off by saving money instead of consumption since the prices are falling (Mundell, 1963, pp 280-283). When consumers save money instead of consumption, it can lead to a dangerous spiral where the country's economy can be harmed and thus have a substantial potential impact on how good the UIP holds.

2.4 Literature Review

Empirical studies have demonstrated that currencies in high-interest rate countries do not depreciate as much as guided by IRP which is shown by Hansen & Hodrick (1980), Fama (1984), Froot & Thaler (1990), Engel (1996) and Lustig & Verdelhan (2007). More examples of UIP violations are also shown by Bekaert & Hodrick (2014, pp 235-241); the regression results of the unbiasedness hypothesis show that most currencies do not depreciate as much as the forward discount.

There are also studies on UIP in countries that change their monetary regime (shock/crisis), such as moving from fixed to a floating currency. Flood & Rose (2002) used daily data for 23 developed and developing countries while focusing on the different crisis each country experienced in the turmoils of the 1990s and comparing the results with a country not experiencing a significant crisis. Flood & Rose (2002) find that the UIP better suits the data from the 1990s than historically. Flood & Rose (2002) also uncovered that UIP systematically works better for countries which went through a change in their monetary regime than for countries which based their interest rate on a fixed or partly fixed exchange rate. Lastly, Flood & Rose (2002) conclude that UIP still does not hold. When countries have different interest rates, and it is proved that the exchange rate cannot neutralize the interest rate differential, it opens for speculation opportunities. One of the typical examples of speculations which by, some studies has proven profitable, is the "Carry Trade." Carry trade received much attention of researchers such as Gyntelberg & Remolona (2007) who find profitable carry trades.

On the other hand, multiple studies also report that UIP holds. A study by Chinn & Meredith (2004) argues that most studies have used short-term data, while Chinn & Meredith used interest rates on longer-maturity bonds. These long-term regressions yield greater support for UIP. Somewhat similar research has been done by Lothian (2016) who re-examined the performance of UIP where he ran the regression over a time span of 90 to 217 years. Lothian's results, similar to that of Chinn and Meredith, are in line with UIP. Another study which finds evidence for the long-term UIP is a study by Lustig et al. (2015).

Furthermore, Lee (2013) estimated UIP slope parameters using a large number of cross-country bilateral exchange rates from a broad spectrum of developed and developing countries. Empirical evidence in Lee's study shows that short-term (one month) UIP holds well, and the failure of UIP is primarily due to the key currency bias. A key currency refers to a stable and globally traded currency which is essential for international transactions. The key currency bias is similar to the home equity bias in the sense that although UIP theory calls for the expected appreciation of the local currency when interest rate for key currency countries is higher than the domestic interest rate, the key currency is preferred to the local currency whenever the key currency offers higher interest rate (Lee, 2013). UIP fails more often when a key currency is involved in the bilateral exchange rate, especially when a key currency offers a higher return on capital than when only non-key currencies are involved. Lee (2013) found that UIP seems to hold well among a currency pair of developed and developing countries, but UIP does not hold among key currencies. Lee (2013) also states that UIP does not hold among key currencies even when taking transaction costs into account.

If both CIP and UIP hold, it leads us to the unbiasedness hypothesis. The unbiasedness hypothesis says that the forward exchange rate is an unbiased predictor of the future spot exchange rate. The failure of the unbiasedness hypothesis opens for arbitrage possibilities in the world's largest financial market. Nevertheless, the failure does not automatically reject the efficient market hypothesis since the unbiasedness hypothesis does not allow for a risk premium or transaction costs. A classic challenge is why low interest rate currencies tend to depreciate relative to high interest rate currencies (Burnside et al. 2007, pp. 1). This peculiar phenomenon is referred to as the forward premium puzzle.

On the other hand, a considerable deviation from IRP, which cannot be explained by risk premium or transaction costs, could potentially dismiss the efficient market hypothesis (Gregory & McCurdy, 1984, pp 357). There are various origins for the forward premium puzzle and long and short periods of IRP deviations can come from sources as political risk or default risk (Bekaert & Hodrick, 2014, pp 201-207). It is possible to exploit the forward premium puzzle through multiple cases, and one of them is the carry trade.

2.5 Interest Rate Parity Decomposition

In this part of the thesis, CIP, UIP, and the unbiasedness hypothesis will be derived and explained. CIP will be thoroughly explained, in particular how CIP connects the forward premium and the interest rate differential. After the explanation of CIP, a description of UIP is given. Lastly, the connection between CIP, UIP and the unbiasedness hypothesis is explained.

First and foremost, the two central assumptions needed for IRP to hold must be presented. The first assumption being the free flow of capital, which means that investors can change domestic assets for foreign assets without any government involvement and barriers like foreign exchange control and foreign investment tax. The second assumption is that assets have perfect substitutability, which means investors can always find domestic and foreign bonds that have the same expected return when measured in the same currency.

2.5.1 Covered Interest Rate Parity

CIP states that the return of investing in high-interest currency and low-interest currency is identical when measured in the same currency and the foreign exchange risk is hedged by using a forward contract. The core of CIP is using forward contracts to remove future exchange risk, which is called hedging or covering.

Under CIP, the following equation must hold to eliminate arbitrage opportunity:

$$(1 + i_{t,k}^{d}) = \frac{F_{t,t+k}}{S_t}(1 + i_{t,k}^{f}) \tag{F.1}$$

where $i_{t,k}^{d}$ is the k-period domestic risk-free interest rate, $i_{t,k}^{f}$ is the k-period foreign risk-free interest rate, S_t is the spot foreign exchange rate defined as the domestic price of one unit of foreign currency at time t and $F_{t,t+k}$ is the k-period forward foreign exchange rate at time t. Equation F.1 tells us that investing one unit of domestic currency in the domestic money market is equivalent to exchanging this one unit of domestic currency at the spot exchange rate and then investing in the foreign money market while hedging FX risk with a forward contract (Bekaert & Hodrick 2014, pp 198). The explanation above assumes that all risks are eliminated and that all variables are known at time t.

Bekaert & Hodrick (2014, pp 192-193) explain how the forward premium or discount equals the interest rate differential in the following way if (F.1) is divided by $(1 + i_t^f)$ on both sides and rearranged:

$$\frac{F_{t,t+k}}{S_t} = \frac{1+i_{t,k}^{d}}{1+i_{t,k}^{f}} \qquad \text{(F.2)}$$

Then, 1 is subtracted from both sides and a different common denominator is applied on each side. After simplification, we get:

$$\frac{F_{t,t+k}}{S_t} - 1 = \frac{1+i_{t,k}^{d}}{1+i_{t,k}^{f}} - 1$$

$$\Rightarrow \qquad \frac{F_{t,t+k} - S_t}{S_t} = \frac{i_{t,k}^{d} - i_{t,k}^{f}}{1+ i_{t,k}^{f}} \qquad \text{(F.3)}$$

The left-hand side of the equation (F.3) is the forward premium (discount), and the right-hand side is the interest rate differential. Equation (F.3) is often simplified by taking the logarithm on both sides of the equation, which gives:

$$ln(F_{t,t+k}) - \ ln(S_t) = i_{t,k}^{d} - \ i_{t,k}^{f} \qquad \text{(F.4)}$$

Equation (F.4) is often used in the regression models to test if IRP holds in the literature. It is an approximation of equation (F.3) which is the exact form of CIP. In this thesis, (F.3) is used in the regression models.

2.5.2 Uncovered Interest Rate Parity and the Unbiasedness Hypothesis

In comparison, UIP maintains the same *expected* returns from domestic and foreign money market investments without using a forward contract to cover the foreign exchange risk, which allows for uncertain return caused by the uncertainty of future spot exchange rate (Bekaert & Hodrick, 2014, pp 225).

UIP can be represented by the equation:

$$(1 + i_t^d) \ = \frac{E_t(S_{t+k})}{S_t}(1 + i_t^f) \tag{F.5}$$

Where i_t^d is the domestic risk-free interest rate, i_t^f is the foreign risk-free interest rate, $E_t(S_{t+k})$represents the expected future spot exchange rate at time $t + k$ based on all available information at time t (conditional expectation) and S_t is the spot exchange rate (foreign currency priced in domestic currency) at time t. The only difference between CIP and UIP is the numerator on the right-hand side of the equation where CIP has the forward rate, and UIP has the expected future spot rate. The left-hand side of the UIP equation is the domestic money market return. The right-hand side represents foreign money market return quoted in the domestic currency. A risk-neutral investor will be indifferent from an investment in either country since the expected return will be the same, given that the UIP holds.

For the unbiasedness hypothesis to hold, both CIP and UIP must hold. The unbiasedness hypothesis states that there is no systematic difference between the forward rate and the expected future spot rate (Bekaert & Hodrick, 2014, pp 225). If one of CIP or UIP does not hold, the forward exchange rate will not be an unbiased predictor of the future spot exchange rate. When the CIP equation (F.1) is set to be equal to UIP equation (F.5), the unbiasedness hypothesis can be shown as the following equation when S_t in the denominator and $(1 + i_t^f)$ is eliminated:

$$\frac{E_t(S_{t+k})}{S_t}(1 + i_t^f) = (1 + i_t^d) = \frac{F_{t,t+k}}{S_t}(1 + i_t^f) \tag{F.6}$$

The unbiasedness hypothesis can then be shown as the equation below when both CIP and UIP hold:

$$F_{t,t+k} = \ E_t(S_{t+k}) \tag{F.7}$$

The right-hand side of equation (F.7) is the conditional expectation of future spot FX rate. The conditional expectation is unobserved and therefore hard to test in econometric models. The conditional expectation is formed by the market, based on the information set available at time t. Hence, to deal with the unobservable variable, the assumption of rational expectation is made to specify how investors form their expectation.

2.6 Interest Rate Parity Deviations

In this subchapter, some explanations for potential deviations from IRP are given, among which expectational errors and exchange risk premium are the two primary sources of IRP deviations mentioned in most papers.

2.6.1 Expectational Errors

Expectational errors are among the most frequently debated answers to the failure of the unbiasedness hypothesis (Cavaglia et al. 1993, pp 78). While it is clear that investors will make errors each period, the key feature of expectational errors is that they occur systematically in a way that violates UIP. For example, an irrational investor is an investor making non-optimal decisions such as buying a foreign currency without considering country-specific risk or the country’s economic performance. The irrationality of investors can explain expectational errors. When irrational investors are present in the foreign exchange market, it can lead to changes in the foreign exchange rate which causes IRP to fail. The irrationality of investors is contradictory to the assumptions in this thesis, and it directly violates the unbiasedness hypothesis assumption of rational expectation.

Furthermore, there are two famously discussed possible expectational errors: the learning problems and the peso problems. The learning problems, which Lewis (1989) and Froot & Thaler (1990) looks into, are defined as the investors learning process after a regime change, for instance from fixed to floating exchange rate, and how this affect the exchange rates. However, Lewis (1989) explained that there is evidence against the learning problem since she found evidence for this error to not disappear over time.

The peso problem, however, is when the possibility that some infrequent or unprecedented event may occur, affect asset prices. The event must be difficult or even impossible to accurately predict using historical economic data. The peso problems present a severe difficulty for economists who like to build and estimate economic and financial market models and then use the models to interpret economic data. Krasker (1980) review the difficulty mentioned above.

Empirical economic models designed to match features of the economy, are calibrated or estimated using current and historical data on economic variables. If the historical data used to calibrate or estimate models do not accurately reflect the probabilities of some extremely bad or good things are happening, then the model-based forecast can be inaccurate, and the policy that rests on the models can suffer. Froot & Frankel (1989, pp 139) tested the expectational error hypothesis, and they concluded with the rejection of the hypothesis based on deviation from risk premium. Froot and Frankel could not reject their hypothesis that expectational errors such as irrational investors, the learning problem and peso problem were the source of deviations.

2.6.2 Exchange Risk Premium

Exchange Risk Premium is also often referred to as the Time-Varying Risk Premium (Mark, 1985). If we, contrary to the assumption mentioned in the IRP decomposition, assume that investors are risk averse and the foreign exchange risk is not possible to perfectly diversify, then the interest differential or forward premium (discount) can no longer be interpreted as a fair estimate of the expected change in future exchange rates. Thus, if the domestic currency is viewed as riskier than the foreign currency, domestic interest rates would have to be higher, even if the exchange rate is not expected to change. If the assumption of rational expectations is maintained, then a finding of $\beta \neq 1$implies that interest rate movements are related to changes in the risk premium (Froot & Thaler, 1990, pp 182-185).

If the unbiasedness hypothesis assumption of rational expectation holds, then the error term should equal zero on average, and therefore are all forward and expected future spot rate deviations due to exchange risk premium as discussed by Chinn (2007, pp 1-8). The exchange risk premium can also be explained from an investors standpoint. If this investor holds an equity-based portfolio and r is looking to invest in the FX market, then the investor’s market portfolio can be portrayed through the equity market. The investor can shift the risk of the portfolio when buying foreign exchange if the exchange rate and the equity market portfolio covariates. Let’s say that the investor acquires some currency that leads to increased portfolio risk; then the investor will require some premium for holding an asset of greater risk. The investor will require the premium unless the investors change their degree of risk. (Bekaert & Hodrick, 2014, pp. 228-229). Moreover, the exchange risk premium can be hard to hold accountable since there is empirical evidence, as shown by Mark (1985, pp 3-18), which says the investor must be so risk-averse that it is apart from any reasonable explanation to justify the size of the premium.

At the same time, the capital asset pricing model (CAPM) can be used when explaining IRP deviations through exchange risk premiums. The limitations when explaining exchange risk premiums through CAPM, is that the foreign exchange market does not have a given market portfolio, as the equity market does. These limitations can be explained through the market portfolio in the equity market. Stocks included in the market portfolio are weighted by their relative market capitalization (Dale & Ulvund, 2018, pp 15). For the foreign exchange market, it is impossible to use the CAPM model since there is no given market portfolio, and to choose what currency to include to create such a market portfolio is troublesome. Another concern is the zero-sum game. The foreign exchange market work in such a way that one currency has to depreciate when the other currency in the pair appreciate.

2.6.3 Data Imperfection

The reason why data imperfection can lead to IRP deviations is that imperfect data can give spurious regression results, which is well covered by Taylor (1987, pp 429-438). Taylor explains that a real deviation from IRP corresponds to a potential profit at a given time. Furthermore, it is essential that the data used to test IRP is collected at the same time and that it is usable in a real-life situation. A real-life situation can be explained as using real exchange rate data and real interest rate data. Many IRP studies over the years have not collected the exchange rate and interest data at the same time. One example is the survey done by Frenkel & Levich (1975, pp 325-338) where the exchange rates are aggregated hours after the interest rate data.

To collect real closing exchange rate for multiple currency pairs from different exchanges, which do not have the same closing time, is challenging and can lead to data imperfection. When including exchanges from three different continents, all with different opening hours, we have to collect as equal rates as possible to minimize the potential data imperfection problem. The same issue goes for the interest rates, which is used in CIP regression. These interest rates need to be as close to equal as possible to not encounter data imperfection problems.

2.6.4 Default Risk

The possibility of counterparties default risk, i.e., the borrower may not repay the entire amount of money as promised in a bond, has not been considered so far. When this possibility is reflected in the interest rate, is it possible to find an apparent deviation from interest rate parity that does not represent a riskless arbitrage opportunity (Bekaert & Hodrick 2014, pp 201-202). If lenders require a particular expected return to make a loan, borrowers with higher default risk must offer higher interest rates to increase the expected return on their loans to attract more lenders. Hence, the fact that the interest rates on bank deposits denominated in the same currency in the interbank market are different does not necessarily show market inefficiency (Bekaert & Hodrick 2014, pp 201-202). If there is a deviation from interest rate parity, it does not mean it is a true profit opportunity. Such deviations can mean that the default risk for the particular banks making the quotations is not known (Bekaert & Hodrick 2014, pp 201-202).

2.6.5 Exchange Controls

Another potential cause for IRP deviations is exchange controls. Governments of different countries sometimes interfere with the trading of foreign exchange. They may tax, limit, or prohibit buying of foreign currency by their residents (Bekaert & Hodrick 2014, pp 204-205). For example, in China, each citizen is only entitled to purchase foreign currency with the equivalent value of 60,000 USD each year, and the international transfer of money is under severe control.

The governments may also tax, limit, or prohibit the inflow of foreign investment into their country (Bekaert & Hodrick 2014, pp 204-205). For instance, Brazil initialized a flat tax on foreigners investing in the Brazilian fixed-income market at the end of 2008, and each foreign investor has to pay 6% of their investment to the Brazilian government (Bekaert & Hodrick 2014, pp 201-205). These exchange controls or differential taxes effectively prevent the inflow and outflow of speculative hot money attracted by high interest rates. Therefore, when controlling historical data, exchange control should be taken into consideration. It is possible to be fooled by the appearance of covered interest arbitrage which in fact does not exist because of exchange controls or taxes.

Hence, in this thesis, countries that impose exchange controls will not be analyzed. This to reduce potential spurious results.

2.6.6 Political Risk

Political risk refers to the possibility that a government suddenly impose some form of exchange control or taxes on foreign investment even if these exchange controls are currently not present (Bekaert & Hodrick 2014, pp 205-207). Political risk factors include expropriation or nationalization, contract repudiation, taxes and regulation, exchange controls, corruption, and legal inefficiency. All the factors would in one way or another cause significant potential loss to multinational companies and foreign investors. These political factors mainly exist in some developing countries. In some extreme cases, the governments of these countries default on their sovereign debts, for example, Russia and Ecuador defaulted on obligations to foreign investors in the late 1990s, Argentina also defaulted on its international debt in 2002, and Ecuador defaulted again in 2008 (Bekaert & Hodrick 2014, pp 205-207).

Hence, in this thesis, countries with a high level of political risk will not be analyzed. This to reduce potential spurious results.

2.6.7 Transaction Cost

In the construction of empirical variables, the facts that there is a difference between bid rate (buying price) and ask rate (selling price) for currencies are ignored. The differences in deposit and lending rates are also ignored in the parity explanations. A currency's bid and ask rate is the price received when selling and buying currency. The difference between the bid and ask rate, the spread, is an integral part of the FX market since it reflects the cost from both exchange transactions (Bekaert & Hodrick 2014, pp 196-200). The spread is the differential to be paid when buying and selling the same currency at the same time. In addition to the spread, a provision for each transaction must also be paid, and these are the central part of the FX market transaction costs. There is also a spread in the interest rates. The spread in interest rates comes from the difference in the lending rate and the deposit rate and translates to the transaction cost in the money market. There has been a focus on different influential factors on transaction cost, but the main factor is FX market uncertainty. The spreads are there to ensure that parties will be compensated for their investment risks.

In the survey by Taylor (1987, pp 429-438) the transactions cost is included in the CIP equation. The CIP arbitrage argument which tells us that the equilibrium, of the forward premium equal the interest differential, will be hampered if transaction cost is included. When including transaction cost, the forward premium should be within a range of the interest differential for there to be no profitable arbitrage opportunities. The upper and lower limits of this range depend on both the interest rate differential and the transaction cost. Within this range, the cost is larger than the arbitrage profit for traders on both sides, i.e., no matter if the trader goes long or short on the domestic currency. When presenting the empirical results, the potential impact of transaction costs will be discussed.

2.6.8 Financial Crisis

Bekaert & Hodrick (2014, pp 186-190) described that deviations from CIP especially occurs when the market is volatile. From 2007 until 2009 a financial crisis hit the stock and foreign exchange market and the whole globe was sent into recession. It is therefore likely to believe that this period could influence CIP regression which includes this period. For most of the post-Bretton Woods period until 2007, CIP was one of the most reliable and relied upon parity conditions in international finance, but CIP seems to not hold as good after this period (Levich, 2017, pp 1-32). Moreover, if the dataset used in the regression consists of a time frame, which is long enough, the deviations financial crisis should be averaged out. This is done by Lothian (2016) who uses ultra-long time series in his regressions.

3. Methodology

In this chapter we will describe the nature of the different tests employed in the empirical analysis and derive the econometric regressions used.

3.1 Testing Covered Interest Rate Parity

When testing CIP, the regression will be based on (F.1) from chapter 2:

$$(1 + i_{t,k}^{d}) = \frac{F_{t,t+k}}{S_t}(1 + i_{t,k}^{f}) \tag{F.1}$$

also, if CIP holds, we have from (F.2) and (F.3) that:

$$\frac{F_{t,t+k}}{S_t} - 1 = \frac{1+i_{t,k}^{d}}{1+i_{t,k}^{f}} - 1$$

Which can be interpreted as the forward premium or discount, equals the interest rate differential between the home and foreign country. Since all the variables $F_{t,t+k}$, S_t, $i_{t,k}^{d}$, $i_{t,k}^{f}$ are observed at time t, CIP can be tested by the following econometric model with the exact changes:

$$\frac{F_{t,t+k} - S_t}{S_t} = \alpha + \beta\left(\frac{1+i_{t,k}^{d}}{1+i_{t,k}^{f}} - 1\right) + \eta_{t+k} \tag{F.8}$$

For the CIP regression, the null hypothesis is: $\alpha = 0\ and\ \beta = 1$ which means the expectation of forward return should be equal to the expectation of the exact interest differential. An exact difference for interest rates is chosen to allow for the possibility that historical interest rate was “high.” For example, in the dataset, the interbank rates for Norway was above seven percent in 2002.

Typically, the estimate of β from the CIP regression is close, but not exactly equal to one. This can come from small errors in the interest rates and or the forward used in the dataset. It is also possible that some of the IRP deviations from chapter 2.6 are present.

3.2 Testing the Unbiasedness Hypothesis

As mentioned in theory, the conditional expectation of the future spot exchange rate, in formula (F.7), is unobserved and therefore hard to test in an econometric model. We also explained the rational expectation and the risk neutrality assumptions. The rational expectation and the risk neutrality will be the basis for how the regression in this thesis is postulated.

$$F_{t,t+k} = E_t(S_{t+k}) \tag{F.7}$$

F.7 is the essential equation representing the unbiasedness hypothesis. However, the linear regression cannot be used to test this relationship directly as the conditional expectation, $E_t(S_{t+k})$, normally is unobservable. It is too difficult to do surveys to find the investors' expectations accurately. Therefore, rational expectation is assumed to avoid this problem and continue the linear regression analysis with the ex-post spot FX rates. The rational expectation assumption implies that the measurement error of the truly expected depreciation is random and thus zero on average (Froot & Frankel, 1989, 139-161). The last statement can be expressed as:

$$S_{t+k} = E_t(S_{t+k}) + \eta_{t+k} \tag{F.9}$$

The error term η_{t+k} can be regarded as new information that moved the exchange rate, which was unanticipated by rational investors at time t. From above, we see that rational expectation implies that the error term is equal to zero.

Reformulating (F.7) so that:

$$S_{t+k} = F_{t,t+k} + \eta_{t+k} \tag{F.10}$$

To deal with the problem that both S and F are likely not stationary, it is common to instead focus on the relative change of the two variables. If we divide each side in (F.10) by S_t and subtracting 1 in the form of $\frac{S_t}{S_t}$ and then we get:

$$\frac{S_{t+k} - S_t}{S_t} = \frac{F_{t,t+k} - S_t}{S_t} + \eta_{t+k} \tag{F.11}$$

Rewriting the above equation in the form of a testable econometric equation:

$$\frac{S_{t+k} - S_t}{S_t} = \alpha + \beta\left(\frac{F_{t,t+k} - S_t}{S_t}\right) + \eta_{t+k} \tag{F.12}$$

The two null hypotheses are that $\alpha = 0 \; and \; \beta = 1$, which translates to the realized change in the exchange rate is equivalent to the forward premium or discount plus a random error term η_{t+k}. In other words, the unbiasedness hypothesis only holds when both variables satisfy a linear relationship with the slope equal to 1 and the intercept equal to 0.

To deal with serial correlation problems, we add a lagged dependent variable as the regressor into (F.12) and get:

$$\frac{S_{t+k} - S_t}{S_t} = \alpha + \beta(\frac{F_{t,t+k} - S_t}{S_t}) + \frac{S_{t+k-1} - S_{t-1}}{S_{t-1}} + \eta_{t+k} \qquad \text{(F.13)}$$

If the regression yield results in which $\beta \neq 1$ some sort of deviations are present. Potential IRP deviations are explained in chapter 2.6.

4. Data Description

Time series data of spot exchange rates, forward rates, and interest rates have been collected for all currency pairs to test CIP and the unbiasedness hypothesis. Data is collected for the period 01/01/2002 to 19/10/2018. 1-month and 3-month forward exchange rate are collected for the regressions. Key policy rates for all countries are also collected, so that we can remove the days around changes in the key policy rate from the whole data. For the CIP regression, interbank interest rates for all countries are collected. The Thomson Reuter Datastream is the source of all the data used in this empirical analysis. R is used for all altering of data and to run all regressions.

4.1 Spot Exchange Rates

The exchange rate data consist of six different currency pairs: CAD/USD, EUR/USD, JPY/USD, NOK/USD, CHF/USD and GBP/USD. The selected currency pairs are mostly the major currencies in the foreign exchange market, which are liquid and actively traded currencies. Choosing liquid and actively traded currencies decreases the probability of choosing wrongly priced currency pairs and decreases the transaction costs as bid/ask spreads. A table containing all exchange rates can be found in Appendix A5.

All the exchange rates are given as daily observations and are collected from the Global Treasury Information Service (GTIS) database in Datastream. In the GTIS database, all exchange rates are quoted at 18:00 New York (22:00 GMT). The GTIS database is used to ensure that all the data are from the same source and that it is collected at the same time of day.

4.2 Forward Rates

As forward contracts are more flexible and available than futures contracts for most currency pairs, and forward contracts do not require depositing a margin, they are preferred over futures when we select data for testing CIP. Another important aspect is data availability. Forward contracts are readily available from Thomson Reuter Datastream, and thus, based on these criteria, we decide upon using forward in the empirical analysis.

The forward exchange rate data consist of the same six currency pairs as the spot exchange rate, for the same period. All the forward exchange rates are given as daily observations and are collected from the WM/Reuter database in Datastream. All closing forward exchange rates are given as middle rates, which means that the rates are the average between bid and ask price. Closing forward exchange rates are fixed at 4 p.m. UK time.

Both 1-month and 3-month forward exchange rates used in this regression are denoted as the domestic price of 1 USD. A table containing all forward contracts used can be found in Appendix A.5.

4.3 Interest Rates

The interest rates used to test CIP should be collected from the same source to ensure equality from the dataset. There are many different types of interest rate data available for the CIP regression. Some researchers such as Chinn & Meredith (2004) use government bond yields as the interest rates in their regression. Baba & Packer (2008) and Dale & Ulvund (2018) use interbank rates to test the relationship between the forward premium and the interest rate differential between two countries. Interbank rates are used since they are set on a daily basis, which means that if the FX market is efficient, any changes in the interbank interest rate should instantly be reflected in the forward premium. Other types of interest rates could give deviations from CIP if they are not set on short enough maturity (Dale & Ulvund, 2018, pp 32). Based on this argument we decide to use interbank rates when testing CIP.

All interbank rates have been collected from Thomson Reuter Datastream for all currency pairs, for the period 01/01/2002 to 19/10/2018. Moreover, all interbank rates are given as daily observations of one-year percentage rates.

The interbank rates used for Canada are the Canadian Dealer Offered Rate (CDOR) collected through the CIBC World Markets database in Thomson Reuter Datastream, and are updated at 11:00 am ET. The interbank rates used for the Norwegian Krone is the Norwegian Interbank Offered Rate (NIBOR). The NIBOR is officially updated once a day, at 12:00 am CET, by a small group of large Norwegian banks (Store Norske Leksikon). The interbank rates used for the Euro, Japanese Yen, Swiss Franc, UK Pound, and US Dollar are collected through the ICE Benchmark Administration Ltd (IBA) database in Thomson Reuter Datastream, and the rates are updated at 11:55 am GMT.

Notice that all the interbank rates are not from the same source. The interbank rates for Canada (CDOR) and Norway (NIBOR) are not from the same source as the LIBOR rates obtained for the other countries. In chapter 2.6 this issue is described as a potential source of data imperfection, and thus it can have an impact on the regression results.

4.4 Key Policy Rates

The key policy rates used in this thesis are the countries' central bank interest rate, which are the benchmark interest rates central banks use to influence financial market (Bank of Canada). The key policy rates in this thesis are used to control the sample. This is done by removing a day or a time interval when the key policy rate of one or both countries in a currency pair change. This control is then used to check if the unbiasedness hypothesis holds better when removing these dates. Am issue when including the key policy rate is that many countries included in the dataset had a floating key policy rate in the 1990s. The floating interest rate policy changed multiple times over very short time intervals. Hence, to be sure that not too many data points are excluded, the dataset is set to start from 01/01/2002.

The key policy rates used to adjust the dataset are all central bank policy middle rates based on availability in Datastream. For EU, the key policy rate is the Eurozone Interest Rate. A list over interbank rates and key policy rates are provided in Appendix A.6.

4.5 Variable Definitions

When doing the regressions of 1-month change in spot exchange rate on forward return, the change in spot exchange rate is calculated as $\Delta S = \frac{S_{t+22}-S_t}{S_t}$on day $t+22$ and it corresponds to the 1-month forward return on day t, $fp_{t,t+22} = \frac{F_{t,t+22}-S_t}{S_t}$. For the 3-month regressions, the change in spot exchange rate is calculated as $\Delta S = \frac{S_{t+66}-S_t}{S_t}$on day $t+66$ and it corresponds to the 3-month forward return on day t, $fp_{t,t+66} = \frac{F_{t,t+66}-S_t}{S_t}$. The data is modified accordingly to match the independent variables and dependent variables. Compared to most literature which uses monthly observations, daily observations are used in this thesis. By using daily observations, our dataset will include significantly more data points than most other papers.

The interest rate differential is calculated as the exact interest differential $diff(i) = (\frac{1+i^d/100}{1+i^f/100})^{\frac{1}{12}} - 1$ for 1-month maturity and $diff(i) = (\frac{1+i^d/100}{1+i^f/100})^{\frac{1}{4}} - 1$ for 3-month maturity. Here, $i^d/100$ is the yearly domestic interest (of any maturity). i^d and i^f are denoted as the number of percentages in the dataset. The data is given as daily, while the interest rates are yearly rates.

5. Empirical Analysis

Empirical literature usually states that CIP holds if markets are efficient and there are no government controls to prevent arbitrage (Bekaert & Hodrick, 2014, pp 189). When literature is testing whether the unbiasedness hypothesis holds, they typically only refer to that CIP holds without exhibiting any proof. We will, on the other hand, start by testing if CIP holds before we test the unbiasedness hypothesis.

The research question for our thesis is to check whether removing days when central banks make changes to their key policy rate will make the regression results more in line with the unbiasedness hypothesis. It is equivalent to check how central bank announcements impact the foreign exchange market.

The empirical analysis consists of three parts. First, we test CIP using only one observation per month or quarter. Second, we test the unbiasedness hypothesis using one observation per month or quarter. Lastly, we test the unbiasedness hypothesis using daily observations, while removing days of key policy rate changes. The first test for the unbiasedness hypothesis is a replication of how literature normally tests it, while the second test is based on our research question.

For all regressions, we run the Breusch-Pagan test for heteroskedasticity, and also, we run the Durbin-Watson and Breusch-Godfrey test for serial correlation. A thorough explanation of econometrics can be found in Appendix A.1.

5.1 Covered Interest Rate Parity replication of literature

CIP is tested by the econometric regression based on the model from chapter 3.1:

$$\frac{F_{t+k} - S_t}{S_t} = \alpha + \beta\left(\frac{1 + i_{t,k}^d}{1 + i_{t,k}^f} - 1\right) + \eta_{t+k} \tag{F.8}$$

The null hypotheses for all regressions are: $\alpha = 0 \; and \; \beta = 1$.

CIP is tested with one observation per month or quarter, in the same way as how literature usually tests CIP. The results from the test will be compared to literature such as Fratianni &

Wakeman (1982), Crowder (1995) and Liao (2016). If the test results yield a $\beta \neq 1$then some factors of the deviations mentioned in chapter 2.6 might be present. It is likely that our test results will show some deviations from $\beta = 1$based on the explanations given in chapter 2.6 and 4.3.

Table 1: Regression results for replication of the uncovered interest rate parity.

CIP	**Alpha (t-value)**	**Beta (t-value β=1)**	**Std.error (β)**	**R^2 (adj)**
CAD/USD 1 month	0.0002 (0.728)	**1.1873** (0.545)	0.3434	0.0377
CAD/USD 3 month	*0.0009 (1.368)*	***0.8196*** *(-0.705)*	*0.2557*	*0.1235*
EUR/USD 1 month	0.0002 (0.947)	**0.9574** (-0.239)	0.1780	0.1277
EUR/USD 3 month	*-0.0001 (-0.441)*	***0.9754*** *(0.33)*	*0.0628*	*0.5602*
JPY/USD 1 month	-0.0007 (-2.641)	**0.8419** (-0.91)	0.1738	0.1107
JPY/USD 3 month	*-0.0009 (-1.76)*	***0.9633*** *(-0.436)*	*0.0843*	*0.48*
NOK/USD 1 month	0.0002 (0.692)	**1.0814** (0.629)	0.1295	0.2108
NOK/USD 3 month	*0.0000 (0.117)*	***0.9574*** *(0.344))*	*0.0564*	*0.6035*
CHF/USD 1 month	-0.0003 (-1.113)	**0.7311** (-1.633)	0.1647	0.0556
CHF/USD 3 month	*-0.0006 (-1.423)*	***0.8501*** *(-1.84)*	*0.0815*	*0.4417*
GBP/USD 1 month	0.0001 (0.554)	**1.2030** (1.151)	0.1764	0.1821
GBP/USD 3 month	*-0.0001 (-0.412)*	***1.1157*** *(1.485)*	*0.0779*	*0.6859*

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Test results for the Breusch-Pagan tests and Durbin-Watson tests can be found in Appendix A.2. For the 1-month case, the Breusch-Pagan test results show that heteroskedasticity is not present for CAD/USD, JPY/USD, CHF/USD and GBP/USD, but it is present at a 5% level for EUR/USD and NOK/USD. Moreover, the Breusch-Pagan test for the 3-month case confirms that heteroskedasticity is not present for any currency pairs. The Durbin-Watson test results confirm that no serial correlation is present for all currency pairs.

Our main finding here is that the regression results are in line with the literature, which means that the β is close to one, and CIP holds. From the table, we can see that all β (slope coefficient on the interest differential) are not significantly different from 1 or we fail to reject the null hypothesis that $\beta = 1$. Hence, we fail to reject CIP. Nevertheless, persistent deviation from $\beta = 1$ exists, especially the 1-month case for CHF/USD deviates. When comparing to empirical literature which also tests CIP, we can see that our results are in line with the literature such as: Fratianni & Wakeman (1982), Crowder (1995) and Liao (2016).

5.2 The Unbiasedness Hypothesis replication of literature

The unbiasedness hypothesis is tested by:

$$\frac{S_{t+k} - S_t}{S_t} = \alpha + \beta\left(\frac{F_{t,t+k} - S_t}{S_t}\right) + \eta_{t+k} \tag{F.12}$$

The null hypotheses for all regressions are: $\alpha = 0 \; and \; \beta = 1$.

In this subchapter, the regression of change in spot FX rate on forward return is conducted as a replication of how the literature typically tests the unbiasedness hypothesis. Literature[1] often use a simplified approximation which takes the natural logarithm on both side of the equation (F.12), using only one observation per month for the 1-month case and one observation per quarter for the 3-month case. The simplified approximation gives us the following model for testing the unbiasedness hypothesis:

$$ln\, S_{t+k} - ln\, S_t = ln\, F_{t,t+k} - ln\, S_t + \epsilon(t+k) \tag{F.14}$$

Many papers also conduct regression of $ln\, S_{t+k} - ln\, S_t$ on the interest differential $i^d_{t,k} - i^f_{t,k}$ by substituting equation (F.4) into (F.14):

$$ln\, S_{t+k} - ln\, S_t = i^d_{t,k} - i^f_{t,k} + \epsilon(t+k) \tag{F.15}$$

Here, $\epsilon(t+k)$ is the error term with mean equal to 0.

[1] Selection of papers using the log-version: Baillie & Kilic (2005), Chinn & Meredith (2004), Chinn & Quayyum (2012), Flood & Roose (2002), Håland (2003), Ismailov & Rossi (2016), Lee (2013) and Ånnestad & Valstadsve (2016).

(F.14) And (F.15), are two regression models often used by empirical literature to test the UIP or the unbiasedness hypothesis. However, in this thesis, we will not be using the logarithm form model described above. Instead, model (F.12) of the exact changes described in the methodology chapter is used for better accuracy. The replicating analysis is conducted so we can compare our results with how the literature normally tests the unbiasedness hypothesis using the same time frame and data used in our analysis in chapter 5.3.

It is worth mentioning that when choosing different starting date of the monthly and quarterly data, the regression results can be significantly different. A possible explanation can be the sampling bias. As the number of data points for the 1-month and 3-month case is only 198 and 65 respectively, the regression results are prone to changes in the data set. This issue is one of the reasons why we use daily observations in chapter 5.3.

Test results for the econometric Breusch-Pagan and Durbin-Watson tests can be found in Appendix A.3. Note that heteroskedasticity is present at a 5% level for CAD/USD and JPY/USD in the 1-month case, and for GBP/USD in the 3-month case. Moreover, the Durbin-Watson test shows that serial correlation is not an issue for any currency pair. The associated table below is presented with the Newey West estimates of the coefficients.

Table 2: Regression results for replication of the unbiasedness hypothesis.

	Alpha (t-value)	**Beta (t-value β=1)**	**Std.error (β)**	**R^2 (adj)**
CAD/USD 1 month	-0.0003 (-0.171)	**-0.5996*** (-2.588)	0.6180	0.0017
CAD/USD 3 month	*-0.0039 (-0.703)*	***1.067*** *(0.051)*	*1.322*	*-0.0047*
EUR/USD 1 month	-0.0009 (-0.407)	**-0.6901 .** (-1.763)	0.9589	-0.0014
EUR/USD 3 month	*-0.0034 (-0.459)*	***-1.492*** *(-1.218)*	*2.045*	*-0.0023*
JPY/USD 1 month	-0.0001 (-0.030)	**0.1750** (-1.355)	0.6089	-0.0047
JPY/USD 3 month	*0.0046 (0.560)*	***1.3676*** *(0.396)*	*0.9285*	*0.0044*
NOK/USD 1 month	-0.0002 (-0.089)	**0.1958** (-0.788)	1.0207	-0.0046
NOK/USD 3 month	*0.0000 (0.001)*	***0.1516*** *(-0.622)*	*1.3645*	*-0.0154*
CHF/USD 1 month	-0.0044 (-2.286)	**-2.332**** (-3.065)	1.087	0.03831
CHF/USD 3 month	*-0.0178 (-2.026)*	***-3.513*** *(-1.952)*	*2.312*	*0.0537*

GBP/USD 1 month	0.0010 (0.472)	**-0.1764** (-1.482)	0.7940	-0.0047
GBP/USD 3 month	*0.0033 (0.592)*	***-0.2429** (-0.482)*	*2.5781*	*-0.0152*

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

From the table we can see that none of the β for the 3-month regressions is significantly different from 1, while in the 1-month regressions, β is significantly different from 1 on a five percent level for CAD/USD, EUR/USD and CHF/USD. That being said, it is interesting to observe that the point estimate for β varies drastically which, of course, reflects the higher standard error of the estimates itself. When looking into the literature, we find that most of our results yield the same sign, except for the 1-month case for NOK/USD and the 1-month and 3-month case for JPY/USD.

Some examples of results from the literature are as follows. Flood & Rose (2002) have a result for CAD/USD for the 1-month regression, which yielded a β of -0.59. Chinn & Meredith (2004) regression yielded a β of -2.88 for JPY/USD in the 3-month case. Lee (2013) got a β of 0.25 for NOK/USD in the 1-month regression, while Chinn & Quayyum (2012) yielded a β of -2.13 for the CHF/USD 3-month regression. Ismailov & Rossi (2016) regression yielded a β of 0.37 for GBP/USD in the 3-month case. From these examples, we can see that our results are more or less in line with the literature, with some exceptions.

5.3 Investigating the effect of change in the key policy rates on the Unbiasedness Hypothesis

When testing the effect in key policy rates on the unbiasedness hypothesis, two different models are tested: a naive model and a lagged model. The naive model is given by (F.12) from chapter 3:

$$\frac{S_{t+k} - S_t}{S_t} = \alpha + \beta\left(\frac{F_{t,t+k} - S_t}{S_t}\right) + \eta_{\boldsymbol{t+k}} \tag{F.12}$$

And the lagged model is given by (F.13):

$$\frac{S_{t+k} - S_t}{S_t} = \alpha + \beta\left(\frac{F_{t,t+k} - S_t}{S_t}\right) + \frac{S_{t+k-1} - S_{t-1}}{S_{t-1}} + \eta_{\boldsymbol{t+k}} \tag{F.13}$$

The null hypotheses for all models are: $\alpha = 0 \; and \; \beta = 1$.

In this subchapter, we investigate the main research question of this thesis. That is, by removing the dates around central banks make changes in the policy rates, whether the regression results will be more in line with the unbiasedness hypothesis. We start by running the naive model on the dataset without removing any days, which will be our reference sample before we start removing the days from the dataset. The variations consist of removing a single day, removing an interval of three and seven days. The three-day interval consists of removing one day before the change in the key policy rate, the day of change, and one day after the change. The seven-day interval consists of removing three days before the change in the key policy rate, the day of change, and three days after the change. Lastly, we run the lagged model with all the same variations as in the naive model. In total, we run two tests for each variation of removed days, and maturity.

To address our research question, we have to be able to remove days as mentioned above, and thus we use the variables defined in chapter 4.5. Using daily observations gives us an enormous dataset compared to using monthly or quarterly observations. If we were to remove a whole month or quarter for each change the key policy rate, our dataset would be too small to test the unbiasedness hypothesis. We also discovered that leaping each twenty-second day (monthly) or each sixty-sixth day (quarterly) will yield different regression results based on the starting date of the dataset[2].

However, one main drawback is that by using daily observations to calculate the forward return and spot FX rate change, there will be substantial overlapping in the period covered between consecutive observations of forward return and spot FX rate change. For example, the 1-month forward return from 1/1/2002 to 1/2/2002 and the 1-month forward return from 2/1/2002 to 2/2/2002 have the days from 2/1/2002 to 1/2/2002 overlapping. Hence, the forward return and spot FX rate change using daily observations are not entirely independent, and thus there exists a serial correlation problem. The serial correlation issue is also why we include the lagged model (F.13).

[2] By replicating the Ånnestad & Valdstadsve (2016) study, we found that starting the dataset on 31.12.1999 instead of 03.01.2000 yield strikingly different β for all included currency pairs.

When controlling for the econometric issues like heteroskedasticity and serial correlation, a series of tests are conducted[3]. To check whether heteroskedasticity is present in the data we use the Breusch-Pagan test. For serial correlation in the naive model, we use the Durbin-Watson test, while in the lagged model we use the Breusch-Godfrey test. Lastly, we argue that stationarity is not present based on our explanation from 3.2: one solution for non-stationary data is to take the first difference, which is precisely how our model is postulated.

When comparing our results against literature, the following papers are used: Baillie & Kilic (2005), Chinn & Meredith (2004), Chinn & Quayyum (2012), Dale & Ulvund (2018), Flood & Roose (2002), Håland (2003), Ismailov & Rossi (2016), Lee (2013) and Ånnestad & Valstadsve (2016). The codes in the tables mean the following: 1m is the 1-month maturity and the 3m is the 3-month maturity. 0d, 1d, 3d, and 7d means zero, one, three and seven days have been removed when the key policy rate changes.

5.3.1 CAD/USD

Table 3: Regression results 1-month CAD/USD without lags

CAD/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
1m	-0.0008 (-0.286)	**0.0791***** (-5.154)	0.1787	-0.0001
1m, 1d	-0.0007 (-0.263)	**0.0586***** (-5.175)	0.1819	0.0002
1m, 3d	-0.0006 (-0.224)	**0.0775***** (-4.645)	0.1986	-0.0002
1m, 7d	-0.0004 (-0.133)	**0.0126***** (0.053)	0.2382	-0.0004

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

[3] Tests results for each currency pair can be found in Appendix A.4.1 to A.4.6.

Table 4: Regression results 1-month CAD/USD with one lag

CAD/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
1m, 1 lag	-0.0004(-2.927)	**0.9177** (-1.301)	0.06322	0.9096
1m, 1d, 1 lag	-0.0004(-2.754)	**0.9053** (-1.615)	0.0586616	0.9101
1m, 3d, 1 lag	-0.0004(-2.834)	**0.9091** (-1.405)	0.06467	0.9123
1m, 7d, 1 lag	-0.0004(-2.648)	**0.8718*** (-2.468)	0.05195	0.9147

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 5: Regression results 3-month CAD/USD without lags

CAD/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
3m	-0.0026 (-0.311)	**0.6693** (-0.583)	0.5674	0.002668
3m, 1d	-0.0024 (-0.286)	**0.6710** (-0.564)	0.5831	0.002631
3m, 3d	-0.0020 (-0.248)	**0.7048** (-0.495)	0.5964	0.002834
3m, 7d	-0.0012 (-0.129)	**0.6656** (-0.533)	0.6278	0.00236

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 6: Regression results 3-month CAD/USD with one lag

CAD/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
3m, 1 lag	-0.0006(-3.603)	**0.67299***** (-6.361)	0.05141	0.97
3m, 1d, 1 lag	-0.0006(-3.409)	**0.6699***** (-6.519)	0.05065	0.9702
3m, 3d, 1 lag	-0.0006(-3.397)	**0.6624***** (-6.591)	0.05122	0.9709
3m, 7d, 1 lag	-0.0006(-3.475)	**0.6523***** (-6.526)	0.0533	0.9717

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

As we can see from the results, the 3-month regression result deviates from the unbiasedness hypothesis significantly less than the 1-month case. The CAD/USD regression results show very little difference in models with 0, 1, 3 or 7 days removed. On the other hand, the CAD/USD results are significantly different from the results in chapter 5.2. The 1-month now yields β close to 0, which is very different from the $\beta = -0.6$ in chapter 5.2, while the 3-

month yield β close to 0.7. This is also strikingly different from most empirical literature. Nevertheless, the α values are close to 0 for all currency pairs in chapter 5.3.

For the CAD/USD, we see that removing the days that central banks change the key policy rate does not lead to a significant change in the regression results. The β changes by less than 0.1 in the 1-month and 3-month case for both the naive and lagged model. The lagged model helps correcting for the serial correlation issue for all currency pairs in chapter 5.3, but it does not have an impact on the results when removing the days.

When testing the lagged model, the β value for the 1-month case change considerably and are now more in line with the unbiasedness hypothesis. However, the lagged model only gives minor changes in the result for the 3-month cases. The lagged model gives us results which are substantially different from most literature except Lothian (2016), which uses ultra-long time series and get a $\beta = 0.9$ for CAD/USD.

5.3.2 EUR/USD

Table 7: Regression results 1-month EUR/USD without lags

EUR/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2 adj**
1m	-0.0010 (-0.297)	**-0.0668***** (-4.584)	0.2327	-0.0002
1m, 1d	-0.0010 (-0.308)	**-0.0955***** (-4.651)	0.2355	-0.0001
1m, 3d	-0.0010 (-0.309)	**-0.0979***** (-4.585)	0.2394	-0.0001
1m, 7d	-0.0010 (-0.293)	**-0.1598***** (-4.302)	0.2696	0.0003

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 8: Regression results 1-month EUR/USD with one lag

EUR/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2 adj**
1m, 1 lag	0.0000 (0.046)	**0.8843*** (-2.409)	0.0480	0.9212
1m, 1d, 1 lag	0.0000 (0.137)	**0.8921*** (-2.246)	0.0480	0.9216
1m, 3d, 1 lag	0.0000 (0.0070)	**0.8977*** (-2.043)	0.0500	0.9223
1m, 7d, 1 lag	-0.0000 (-0.016)	**0.8777*** (-2.237)	0.0547	0.924

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 9: Regression results 3-month EUR/USD without lags

EUR/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2 adj**
3m	-0.0029 (-0.275)	**0.1243** (-0.804)	1.0893	-0.0001
3m, 1d	-0.0028 (-0.267)	**0.1130** (-0.812)	1.092	-0.0002
3m, 3d	-0.0026 (-0.242)	**0.1200** (-0.774)	1.137	-0.0002
3m, 7d	-0.0021 (-0.192)	**0.1124** (-0.747)	1.1878	-0.0002

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 10: Regression results 3-month EUR/USD with one lag

EUR/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2 adj**
3m, 1 lag	0.0003 (1.683)	**0.5333***** (-10.92)	0.0428	0.9727
3m, 1d, 1 lag	0.0002 (1.463)	**0.5379***** (-10.05)	0.0460	0.9727
3m, 3d, 1 lag	0.0002 (1.445)	**0.5381***** (-10.31)	0.0448	0.9729
3m, 7d, 1 lag	0.0003 (1.611)	**0.5113***** (-11.2)	0.0436	0.9734

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

The results for EUR/USD resemble the CAD/USD results in the way that the 3-month case is closer to the unbiasedness hypothesis than the 1-month case. The 1-month regression results show that β is different from 1 at a significance level of 0 for the naive models and β is different from 1 at a significance level of 0.01 for the lagged models. The 3-month regression, on the other hand, shows that β is not significantly different from 1 for the naive models. However, the results show β significantly different from 1 for the lagged models even though β values are close to 1. In general, the EUR/USD regressions show little evidence that the unbiasedness hypothesis holds.

For both the naive and lagged models, we see that the β does not change significantly. The changes in β for all regressions are less than 0.1 when removing 0, 1, 3 or 7 days. It means, as mentioned in the CAD/USD case that removing the days that central banks change the key policy rate does not impact our regression results.

When comparing the results to 5.2, we see that our regression yields completely different results with βvalues much closer to 1. Our results also to some extent differ from empirical literature results such as Flood & Rose (2002) and Lee (2013). Flood & Rose got a β of 0.13 for the 1-month regression, and -0.11 for the 3-month regression (for DEM/USD), while Lee got a β of -0.55 for the 1-month regression, and -0.47 for the 3-month regression.

5.3.3 JPY/USD

Table 11: Regression results 1-month JPY/USD without lags

JPY/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2 adj**
1m	-0.0001 (-0.037)	**0.2048***** (-3.599)	0.2210	0.0003
1m, 1d	-0.0001 (-0.030)	**0.1841***** (-3.631)	0.2247	0.0002
1m, 3d	-0.0000 (-0.004)	**0.1852***** (-3.614)	0.2255	0.0002
1m, 7d	0.0001 (0.046)	**0.1987***** (-3.495)	0.2293	0.0002

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 12: Regression results 1-month JPY/USD with one lag

JPY/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2 adj**
1m, lagged	0.0010 (6.467)	**0.7201***** (-4.93)	0.0568	0.9101
1m, 1d, lagged	0.0010 (6.514)	**0.7125***** (-5.267)	0.0546	0.9107
1m, 3d, lagged	0.0010 (6.399)	**0.7037***** (-5.292)	0.0560	0.9114
1m, 7d, lagged	0.0010 (5.541)	**0.6708***** (-5.943)	0.0554	0.9124

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 13: Regression results 3-month JPY/USD without lags

JPY/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2 adj**
3m	0.0021 (0.196)	**0.8131** (-0.298)	0.6272	0.0053
3m, 1d	0.0022 (0.203)	**0.8214** (-0.285)	0.6271	0.0054
3m, 3d	0.0023 (0.281)	**0.8464** (-0.243)	0.6327	0.0056
3m, 7d	0.0026 (0.237)	**0.8992** (-0.157)	0.6406	0.0061

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 14: Regression results 3-month JPY/USD with one lag

JPY/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2 adj**
3m, lagged	0.0013 (6.670)	**0.3187***** (-19.96)	0.0341	0.9714
3m, 1d, lagged	0.0013 (6.580)	**0.3230***** (-19.54)	0.0365	0.9714
3m, 3d, lagged	0.0013 (6.398)	**0.3217***** (-18.83)	0.0360	0.9714
3m, 7d, lagged	0.0012 (6.240)	**0.3096***** (-19.25)	0.0359	0.9716

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

For the naive model, all β for the 1-month regressions are significantly different from 1, while the β for the 3-month case is not significantly different from 1, in the naive model. For the lagged model, the β for both the 1-month and 3-month cases are significantly different from 1.

Compared to the two currency pairs above, the results from JPY/USD also yield a β closer to 1 for the 3-month regression. Moreover, the lagged model in the 3-month case yields a β less in favor of the unbiasedness hypothesis, which is opposite to the case for other currency pairs. Removing the days of changes in the key policy rate does not make any significant changes to the regression results for JPY/USD.

For the JPY/USD, we see that removing the key policy rate changing days do not yield significant changes in β values for both the naive or the lagged model. The changes in β from removing 0, 1, 3 and 7 days are less than 0.1 for all JPY/USD tests.

It can be seen that the results have the same sign and the β resembles the results from 5.2, especially for the 1-month regression. Nevertheless, our results are quite far from the literature. Lee (2013) got a β of -2.8 and -3 for the 1-month case and 3-month case. On the other hand, Dale & Ulvund (2018) got a β of 0.5 when regressing on the overnight forward rates, which is parallel to our way of defining variables in chapter 4.5

5.3.4 NOK/USD

Table 15: Regression results 1-month NOK/USD without lags

NOK/USD	Alpha (t-value)	Beta (t-value)	Std.error (β)	R^2
1m	0.0002 (0.080)	**-0.1352***** (-4.882)	0.2325	0.0000
1m, 1d	0.0003 (0.089)	**-0.1556***** (-4.957)	0.2331	0.0001
1m, 3d	0.0003 (0.108)	**-0.1877***** (-5.058)	0.2348	0.0002
1m, 7d	0.0005 (0.169)	**-0.2315***** (-4.710)	0.2615	0.0004

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 16: Regression results 1-month NOK/USD with one lag

NOK/USD	Alpha (t-value)	Beta (t-value)	Std.error (β)	R^2
1m, lagged	-0.0007 (-3.939)	**0.7553***** (-3.937)	0.06215	0.905
1m, 1d, lagged	-0.0007 (-3.882)	**0.7597***** (-3.729)	0.06443	0.9053
1m, 3d, lagged	-0.0007 (-3.834)	**0.7645***** (-3.496)	0.06737	0.9062
1m, 7d, lagged	-0.0006 (-3.218)	**0.6985***** (-5.074)	0.05942	0.9071

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 17: Regression results 3-month NOK/USD without lags

NOK/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
3m	-0.0001 (-0.010)	**0.3444** (-0.595)	1.1010	0.0008
3m, 1d	-0.0000 (-0.002)	**0.3751** (-0.560)	1.1162	0.0009565
3m, 3d	0.0004 (0.039)	**0.3500** (-0.555)	1.1705	0.0007557
3m, 7d	0.0011 (0.111)	**0.3125** (-0.544)	1.2644	0.0004821

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 18: Regression results 3-month NOK/USD with one lag

NOK/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
3m, lagged	-0.0011 (-3.656)	**0.4532***** (-7.522)	0.07269	0.9701
3m, 1d, lagged	-0.0012 (-3.667)	**0.4555***** (-7.259)	0.07501	0.9703
3m, 3d, lagged	-0.0012 (-3.549)	**0.4540***** (-6.949)	0.07857	0.9709
3m, 7d, lagged	-0.0010 (-3.38)	**0.4119***** (-8.837)	0.06655	0.9724

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Like previous currency pairs, the β for the 1-month case is significantly different from 1 for both the naive and lagged model, while the β for the 3-month case is significantly different from 1 only for the lagged model. However, the 1-month β in the lagged models are above 0.7 and close to 1, while the 3-month β in the lagged models are above 0.4.

It can be seen that when removing days from the dataset, the changes in the regression results are not significant. Removing seven days in the 1-month case yields a maximum change in β of only 0.1 when comparing to the results without removing any days.

The interpretation from the NOK/USD results is similar to earlier currency pairs. Removing the key policy rate changing days does not yield a significant change in the β values. As for the other currency pairs, removing the days for NOK/USD leads to changes in β that are less than 0.1.

The 1-month regressions yield negative β for the naive model, which is the opposite of what literature as Flood & Rose (2002) and Lee (2013) reports. They get a β of 0.6 and 0.3 for the

1-month maturity. On the other hand, Dale & Ulvund (2018) paper got a β of -1.4 for the same maturity. The same relationship is present for the 3-month case. Our results for the 3-month regression have the opposite sign compared to literature such as Lee (2013), which get a β of -0.3. The difference to the literature can also be seen when comparing these results to the results in chapter 5.2. While the 3-month result is not too far off, the 1-month result is significantly different.

5.3.5 CHF/USD

Table 19: Regression results 1-month CHF/USD without lags

CHF/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
1m	-0.0023 (-0.739)	**-0.1389***** (-5.336)	0.2134	-0.0000
1m, 1d	-0.0023 (-0.715)	**-0.1339***** (-5.219)	0.2172	-0.0000
1m, 3d	-0.0024 (-0.808)	**-0.2198***** (-4.939)	0.2470	0.0003
1m, 7d	-0.0026 (-0.974)	**-0.4508***** (-5.709)	0.2541	0.0018

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 20: Regression results 1-month CHF/USD with one lag

CHF/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
1m, lagged	0.0009 (4.059)	**1.0334** (0.231)	0.1443	0.9092
1m, 1d, lagged	0.0009 (4.059)	**1.0341** (0.232)	0.1466	0.909
1m, 3d, lagged	0.0008 (4.597)	**0.9140** (-1.398)	0.06156	0.9148
1m, 7d, lagged	0.0008 (4.286)	**0.8496**** (-2.799)	0.05373	0.9196

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 21: Regression results 3-month CHF/USD without lags

CHF/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
3m	-0.0069 (-0.821)	**0.0282 .** (-1.673)	0.5810	-0.0002256
3m, 1d	-0.0069 (-0.821)	**0.0310 .** (-1.701)	0.5670	-0.0002275
3m, 3d	-0.0069 (-0.817)	**-0.0092** (-1.584)	0.6371	-0.0002404
3m, 7d	-0.0074 (-0.914)	**-0.1949 .** (-1.917)	0.6232	0.0000

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 22: Regression results 3-month CHF/USD with one lag

CHF/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
3m, lagged	0.0021 (4.847)	**0.6725**** (-2.926)	0.1119	0.9605
3m, 1d, lagged	0.0020 (4.703)	**0.6740**** (-2.825)	0.1154	0.9604
3m, 3d, lagged	0.0017 (6.959)	**0.5750***** (-7.886)	0.05389	0.9626
3m, 7d, lagged	0.0015 (6.511)	**0.5320***** (-10.12)	0.04624	0.963

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

CHF/USD results differ from the other currency pairs when looking at the significance. The results from the naive model give β values significantly different from 1 for both cases, while the lagged model only yield results significantly different than 1 for the 3-month case.

The β values in the naive model are either negative or close to zero and removing more days only make β more negative. The results from the 1-month regression with seven removed days yield strikingly different β compared to not removing any days. The β from removing seven days and not removing any days differs with 0.3, which is the most significant difference for all our regressions. Nevertheless, when removing days for the lagged model in the 1-month case, the β changes by only 0.18. When we investigate the 3-month case for the naive and lagged models, we see that β changes by respectively 0.17 and 0.14. These β values have the largest differences we find when removing the key policy rate changing days among all currency pairs.

The results for CHF/USD also differ considerably from the results in 5.2, as well as from empirical literature. However, the β for CHF/USD has the same sign as in the literature. One example is Baillie & Killic (2005) who got a β of -1.4 for the 1-month maturity, while Ismailov & Rossi (2016) got a β of -0.6 for the 3-month maturity. On the other hand, Lothian (2016) get a β of 0.5 for CHF/USD while using ultra long maturity. For the lagged model we see that the β changes considerably toward that the unbiasedness hypothesis holds, which is the same result as we have seen in the above currency pairs.

5.3.6 GBP/USD

Table 23: Regression results 1-month GBP/USD without lags

GBP/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
1m	0.0010 (0.320)	**-0.1913***** (-3.806)	0.3130	0.0002
1m, 1d	0.0009 (0.300)	**-0.2067***** (-3.969)	0.3041	0.0002
1m, 3d	0.0008 (0.258)	**-0.2179***** (-3.923)	0.3104	0.0003
1m, 7d	0.0005 (0.189)	**-0.2183*** (**-3.941)	0.3091	0.0002

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 24: Regression results 1-month GBP/USD with one lag

GBP/USD	**Alpha (t-value)**	**Beta (t-value)**	**Std.error (β)**	**R^2**
1m, lagged	-0.0005 (-3.402)	**0.6954***** (-6.408)	0.04754	0.915
1m, 1d, lagged	-0.0005 (-3.199)	**0.6954***** (-6.53)	0.0467	0.9153
1m, 3d, lagged	-0.0005 (-3.218)	**0.6881***** (-6.466)	0.04824	0.9145
1m, 7d, lagged	-0.0005 (-3.225)	**0.6969***** (-5.951)	0.0509	0.9147

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 25: Regression results 3-month GBP/USD without lags

GBP/USD	Alpha (t-value)	Beta (t-value)	Std.error (β)	R^2
3m	0.0024 (0.305)	**0.1160** (-0.824)	1.0726	-0.0001436
3m, 1d	0.0024 (0.300)	**0.1110** (-0.825)	1.0778	-0.0001535
3m, 3d	0.0023 (0.286)	**0.0993** (-0.805)	1.1191	-0.0001748
3m, 7d	0.0021 (0.261)	**0.0575** (-0.797)	1.1824	-0.0002254

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

Table 26: Regression results 3-month GBP/USD with one lag

GBP/USD	Alpha (t-value)	Beta (t-value)	Std.error (β)	R^2
3m, lagged	-0.0007 (-3.666)	**0.3910***** (-11.06)	0.05508	0.972
3m, 1d, lagged	-0.0007 (-3.566)	**0.3974***** (-10.03)	0.06007	0.972
3m, 3d, lagged	-0.0007 (-3.433)	**0.3893***** (-10.11)	0.06039	0.9722
3m, 7d, lagged	-0.0006 (-2.906)	**0.3865***** (-8.913)	0.06883	0.9727

Signif. codes: 0 (***) | 0.001 (**) | 0.01 (*) | 0.05 (.) | 0.1 ()

For the naive model, both 1-month and 3-month regressions yield β values close to 0. The β for the 1-month case is significantly different from 1 in both models, while β for the naive model in the 3-month case is not.

As for all other currency pairs except CHF/USD, removing the key policy rate changing days yield insignificantly different β. The change is less than 0.1 for all GBP/USD regressions.

Compared to 5.2, the results are quite similar, but the β in the 3-month case changed from negative in 5.2, to positive in this test. The results in this test differ from the literature. Especially the lagged model provides different β values. When comparing the results from the lagged model to other papers as Dale & Ulvund (2018) who get a positive β of 0.3 for the 1-month regression, and Ismailov & Rossi (2016) who finds a β of 0.4 for the 3-month regression, we see that the results for the lagged version are not too far away. On the other hand, literature such as Flood & Rose (2002) and Lee (2013) find β which is below -1 for both maturities.

5.4 Summary of regression results

The Breusch-Pagan tests unveil that we have issues with heteroskedasticity in our regression, and we implemented Newey-West estimators to correct for the heteroskedasticity issue. Moreover, the Durbin-Watson test confirms that we have substantial issues with serial correlation, just as expected. In order to remove the effect of serial correlation on the slope coefficient of forward return, we conducted regressions with the lagged dependent variable (spot FX rate change) as extra regressors. The regressions with lags show significantly different β values, as well as standard errors and R^2. The Breusch-Godfrey test tells us that adding the first lag of dependent variable correct for serial correlation at a 5% level for most currency pairs for both 1-month and 3-month cases.

From our regression, results we see that removing days only had some impact for the CHF/USD coefficient. For CHF/USD, when removing seven days, the slope coefficient β of the regression changed by 0.31 for the 1-month maturity and 0.17 for the 3-month maturity. All other currency pairs had changes in their coefficient by less than 0.1, and thus there is no significant impact on the unbiasedness hypothesis. After controlling for the lagged model, we see that the slope coefficient of forward return is close to one, but removing days in the lagged model yield insignificant changes to the slope coefficient for all currency pairs. The most significant difference from removing days is, as in the naive model, the 1-month case for CHF/USD with a change of 0.184.

Why removing days around changes in the key policy rate does not lead to significantly different regression results for most currencies can be explained by the arguments below.

The financial market is highly efficient. Central banks usually have fixed schedule to announce their monetary policies. In these announcements, central banks would inform the market about any changes in the key policy rate, as well as other relevant financial information. Some central banks may also give predictions of future key policy rates. The market well knows all this information, so the effect of a change in key policy rate might be digested by the market long before the central banks make these announcements.

Nevertheless, if our dataset is based on a shorter time frame, then an unanticipated change in the key policy rate could lead to more extensive changes in the FX rates and thereby change the coefficient. Under a longer time frame, the effect of changes in key policy on foreign exchange market is smaller. A longer time frame makes the data less prone to surprises, like the financial crisis in 2007, as described by Chinn & Meredith (2004, pp 427-428).

We also want to make a note of how the starting date of the data can impact the results. When the dataset is considerably large, as when using daily observations, shifting the starting date does not lead to significant changes in the regression results. Whereas, regressions using only one observation per month or quarter yield significantly different regression results when shifting the starting date by as little as one day.

6. Conclusion

The research question for this thesis is whether removing days when central banks change their key policy rates would make the regression results more in line with the unbiasedness hypothesis. By conducting regression tests, we have identified that removing the days of a change in key policy rate from the dataset does not lead to significant changes in the slope coefficient of forward return. Hence, we conclude that removing the days of a change in key policy rate does not affect the validity of the unbiasedness hypothesis significantly. On the other hand, we find that using daily observations of 1-month and 3-month maturities forward return data yield regression results significantly more in line with the unbiasedness hypothesis, compared to the existing literature.

As we anticipated before starting on the empirical analysis, some econometric issues would arise due to our variable definitions. We tried to control the potential econometric problems by adding lagged dependent variables. More sophisticated econometric methods might be applied to address the potential econometric problems totally, but it is beyond the scope of this thesis. We recognize that a more in-depth study can be done to address the research question of this thesis by adding more variables or applying more advanced econometric techniques. This thesis provides a good starting point for discussion and further research.

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8. Appendix

A.1 Econometrics

In order to do OLS regression on time series data instead of cross-sectional data, the assumptions must be altered. The data used in this thesis needs to fulfill five assumptions in order for the ordinary least squares (OLS) method to give us the best possible estimates. Then the OLS estimators $\hat{\alpha}$and $\hat{\beta}$and are the Best Linear Unbiased Estimators (BLUE) of $\alpha$and β. BLUE means that the OLS estimators of α and β have the lowest possible variance and are both linear and unbiased. Since the data is time series data, the time series assumptions from Wooldridge (Wooldridge, 2016, pp 312-322) are used. The assumptions are used to ensure that the parameter estimates from the linear regression are valid.

The Classical Linear Model (CLM) Assumptions for time series regression are:

1. **Linear in Parameter.**

The first assumption, Linear in Parameters implies that the regression only consists of linear parameters and it can be shown as the following:

$$y_t = \alpha + \beta x_t + \eta_t$$

The way the UIP regression (F.13) was formed in subchapter 3.2 complies with the criteria set in the linear in parameter assumption here.

2. **No Perfect Collinearity**

Perfect collinearity occurs when two or more predictors are perfectly correlated with each other, which means that it is possible without error to predict one predictor from some combination of the others. An important note for the collinearity assumption is that it allows explanatory variables to be correlated but perfect correlation in the sample is ruled out. In the sample (and therefore in the underlying time series process), no independent variable is constant nor a perfect linear combination of the others.

3. **Zero Conditional Mean**

The Zero Conditional Mean assumption says that for each t, the expected value of the error U_t, given the explanatory variables for all time periods, is zero. The zero conditional mean can be shown mathematically as:

$$E(U_t|\boldsymbol{X}) = 0,\ t\ =\ 1,2,\ldots,n$$

The zero conditional mean assumption is a crucial assumption and implies that the error at time t, U_t, is uncorrelated with each explanatory variable in every time period. Omitted variable bias is often a large cause of violation of the zero conditional mean assumptions. Omitted variable bias occurs when a statistical model leaves out one or more relevant variables. The bias results in the model attributing are the effect of the missing variables to the estimated effects of the included variables.

4. **Homoskedasticity:** $\boldsymbol{Var(u_t|X) = Var(u_t) = \sigma^2, t = 1, 2, \ldots, n}$

Homoskedasticity translates to the variance of the error term must be constant no matter what values of the regressors are. Homoskedasticity means that the model's precision is not dependent on the regressors value. It is said that if the assumptions do not hold, the errors are heteroscedastic. One way to illustrate homoskedasticity is to use a scatter plot with different observations noted over time. To ensure that the variance is constant over time, the distance between the different observations and the average must not increase or decrease over time. Heteroscedasticity, on the other hand, reduces the precision of the estimates in OLS linear regression. The OLS estimators and regression predictions based on the estimators remain unbiased and consistent. The OLS estimators are no longer the BLUE (Best Linear Unbiased Estimators) because they are no longer efficient so that the regression predictions will be inefficient too. Because of heteroscedasticity, the tests of hypotheses, (T-test, F-test) are no longer valid. To decide whether uneven an variance is a problem in the dataset, the Breusch-Pagan test is used (Wooldridge, 2016, pp 392). If heteroskedasticity is a problem, Newey-West estimators are used to correcting for the heteroskedasticity problem. The Breusch-Pagan (BP) test shows BP statistics and p-values. If the BP statistics has a P-value below a given threshold (e.g., $P < 0.05$) then the null hypothesis of homoscedasticity is rejected, and heteroskedasticity exists. To correct for heteroskedasticity, Newey-West estimator is used in the empirical analysis.

5. **No Serial Correlation:** $\boldsymbol{Corr(u_t, u_s|X) = 0\ for\ all\ t \neq\ s}$

The last assumption, no serial correlation, translates to the degree of correlation between time series data and a lagged version of the time series data over consecutive time intervals. Serial correlation is a typical issue with time series data. Some potential explanations of serial correlation are:

- Delayed response on a change in variables based on habits, cyclical or expectations.
- Wrong functional form.
- Effects from shocks not included in the model that can last over multiple periods.
- Seasonality smoothing

Violation of the no serial correlation assumption can make the usual statistical inference unreliable. In the empirical analysis, we run the Durbin-Watson test for serial correlation on the naive model and the Breusch-Godfrey test for the lagged model. The Breusch-Godfrey test used for the lagged model since it allows for lagged dependent variables as well as other regressors that are not strictly exogenous (Wooldridge, 2016, pp 757). If the Durbin-Watson test shows that we have problems with serial correlation, then we can add lags to fulfill the no serial correlation condition (Wooldridge, 2012, pp 399-401).

The interpretation of the Durbin-Watson (DW) test statistics is as follows. The hypothesis of the Durbin-Watson test is:

H0: there is no first-order serial correlation.
H1: there exists first order serial correlation.

The Durbin-Watson test statistic has a value range from 0 to 4. If the DW-statistics is equal to 2, then there is no serial correlation. If 0 < DW-statistic < 2, there is positive autocorrelation meaning that positive errors usually follow positive errors, and negative errors usually follow negative errors. Whereas, when 2 < DW-statistic < 4, there is negative autocorrelation meaning that negative errors usually follow positive errors, and positive errors usually follow negative errors.

Breusch-Godfrey (BG) have the following null hypotheses:

H0: No serial correlation

moreover, we can be interpreted as the following: If the P-value for the BG-statistics is below a threshold (e.g., 5%) then we reject the null hypothesis, and serial correlation is present.

In addition to the assumptions, the concepts of stationarity and weakly dependent time series also need to be explained. A stationary time series process is one whose probability distribution is stable over time in the following sense: when taking any collection of random variables in the sequence and then shift that sequence ahead or back by h time periods, the joint probability distribution must remain unchanged. Stationarity has to do with the joint distributions of a process as it moves through time. Weakly dependent time series, on the other hand, places restrictions on how strongly related the random variables can be as the time distance between them gets large. One way to control for stationarity is to take the first difference (Wooldridge, 2016, pp 358).

A.1.2 Asymptotic properties of OLS

Doing time series regression following the Gauss-Markov theorem and its strict assumptions the OLS estimates will be uncertain and erroneous if some of the assumptions are violated. Some violations could even lead to erroneous signs of OLS estimates or make the variance of OLS estimates uncertain, which means too wide or too narrow confidence intervals. The Gauss-Markov assumptions are stringent assumptions which rarely are all met. The assumptions explain optimal test conditions, but even though the data will not meet all the criteria perfectly, the assumptions are still suitable as a benchmark. In this subchapter, the assumptions (TS) that justify OLS more generally are stated, which is also called asymptotic properties of OLS. (Wooldridge, 2016, pp 348-354). The assumption TS.1 through TS.3 is for consistency, and not unbiasedness, of OLS. When the assumptions TS.4 and TS.5 are added, is it possible to use the usual confidence intervals, t statistics, and F statistics as being approximately valid in large samples.

- Assumption TS.1 (Linearity and weak dependence)

The first assumption is still linearity in the parameters but adding the assumption that $\{(x_t, y_t) : t = 1, 2, ...\}$ is stationary and weakly dependent. In particular, the law of large numbers and the central limit theorem can be applied to sample averages (Wooldridge, 2016, pp 348).

- Assumption TS.2 (No perfect collinearity)

The second assumption, no perfect collinearity, is the same as in the CLM case.

- Assumption TS.3 (Zero conditional mean)

The third assumption is the zero conditional mean. However, in this case, only the explanatory variables x_t = (x_{t1},x_{t2}, ..., x_{tk}) to be contemporaneously exogenous as : E($u_t|\boldsymbol{x_t}$) = 0. Assumption TS.3 is much weaker than the third assumption in the CLM case because it puts no restrictions on how u_t is related to the explanatory variables in other time periods (Wooldridge, 2016, pp 349).

Under the assumptions TS.1 to TS.3, the OLS estimators are consistent: $plim\ \hat{\beta}_j = \beta_j,\ \ j = 0,1,\ldots,k$. Here the conclusion is that OLS estimators are consistent, but not necessarily unbiased. Second, it is less known why the explanatory variables must be exogenous, but weak dependence is required in the underlying time series. Weak dependence is also crucial in obtaining approximate distributional results (Wooldridge, 2016, 348-354).

- Assumption TS.4 (Homoskedasticity)

The fourth assumption is homoskedasticity. In the asymptotic case, the errors are contemporaneous homoskedastic, that is, Var$(u_t|\boldsymbol{x_t}) = \sigma^2$. In TS.4 only the explanatory variables at time t are conditioned, whereas, in CLM assumption 4, it requires the variance of the error term to be constant no matter what values of the regressors are for all time periods (Wooldridge, 2016, pp 351).

- Assumption TS.5 (No serial correlation)

The fifth assumption is no serial correlation. For all $t \neq s,\ E(u_t u_s|\boldsymbol{x_t}, \boldsymbol{x_s})\ =\ \boldsymbol{0}$. In TS.5 only the explanatory variables in the time periods coinciding with $u_t\ and\ u_s$ are conditioned (Wooldridge, 2016, pp 351).

By theory, if all the five assumptions hold, the OLS estimators are asymptotically normally distributed. Furthermore, the usual OLS standard errors, t statistics and F statistics are asymptotically valid (Wooldridge, 2016, pp 348-354).

A.2 Econometric results chapter 5.1

Breusch-Pagan test results for replication of CIP

	1-month BP (p-value)	**3-month BP (p-value)**
CAD/USD	0.2437 (0.6216)	1.0309 (0.3099)
EUR/USD	7.2068 (0.0073)	1.5165 (0.2181)
JPY/USD	0.2904 (0.59)	0.3385 (0.5607)
NOK/USD	5.5125 (0.0189)	0.9574 (0.3278)
CHF/USD	2.2596 (0.1328)	2.1318 (0.1443)
GBP/USD	1.2169 (0.27)	0.0220 (0.8821)

Durbin-Watson test results for replication of CIP

	1-month DW (p-value)	**3-month DW (p-value)**
CAD/USD	1.8464 (0.1227)	1.6001 (0.0377)
EUR/USD	1.9727 (0.2914)	2.1688 (0.7163)
JPY/USD	2.1121 (0.766)	2.2014 (0.7599)
NOK/USD	1.9998 (0.4711)	1.928 (0.3376)
CHF/USD	2.0859 (0.7052)	2.0838 (0.5879)
GBP/USD	1.7072 (0.0157)	1.9085 (0.3091)

A.3 Econometric results chapter 5.2

Breusch-Pagan test results for replication of the Unbiasedness Hypothesis

	1-month BP (p-value)	3-month BP (p-value)
CAD/USD	0.0038 (0.9511)	0.0332 (0.8554)
EUR/USD	7.1246 (0.0076)	2.8612 (0.0907)
JPY/USD	0.0287 (0.8655)	0.2472 (0.6191)
NOK/USD	8.789 (0.00303)	1.4171 (0.2339)
CHF/USD	0.32629 (0.5679)	0.41442 (0.5197)
GBP/USD	2.7282 (0.0986)	6.5116 (0.0107)

Durbin-Watson test results for replication of the Unbiasedness Hypothesis

	1-month DW (p-value)	3-month DW (p-value)
CAD/USD	2.0365 (0.5991)	1.8604 (0.2699)
EUR/USD	1.9502 (0.3576)	1.7163 (0.1087)
JPY/USD	2.0661 (0.6788)	1.9146 (0.3435)
NOK/USD	1.7748 (0.05341)	1.7561 (0.1405)
CHF/USD	2.2501 (0.9618)	2.0069 (0.4902)
GBP/USD	1.7551 (0.03936)	1.6149 (0.0466)

A.4 Econometric results chapter 5.3

A.4.1 CAD/USD

Test for Heteroskedasticity: Breusch-Pagan test results as our UIP regression.

1-month mat.	**Without removing** BP-stat (p-value)	**1 day removed** BP-stat (p-value)	**3 days removed** BP-stat (p-value)	**7 days removed** BP-stat (p-value)
1m without lags	1.3264 (0.2495)	1.3384 (0.2473)	1.6684 (0.1965)	3.6528 (0.0560)
1m with lags	164.73 (0.0000)	161.02 (0.0000)	189.48 (0.0000)	204 (0.0000)
3m without lags	1.4776 (0.2241)	1.8478 (0.174)	1.9953 (0.1578)	1.9495 (0.1626)
3m with lags	166.31 (0.0000)	164.59 (0.0000)	180.43 (0.0000)	180.7 (0.0000)

Test for Serial Correlation in naive model: Durbin-Watson test results.

1-month mat.	**Without removing** DW-stat (p-value)	**1 day removed** DW-stat (p-value)	**3 days removed** DW-stat (p-value)	**7 days removed** DW-stat (p-value)
1m without lags	0.1033 (0.0000)	0.1063 (0.2473)	0.1092 (0.0000)	0.1126 (0.0000)
3m without lags	0.0319 (0.0000)	0.0323 (0.0000)	0.0345 (0.0000)	0.0333 (0.0000)

Test for Serial Correlation in lagged model: Breusch-Godfrey test results.

1-month mat.	**Without removing** BG-stat (p-value)	**1 day removed** BG-stat (p-value)	**3 days removed** BG-stat (p-value)	**7 days removed** BG-stat (p-value)
1m with lags	0.7835 (0.3761)	0.3822 (0.5364)	1.4602 (0.2269)	1.4084 (0.2353)
3m with lags	4.2898 (0.03834)	6.3605 (0.0117)	3.1533 (0.0758)	3.2504 (0.07141)

A.4.2 EUR/USD

Test for Heteroskedasticity: Breusch-Pagan test results as our UIP regression.

1-month mat.	**Without removing** BP-stat (p-value)	**1 day removed** BP-stat (p-value)	**3 days removed** BP-stat (p-value)	**7 days removed** BP-stat (p-value)
1m without lags	9.5699 (0.0020)	10.541 (0.0012)	10.161 (0.0014)	14.004 (0.0002)
1m with lags	80.882 (0.0000)	83.793 (0.0000)	85.441 (0.0000)	79.444 (0.0000)
3m without lags	130.61 (0.0000)	127.41 (0.0000)	127.2 (0.0000)	122.85 (0.0000)
3m with lags	176.67 (0.0000)	177.36 (0.0000)	159.33 (0.0000)	167.25 (0.0000)

Test for Serial Correlation in naive model: Durbin-Watson test results.

1-month mat.	**Without removing** DW-stat (p-value)	**1 day removed** DW-stat (p-value)	**3 days removed** DW-stat (p-value)	**7 days removed** DW-stat (p-value)
1m without lags	0.0911 (0.0000)	0.0936 (0.0000)	0.0980 (0.0014)	0.1098 (0.0002)
3m without lags	0.0285 (0.0000)	0.0289 (0.0000)	0.0291 (0.0000)	0.0304 (0.0000)

Test for Serial Correlation in lagged model: Breusch-Godfrey test results.

1-month mat.	**Without removing** BG-stat (p-value)	**1 day removed** BG-stat (p-value)	**3 days removed** BG-stat (p-value)	**7 days removed** BG-stat (p-value)
1m with lags	2.5457 (0.1106)	2.1004 (0.1473)	3.383 (0.0659)	0.6081 (0.4355)
3m with lags	0.9256 (0.336)	1.3531 (0.2447)	2.3854 (0.1225)	2.0455 (0.1527)

A.4.3 JPY/USD

Test for Heteroskedasticity: Breusch-Pagan test results as our UIP regression.

1-month mat.	**Without removing** BP-stat (p-value)	**1 day removed** BP-stat (p-value)	**3 days removed** BP-stat (p-value)	**7 days removed** BP-stat (p-value)
1m without lags	1.2228 (0.2688)	1.3198 (0.2506)	1.4561 (0.2275)	1.0098 (0.3149)
1m with lags	6.335 (0.042)	6.199 (0.0451)	5.6531 (0.0592)	6.846 (0.03261)
3m without lags	10.652 (0.0011)	9.8554 (0.0017)	9.721 (0.0018)	8.8843 (0.0029)
3m with lags	1.9308 (0.3808)	2.1229 (0.3459)	2.3305 (0.3119)	2.7908 (0.2477)

Test for Serial Correlation in naive model: Durbin-Watson test results.

1-month mat.	**Without removing** DW-stat (p-value)	**1 day removed** DW-stat (p-value)	**3 days removed** DW-stat (p-value)	**7 days removed** DW-stat (p-value)
1m without lags	0.0956 (0.0000)	0.0965 (0.0000)	0.0971 (0.0000)	0.1001 (0.0000)
3m without lags	0.0294 (0.0000)	0.0298 (0.0000)	0.0306 (0.0000)	0.0307 (0.0000)

Test for Serial Correlation in lagged model: Breusch-Godfrey test results.

1-month mat.	**Without removing** BG-stat (p-value)	**1 day removed** BG-stat (p-value)	**3 days removed** BG-stat (p-value)	**7 days removed** BG-stat (p-value)
1m with lags	8.6889 (0.0032)	6.8463 (0.0089)	8.2939 (0.0040)	8.1223 (0.0044)
3m with lags	1.8944 (0.1687)	1.6587 (0.1987)	2.0815 (0.1491)	2.3728 (0.1235)

A.4.4 NOK/USD

Test for Heteroskedasticity: Breusch-Pagan test results as our UIP regression.

1-month mat.	**Without removing** BP-stat (p-value)	**1 day removed** BP-stat (p-value)	**3 days removed** BP-stat (p-value)	**7 days removed** BP-stat (p-value)
1m without lags	5.154 (0.0232)	5.3964 (0.0212)	5.5747 (0.0182)	6.4583 (0.0110)
1m with lags	174.24 (0.0000)	172.81 (0.0000)	175.31 (0.0000)	149.36 (0.0000)
3m without lags	105.19 (0.0000)	106.96 (0.0000)	107.23 (0.0000)	106.17 (0.0000)
3m with lags	299.25 (0.0000)	299.3 (0.0000)	299.6 (0.0000)	325.79 (0.0000)

Test for Serial Correlation in naive model: Durbin-Watson test results.

1-month mat.	**Without removing** DW-stat (p-value)	**1 day removed** DW-stat (p-value)	**3 days removed** DW-stat (p-value)	**7 days removed** DW-stat (p-value)
1m without lags	0.1093 (0.0000)	0.1117 (0.0000)	0.1140 (0.0000)	0.1200 (0.0000)
3m without lags	0.0301 (0.0000)	0.0304 (0.0000)	0.0310 (0.0000)	0.0324 (0.0000)

Test for Serial Correlation in lagged model: Breusch-Godfrey test results.

1-month mat.	**Without removing** BG-stat (p-value)	**1 day removed** BG-stat (p-value)	**3 days removed** BG-stat (p-value)	**7 days removed** BG-stat (p-value)
1m with lags	1.4463 (0.2291)	2.6976 (0.1005)	4.4787 (0.0293)	3.4826 (0.0620)
3m with lags	1.6762 (0.1954)	0.9984 (0.3177)	3.7732 (0.0521)	0.6598 (0.4166)

A.4.5 CHF/USD

Test for Heteroskedasticity: Breusch-Pagan test results as our UIP regression.

1-month mat.	**Without removing** BP-stat (p-value)	**1 day removed** BP-stat (p-value)	**3 days removed** BP-stat (p-value)	**7 days removed** BP-stat (p-value)
1m without lags	8.8769 (0.0029)	9.3287 (0.0023)	5.905 (0.0151)	0.51246 (0.4741)
1m with lags	68.157 (0.0000)	66.986 (0.0000)	30.766 (0.0000)	51.922 (0.0000)
3m without lags	78.174 (0.0000)	75.021 (0.0000)	73.000 (0.0000)	39.588 (0.0000)
3m with lags	111.3 (0.0000)	110.04 (0.0000)	31.836 (0.0000)	21.159 (0.0000)

Test for Serial Correlation in naive model: Durbin-Watson test results.

1-month mat.	**Without removing** DW-stat (p-value)	**1 day removed** DW-stat (p-value)	**3 days removed** DW-stat (p-value)	**7 days removed** DW-stat (p-value)
1m without lags	0.1094 (0.0000)	0.1113 (0.0000)	0.1181 (0.0000)	0.1413 (0.0000)
3m without lags	0.0431 (0.0000)	0.0437 (0.0000)	0.0451(0.0000)	0.0491 (0.0000)

Test for Serial Correlation in lagged model: Breusch-Godfrey test results.

1-month mat.	**Without removing** BG-stat (p-value)	**1 day removed** BG-stat (p-value)	**3 days removed** BG-stat (p-value)	**7 days removed** BG-stat (p-value)
1m with lags	8.5547 (0.0034)	3.737 (0.0532)	5.1383 (0.0234)	1.9164 (0.1663)
3m with lags	3.1526 (0.0758)	0.7463 (0.3876)	0.5739 (0.4487)	0.7955 (0.3724)

A.4.6 GBP/USD

Test for Heteroskedasticity: Breusch-Pagan test results as our UIP regression.

1-month mat.	**Without removing** BP-stat (p-value)	**1 day removed** BP-stat (p-value)	**3 days removed** BP-stat (p-value)	**7 days removed** BP-stat (p-value)
1m without lags	4.5522 (0.0239)	4.6381 (0.0313)	4.6999 (0.0302)	2.4576 (0.117)
1m with lags	116.14 (0.0000)	113.2 (0.0000)	111.31 (0.0000)	85.443 (0.0000)
3m without lags	53.95 (0.0000)	55.285 (0.0000)	56.889 (0.0000)	60.106 (0.0000)
3m with lags	156.5 (0.0000)	153.8 (0.0000)	149.01 (0.0000)	121.75 (0.0000)

Test for Serial Correlation in naive model: Durbin-Watson test results.

1-month mat.	**Without removing** DW-stat (p-value)	**1 day removed** DW-stat (p-value)	**3 days removed** DW-stat (p-value)	**7 days removed** DW-stat (p-value)
1m without lags	0.0955 (0.0000)	0.0961 (0.0000)	0.0976 (0.0000)	0.1045 (0.0000)
3m without lags	0.0288 (0.0000)	0.0291 (0.0000)	0.0296 (0.0000)	0.0305 (0.0000)

Test for Serial Correlation in lagged model: Breusch-Godfrey test results.

1-month mat.	**Without removing** BG-stat (p-value)	**1 day removed** BG-stat (p-value)	**3 days removed** BG-stat (p-value)	**7 days removed** BG-stat (p-value)
1m with lags	30.433 (0.0000)	32.044 (0.0000)	38.44 (0.0000)	28.824 (0.0000)
3m with lags	2.9126 (0.0879)	2.894 (0.0889)	1.1363 (0.2864)	1.8671 (0.1718)

A.5 Table of exchange rates and forward rates

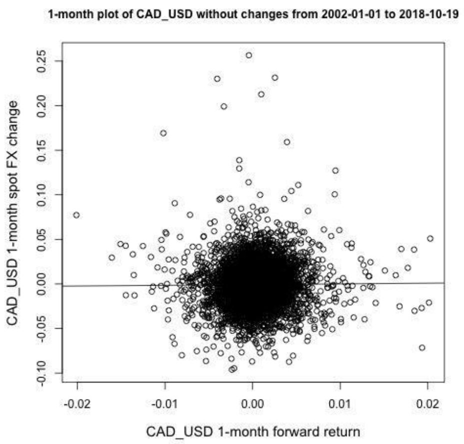
	Spot rates	**1 month Forward**	**3 month Forward**
Canada	USCDNDL	USCAD1F	USCAD3F
EU	USEURO.	EUDOL1F	EUDOL3F
Japan	USJAPYN	USJPY1F	USJPY3F
Norway	USNORGK	USNOK1F	USNOK3F
Switzerland	USSWISF	USCHF1F	USCHF3F
UK	USBRITP	UKUSD1F	UKUSD3F

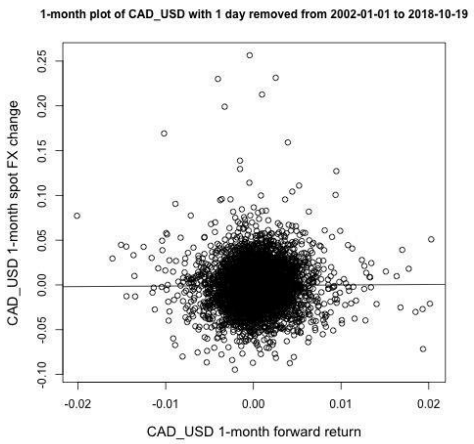
A.6 Table of interest rates

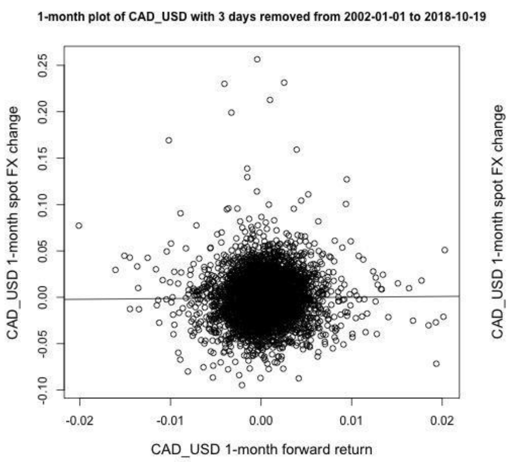
	1 month Interbank	**3 month Interbank**	**Key Policy Rate**
Canada	CIDOR1M	CIDOR3M	CNBCBPR
EU	BBEUR1M	BBEUR3M	EKBCBPR
Japan	BBJPY1M	BBJPY3M	JPCALLT
Norway	NWIBK1M	NWIBK3M	NWBCBPR
Switzerland	BBCHF1M	BBCHF3M	SWBCBPR
UK	BBGBP1M	BBGBP3M	UKBCBPR
US	BBUSD1M	BBUSD3M	USBCBPR

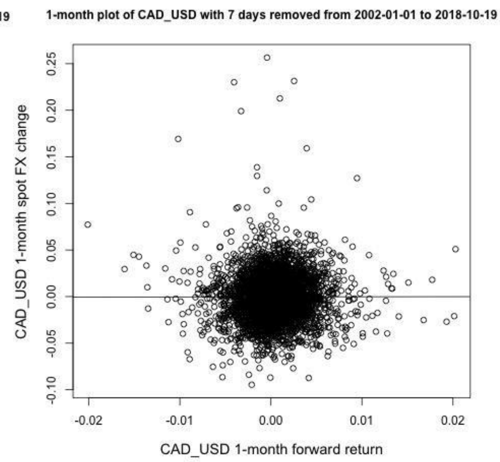
A.7 Plots from chapter 5.3

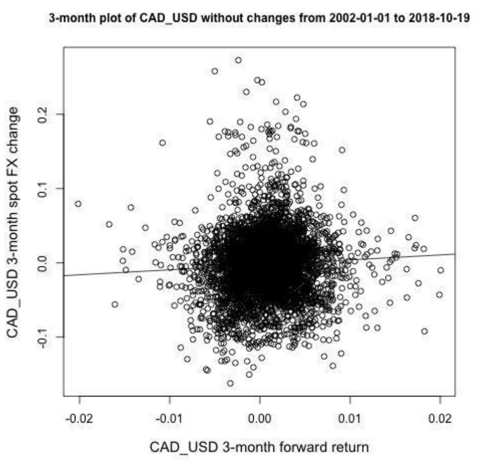
A.7.1 CAD/USD

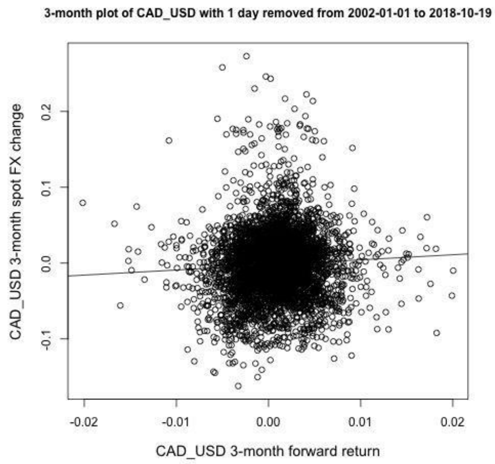


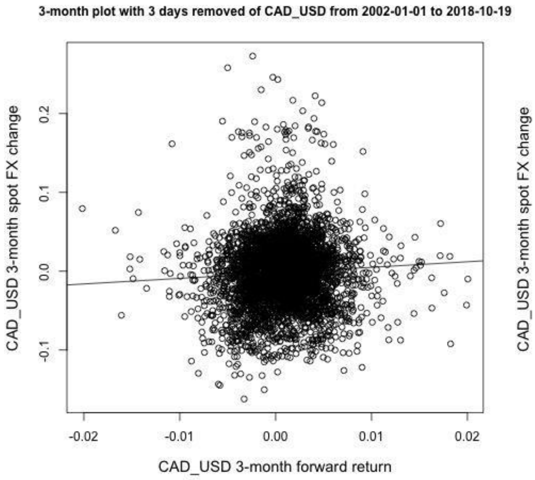


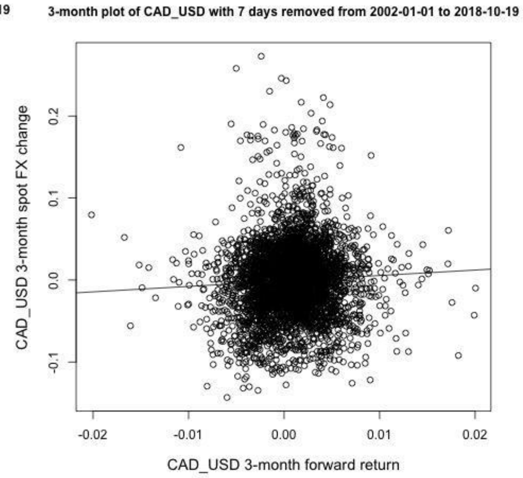




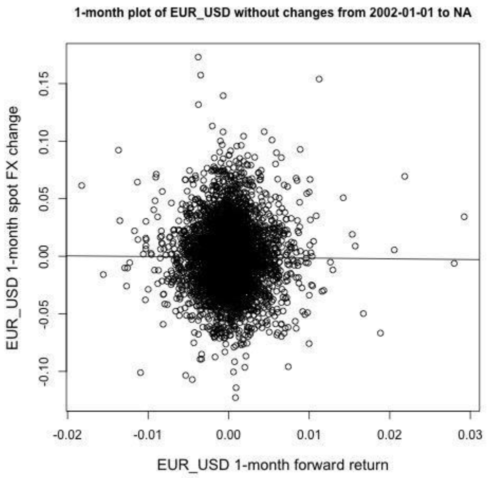


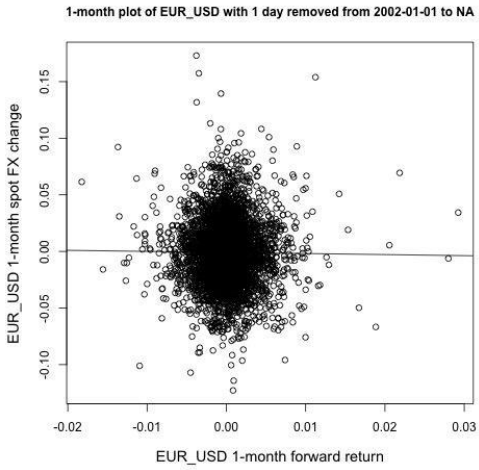


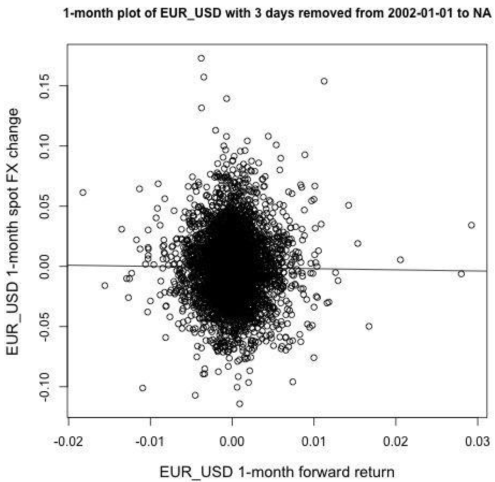

3-month plot with 3 days removed of CAD_USD from 2002-01-01 to 2018-10-19
CAD_USD 3-month spot FX change
CAD_USD 3-month forward return
-0.02 -0.01 0.00 0.01 0.02
-0.1 0.0 0.1 0.2

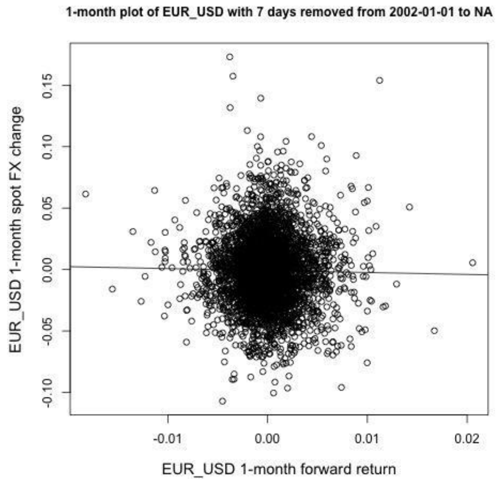

3-month plot of CAD_USD with 7 days removed from 2002-01-01 to 2018-10-19
CAD_USD 3-month spot FX change
CAD_USD 3-month forward return
-0.02 -0.01 0.00 0.01 0.02
-0.1 0.0 0.1 0.2

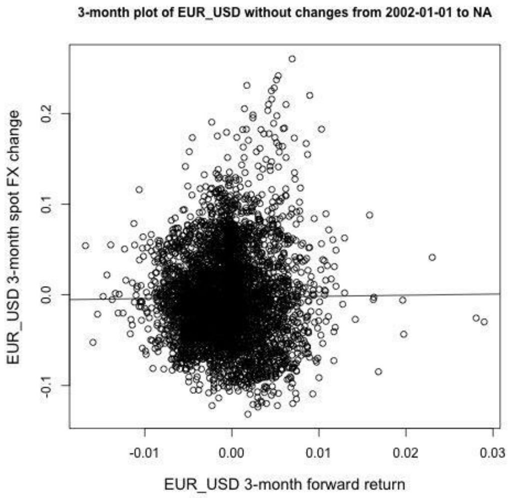
A.7.2 EUR/USD

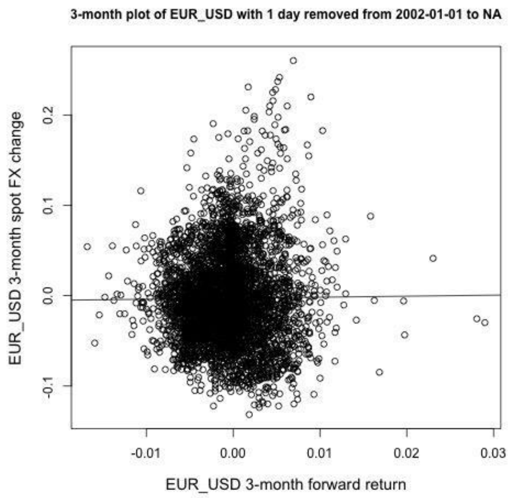

1-month plot of EUR_USD without changes from 2002-01-01 to NA
EUR_USD 1-month spot FX change
EUR_USD 1-month forward return
-0.02 -0.01 0.00 0.01 0.02 0.03
-0.10 -0.05 0.00 0.05 0.10 0.15

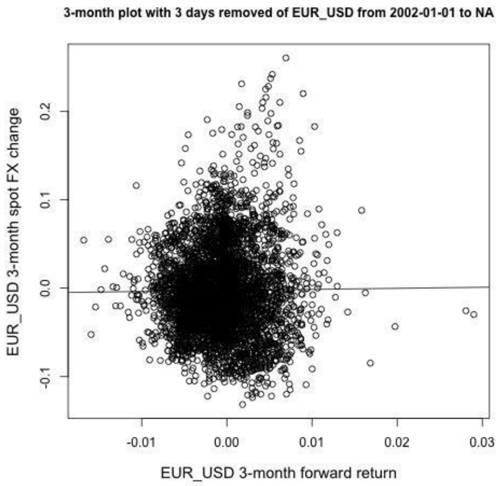

1-month plot of EUR_USD with 1 day removed from 2002-01-01 to NA
EUR_USD 1-month spot FX change
EUR_USD 1-month forward return
-0.02 -0.01 0.00 0.01 0.02 0.03
-0.10 -0.05 0.00 0.05 0.10 0.15

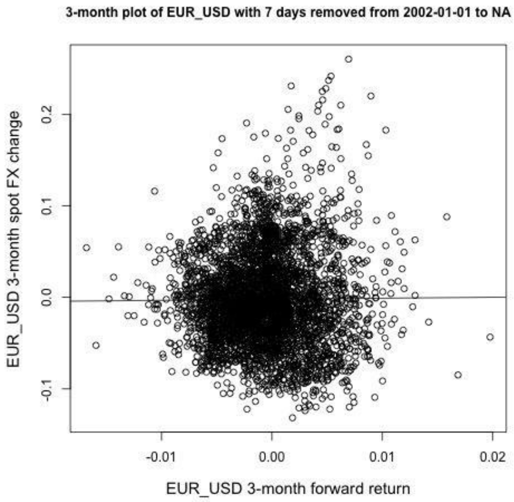

1-month plot of EUR_USD with 3 days removed from 2002-01-01 to NA
EUR_USD 1-month spot FX change
EUR_USD 1-month forward return
-0.02 -0.01 0.00 0.01 0.02 0.03
-0.10 -0.05 0.00 0.05 0.10 0.15


1-month plot of EUR_USD with 7 days removed from 2002-01-01 to NA
EUR_USD 1-month spot FX change
EUR_USD 1-month forward return
-0.01 0.00 0.01 0.02
-0.10 -0.05 0.00 0.05 0.10 0.15

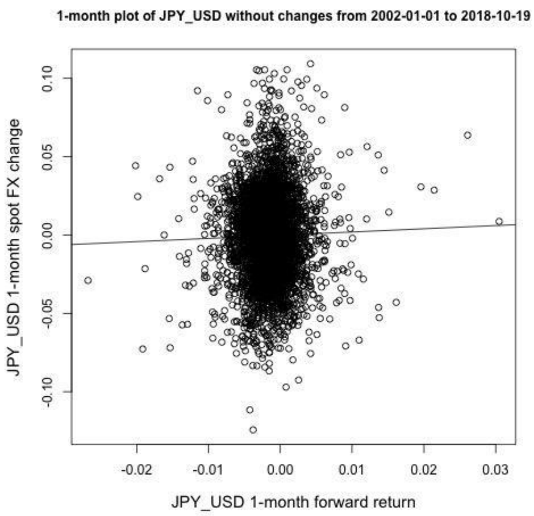

3-month plot of EUR_USD without changes from 2002-01-01 to NA
EUR_USD 3-month spot FX change
EUR_USD 3-month forward return
-0.1 0.0 0.1 0.2
-0.01 0.00 0.01 0.02 0.03

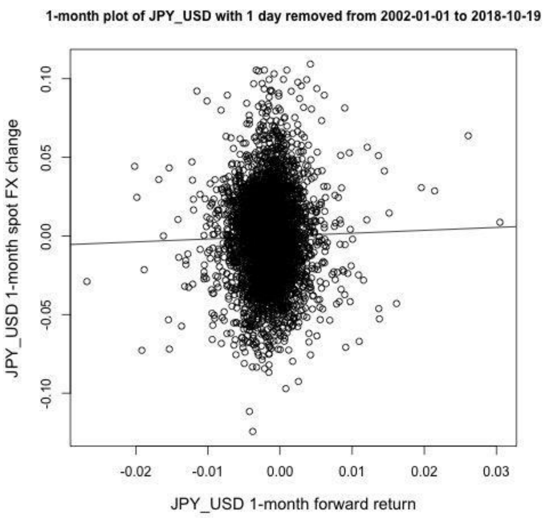

3-month plot of EUR_USD with 1 day removed from 2002-01-01 to NA
EUR_USD 3-month spot FX change
EUR_USD 3-month forward return
-0.1 0.0 0.1 0.2
-0.01 0.00 0.01 0.02 0.03


3-month plot with 3 days removed of EUR_USD from 2002-01-01 to NA
EUR_USD 3-month spot FX change
EUR_USD 3-month forward return
-0.1 0.0 0.1 0.2
-0.01 0.00 0.01 0.02 0.03

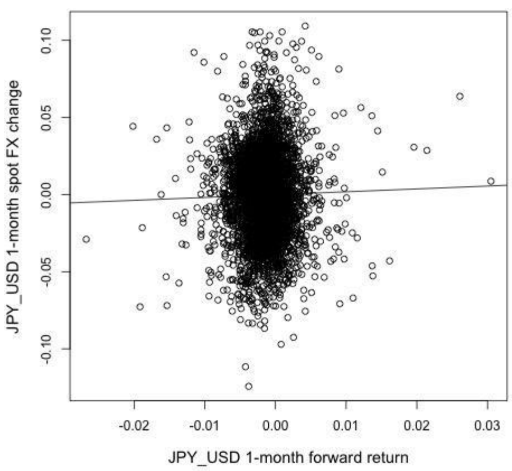

3-month plot of EUR_USD with 7 days removed from 2002-01-01 to NA
EUR_USD 3-month spot FX change
EUR_USD 3-month forward return
-0.1 0.0 0.1 0.2
-0.01 0.00 0.01 0.02

A.7.3 JPY/USD

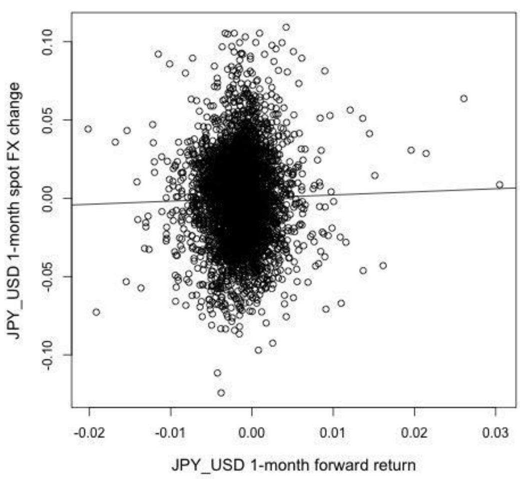

1-month plot of JPY_USD without changes from 2002-01-01 to 2018-10-19
JPY_USD 1-month spot FX change
JPY_USD 1-month forward return
-0.10 -0.05 0.00 0.05 0.10
-0.02 -0.01 0.00 0.01 0.02 0.03


1-month plot of JPY_USD with 1 day removed from 2002-01-01 to 2018-10-19
JPY_USD 1-month spot FX change
JPY_USD 1-month forward return
-0.10 -0.05 0.00 0.05 0.10
-0.02 -0.01 0.00 0.01 0.02 0.03

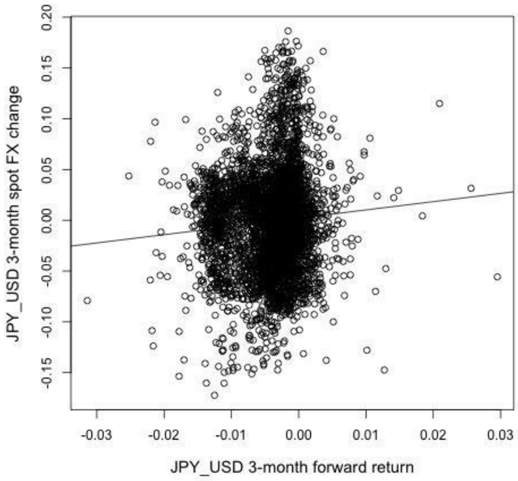
1-month plot of JPY_USD with 3 days removed from 2002-01-01 to 2018-10-19



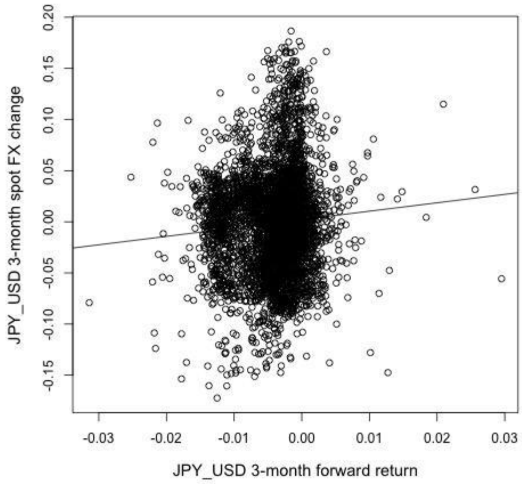
1-month plot of JPY_USD with 7 days removed from 2002-01-01 to 2018-10-19



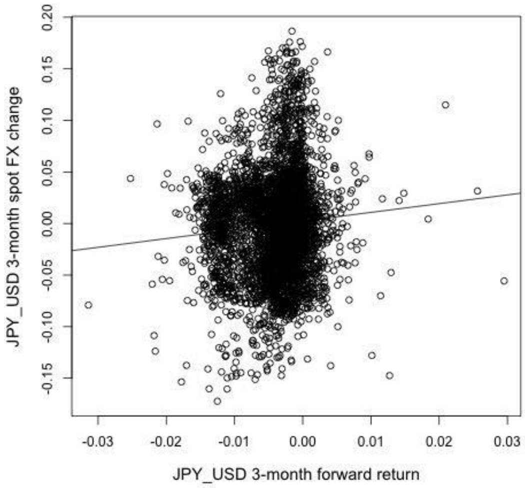
3-month plot of JPY_USD without changes from 2002-01-01 to 2018-10-19



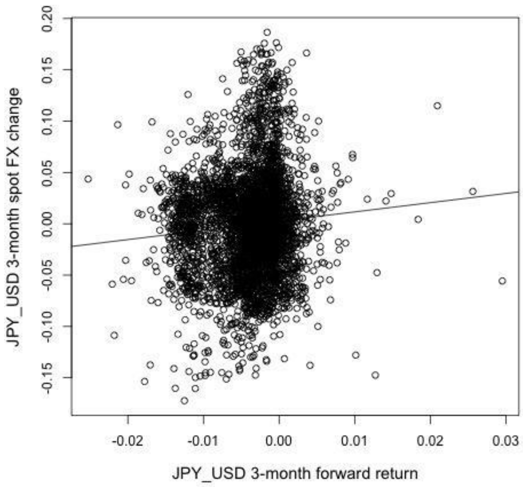
3-month plot of JPY_USD with 1 day removed from 2002-01-01 to 2018-10-19



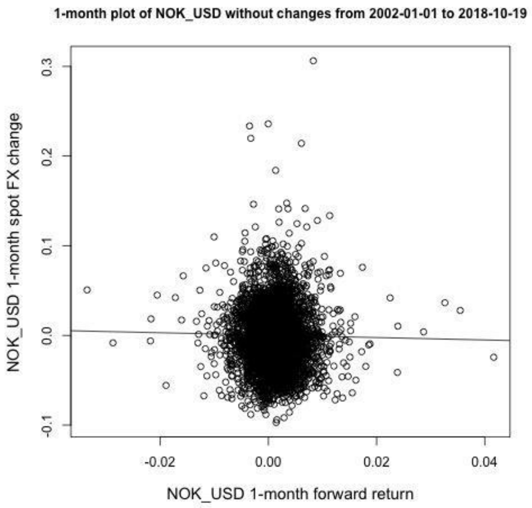
3-month plot with 3 days removed of JPY_USD from 2002-01-01 to 2018-10-19

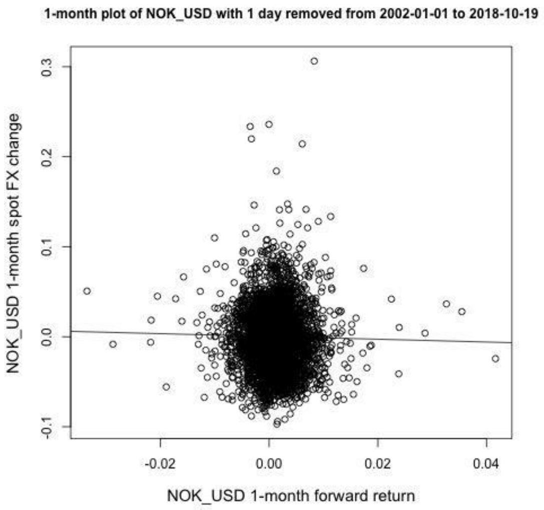


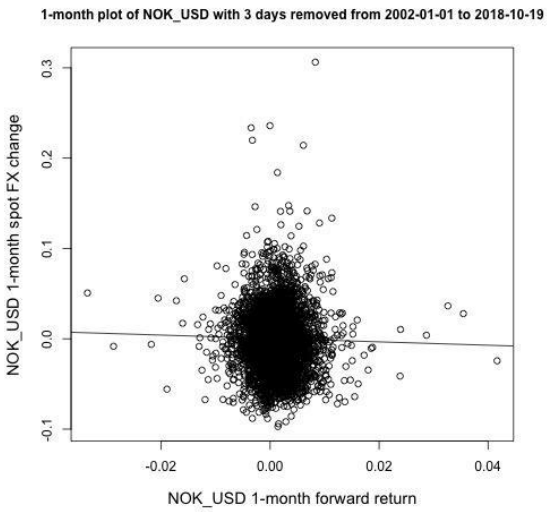
3-month plot of JPY_USD with 7 days removed from 2002-01-01 to 2018-10-19

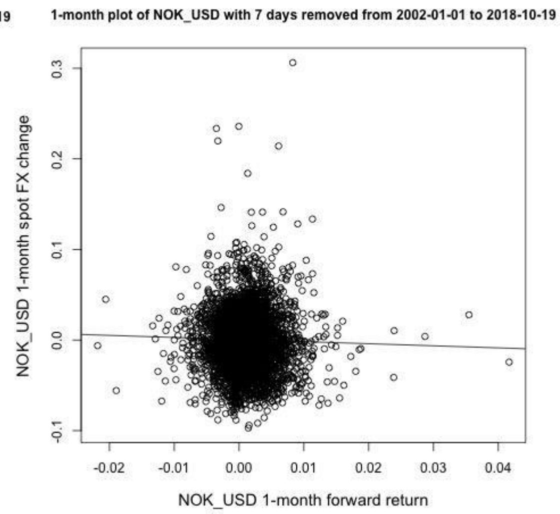


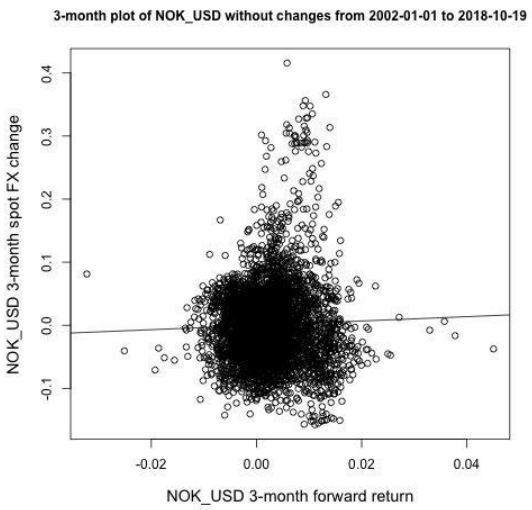
A.7.4 NOK/USD

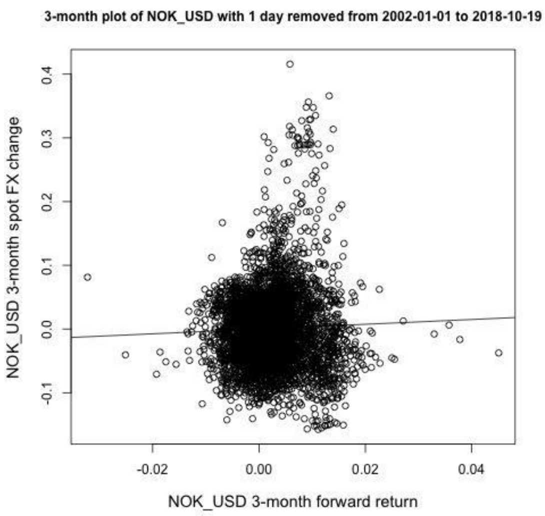

1-month plot of NOK_USD without changes from 2002-01-01 to 2018-10-19
NOK_USD 1-month spot FX change
NOK_USD 1-month forward return

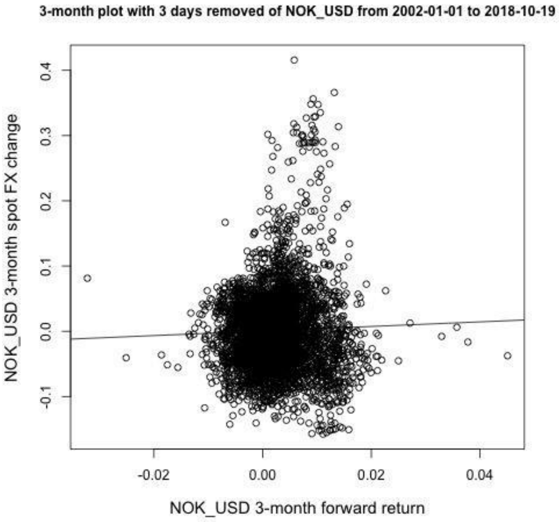

1-month plot of NOK_USD with 1 day removed from 2002-01-01 to 2018-10-19
NOK_USD 1-month spot FX change
NOK_USD 1-month forward return

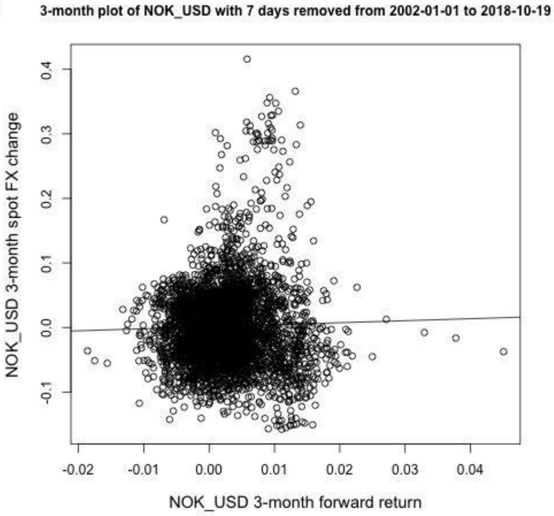

1-month plot of NOK_USD with 3 days removed from 2002-01-01 to 2018-10-19
NOK_USD 1-month spot FX change
NOK_USD 1-month forward return


1-month plot of NOK_USD with 7 days removed from 2002-01-01 to 2018-10-19
NOK_USD 1-month spot FX change
NOK_USD 1-month forward return

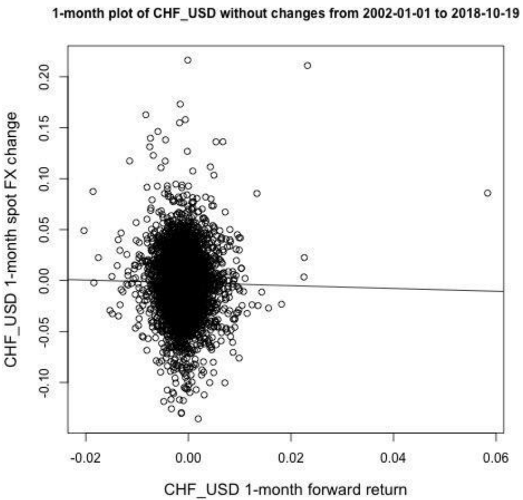

3-month plot of NOK_USD without changes from 2002-01-01 to 2018-10-19
NOK_USD 3-month spot FX change
NOK_USD 3-month forward return

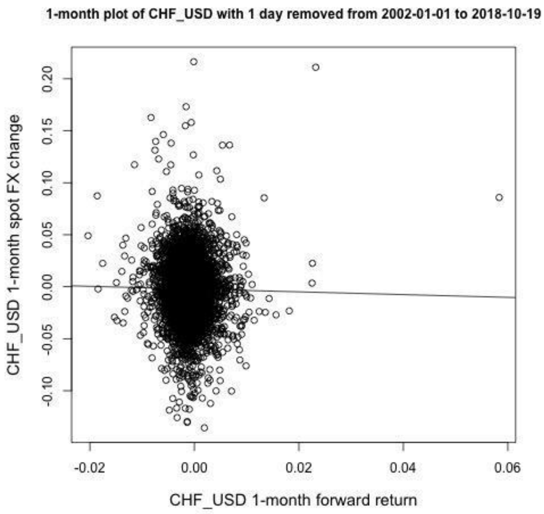

3-month plot of NOK_USD with 1 day removed from 2002-01-01 to 2018-10-19
NOK_USD 3-month spot FX change
NOK_USD 3-month forward return

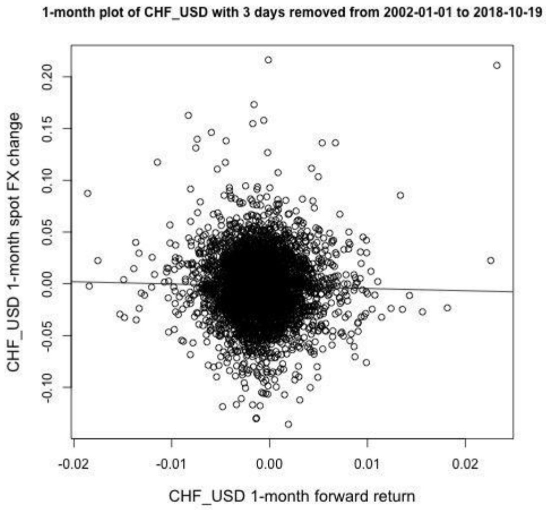

3-month plot with 3 days removed of NOK_USD from 2002-01-01 to 2018-10-19
NOK_USD 3-month spot FX change
NOK_USD 3-month forward return

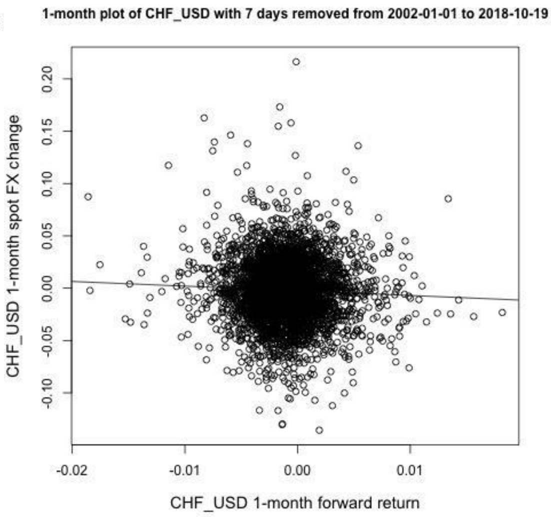

3-month plot of NOK_USD with 7 days removed from 2002-01-01 to 2018-10-19
NOK_USD 3-month spot FX change
NOK_USD 3-month forward return

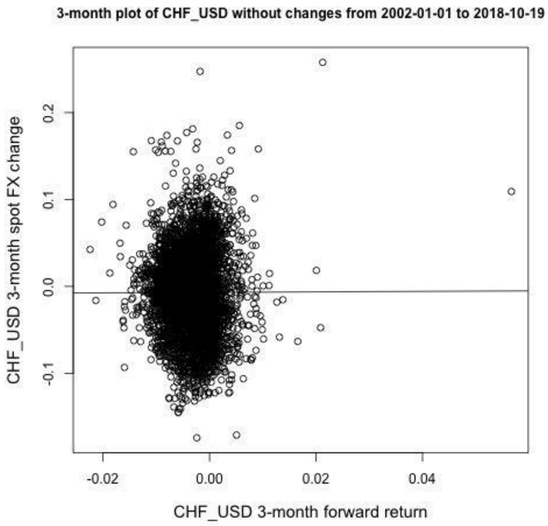
A.7.5 CHF/USD

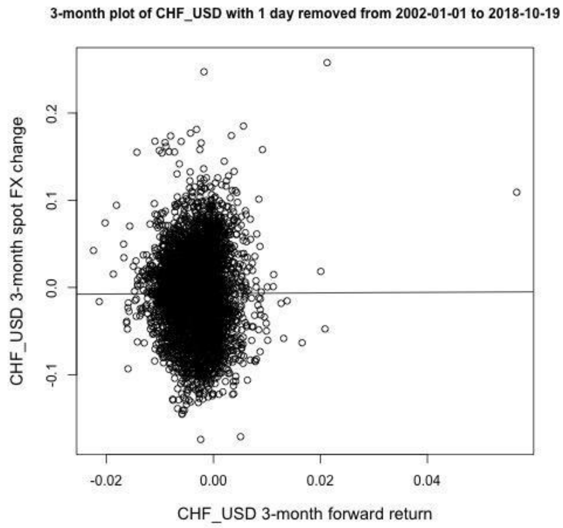

1-month plot of CHF_USD without changes from 2002-01-01 to 2018-10-19
CHF_USD 1-month spot FX change
CHF_USD 1-month forward return

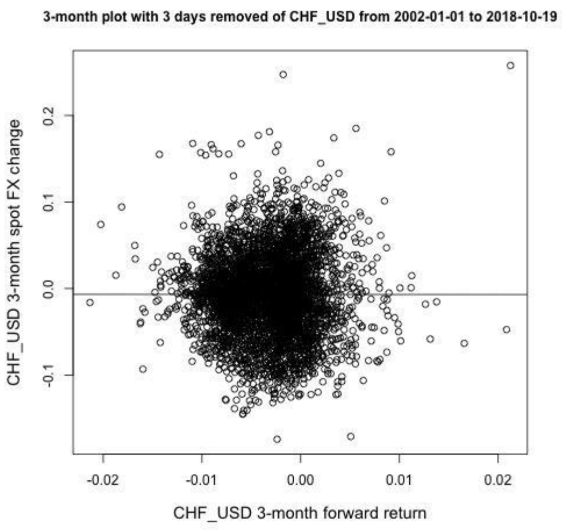

1-month plot of CHF_USD with 1 day removed from 2002-01-01 to 2018-10-19
CHF_USD 1-month spot FX change
CHF_USD 1-month forward return

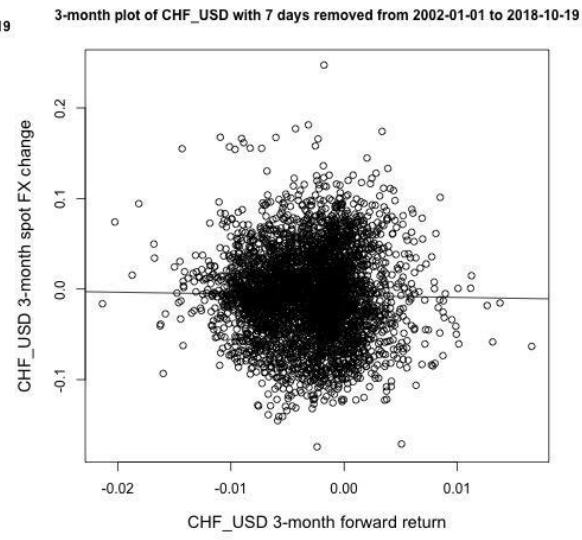

1-month plot of CHF_USD with 3 days removed from 2002-01-01 to 2018-10-19
CHF_USD 1-month spot FX change
CHF_USD 1-month forward return


1-month plot of CHF_USD with 7 days removed from 2002-01-01 to 2018-10-19
CHF_USD 1-month spot FX change
CHF_USD 1-month forward return

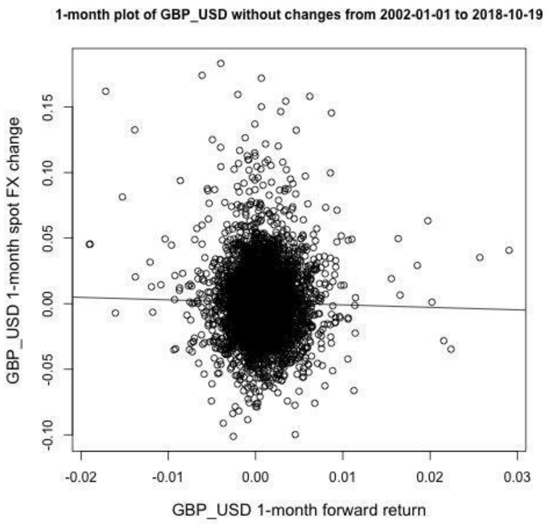

3-month plot of CHF_USD without changes from 2002-01-01 to 2018-10-19
CHF_USD 3-month spot FX change
CHF_USD 3-month forward return

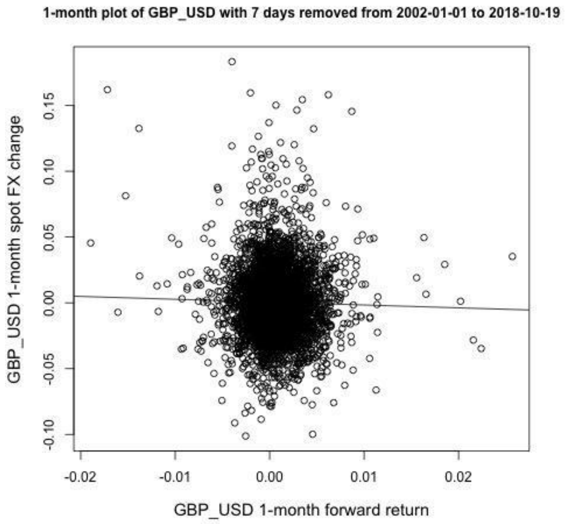

3-month plot of CHF_USD with 1 day removed from 2002-01-01 to 2018-10-19
CHF_USD 3-month spot FX change
CHF_USD 3-month forward return

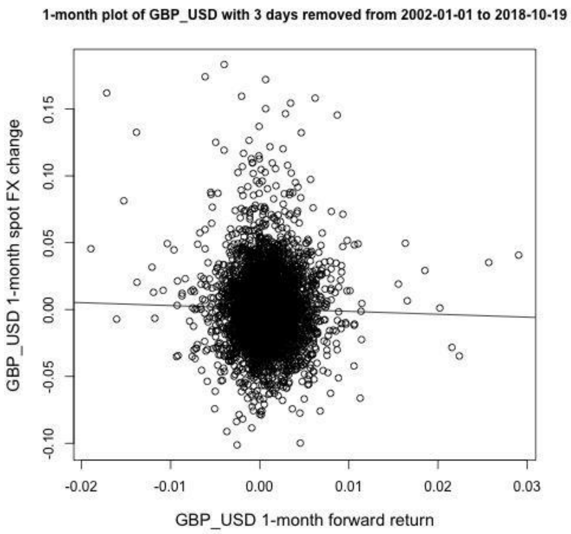

3-month plot with 3 days removed of CHF_USD from 2002-01-01 to 2018-10-19
CHF_USD 3-month spot FX change
CHF_USD 3-month forward return

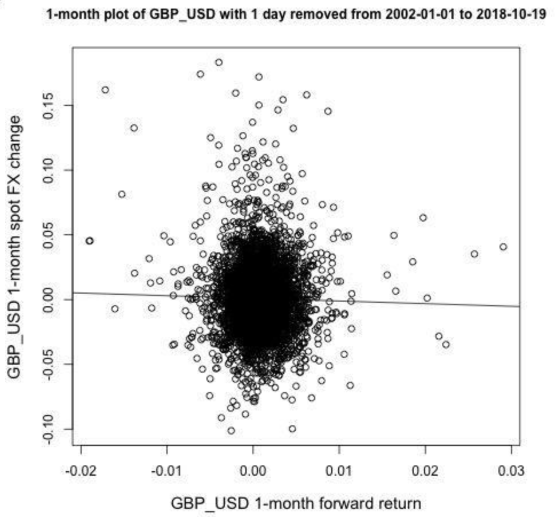

3-month plot of CHF_USD with 7 days removed from 2002-01-01 to 2018-10-19
CHF_USD 3-month spot FX change
CHF_USD 3-month forward return

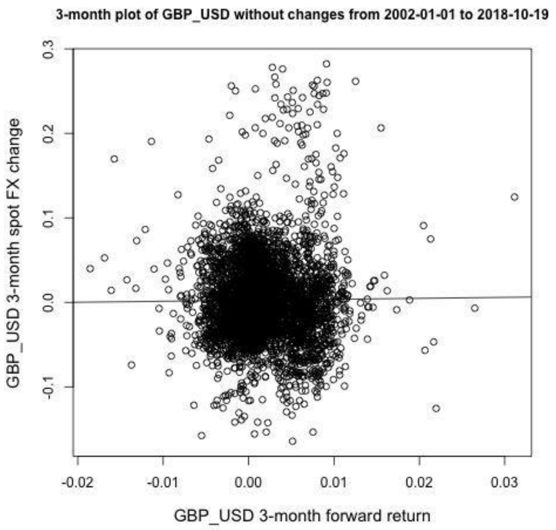
A.7.6 GBP/USD

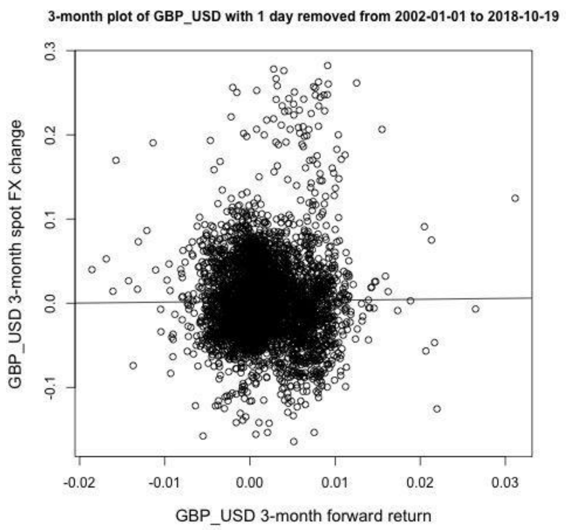

1-month plot of GBP_USD without changes from 2002-01-01 to 2018-10-19
GBP_USD 1-month spot FX change
GBP_USD 1-month forward return

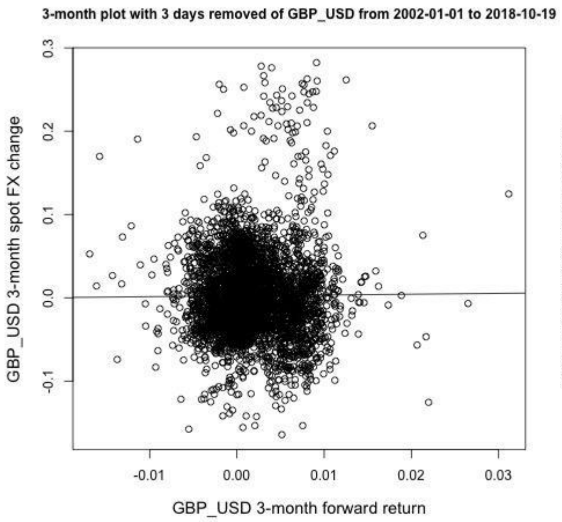

1-month plot of GBP_USD with 7 days removed from 2002-01-01 to 2018-10-19
GBP_USD 1-month spot FX change
GBP_USD 1-month forward return

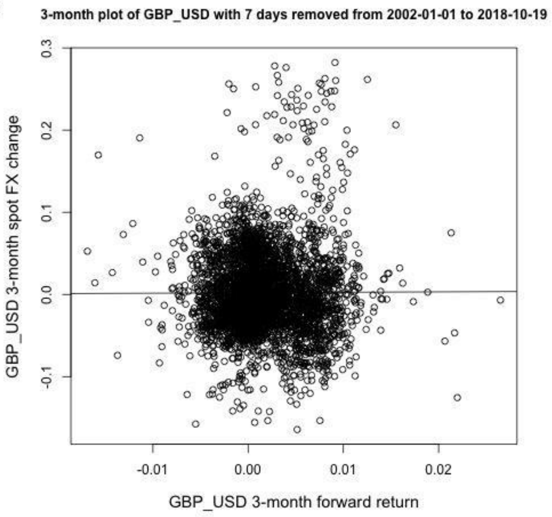

1-month plot of GBP_USD with 3 days removed from 2002-01-01 to 2018-10-19
GBP_USD 1-month spot FX change
GBP_USD 1-month forward return


1-month plot of GBP_USD with 1 day removed from 2002-01-01 to 2018-10-19
GBP_USD 1-month spot FX change
GBP_USD 1-month forward return


3-month plot of GBP_USD without changes from 2002-01-01 to 2018-10-19
GBP_USD 3-month spot FX change
GBP_USD 3-month forward return


3-month plot of GBP_USD with 1 day removed from 2002-01-01 to 2018-10-19
GBP_USD 3-month spot FX change
GBP_USD 3-month forward return


3-month plot with 3 days removed of GBP_USD from 2002-01-01 to 2018-10-19
GBP_USD 3-month spot FX change
GBP_USD 3-month forward return
0.3
0.2
0.1
0.0
-0.1
-0.01
0.00
0.01
0.02
0.03


3-month plot of GBP_USD with 7 days removed from 2002-01-01 to 2018-10-19
GBP_USD 3-month spot FX change
GBP_USD 3-month forward return
0.3
0.2
0.1
0.0
-0.1
-0.01
0.00
0.01
0.02