David Ånnestad and Jørgen Rønning Valstadsve

Risk Premium in Carry Trades

Master's thesis in Master of Science in Business Administration
Supervisor: Michael Kisser
Trondheim, May 2016

Master's thesis

NTNU
Norwegian University of Science and Technology
Trondheim Business School

NTNU
Norwegian University of Science and Technology

David Ånnestad og Jørgen Rønning Valstadsve

Risikopremie i Carry Trades

Risk Premium in Carry Trades

MASTEROPPGAVE - Økonomi og administrasjon/siviløkonom
Trondheim, Mai 2016

Hovedprofil: Finansiering og investering Veileder: Michael Kisser

NTNU
Handelshøyskolen i Trondheim

Preface

This master thesis has been written as a final part of our Master of Science in Business Administration at Trondheim Business School (NTNU).

In this thesis we take a closer look at currency carry trades from 2000 to 2016, and will try to see if we can identify a risk premium connected to it. The reason why we chose this topic was because of the huge impact the recent crash in oil prices had on foreign currency loans. This peaked our interest for trading strategies in the foreign exchange market.

We would like to thank our supervisor Michael Kisser for valuable comments and encouragement during the period.

The contents of this master thesis are the sole responsibility of the authors.

Trondheim
25.05.2016

David Ånnestad

Jørgen Rønning Valstadsve

Abstract

Carry trade strategies has been popular over the years, mainly because of large interest rate differential. This would seemingly create the possibility for traders to profit from excess returns, but according to the theory of uncovered interest rate parity (UIP), the interest rate differential will be offset by a depreciation of the higher interest rate currency. Researchers has often found that UIP does not hold, and have theorized that a lack of risk premium in the condition might be the reason.

This master thesis has studied the following research question:

Carry trade: is it possible to identify a risk premium, and is it time varying?

This thesis has tested for the existence of a risk premium on six different currencies against USD. This was done by creating a regression analysis on time series data for the period of 2000 to 2016. This regression analysis is used to test whether UIP holds, by regressing the changes in exchange rates on the forward premium. The regression was also estimated on two sub periods, in order to see if the financial crisis could affect the results.

The results found in this thesis is contradictory with earlier research in the way that the regression analysis did not find deviations from UIP for most of the currencies and therefore few signs of a risk premium. The results from the two sub periods provided obvious differences in the beta coefficients and therefore a model for a time varying risk premium was analysed.

This model provided results that was consistent with the regression analysis in the way that just one currency showed sign of constant- and time varying risk premium on a five per cent significance level. This thesis could therefore generally not identify a constant- or time varying risk premium.

Sammendrag

Carry trade strategier har vært populære over de siste årene på grunn av de store rentedifferansene mellom ulike land. I utgangspunktet kan dette se ut som en veldig lønnsom strategi, men i følge teorien om udekket renteparitet vil rentedifferansene bli avsatt ved endringen i valutakursen mellom landene. Forskere har ofte kommet frem til at udekket renteparitet ikke holder, og har hevdet at utelatelsen av en risikopremie i forutsetningene kan være årsaken.

Denne masteroppgaven har studert følgende problemstilling:

Carry trade: er det mulig å identifisere en risikopremie, og er den tidsvarierende?

Denne oppgaven har testen eksistensen av risikopremie på seks ulike valutaer (mot USD) ved å foreta en regresjonsanalyse over tidsperioden 2000 til 2016. Denne regresjonsanalysen er brukt til å teste om udekket renteparitet holder. Dette gjøres ved at terminpremien forklarer endringer i valutakursen. Regresjonsanalysen ble også utført på to ulike delperioder for å undersøke om finanskrisen kunne ha påvirket resultatene.

Funnene i denne oppgaven går i mot tidligere forskning ved at regresjonsanalysene ikke fant brudd på udekket renteparitet for de fleste valutaene. Det er derfor få tegn som tyder på risikopremie, men resultatene fra de to ulike delperiodene viste tydelige endringer i beta koeffisienten mellom de to periodene. Det ble derfor utført en analyse for å teste for tidsvarierende risikopremie.

Resultatene fra denne modellen var konsistent med regresjonsanalysen, siden kun en av valutaene viste tegn til konstant- og tidsvarierende risikopremie basert på et signifikansnivå på fem prosent. Oppsummerende kan det konkluderes med at denne oppgaven hverken kunne identifisere en konstant- eller tidsvarierende risikopremie på generell basis.

Table of contents

List of graphs:

List of tables:

1. Introduction

The foreign exchange market is one of the largest markets in the world. It is an over-the-counter market where trading is made through platforms such as the internet or over the phone. It is a global network and it allows participants to trade with their preferred currencies in a twenty-four-hour open market (Shamah, 2013).

There are several important relations in the foreign exchange market including the international parity conditions. There are three international parity conditions that are going to be presented in order to explain the important financial relationships used in this thesis. Covered interest rate parity (CIP) is an arbitrage condition that needs to hold in order to avoid the possibility for risk-free profit. (Butler, 2012). On the other hand, the last two are based on assumptions. These conditions are uncovered interest rate parity (UIP) and relative purchasing power parity (relative PPP).

One of the more popular strategies in foreign exchange markets is the carry trade, which consist of different types of investments, with currency as the most common. The currency carry trade (herby referred to only as the carry trade) consists of investing in currencies with higher interest rates, financed by borrowing in lower interest rate currencies. The interest rate differential between a high- and low interest rate currency would make this transaction profitable; however, the forward exchange rates indicate that the interest rate differential will be offset by an expected depreciation of the investment currency. This is the basic intuition behind the UIP condition (Brunnermeier et al., 2009).

The actual return on a carry trade is not always as predicted by UIP, since the forward exchange rates might not reflect the actual changes in the spot exchange rates. This is because the foreign exchange market is highly volatile, and the forward exchange rate is a biased predictor. This is known as the forward premium puzzle and refers to situations where the actual changes in exchange rates are not offset by the interest rate differential (Brunnermeier et al., 2009).

The research question in this thesis has been divided into two main objectives. Firstly, to examine whether it is possible to identify a risk premium related to carry trade returns. There are several ways to do this, but this thesis follows a traditional regression analysis introduced by Fama (1984) to see if the UIP condition hold. If the UIP does not hold in the data sample, significant deviations have been looked upon as an observed risk premium and not a violation of rational expectations.

The second objective was inspired by a study done by Aysun and Lee (2014), which found that deviations from the UIP condition was due to a time varying risk premium. This thesis would examine the same signs of deviations from the UIP condition by following their model based on excess returns.

Based on these two main objectives the following research question has been chosen:

Carry trade: is it possible to identify a risk premium, and is it time varying?

The thesis is structured in the following way: Chapter 2 provides some fundamental theory about foreign exchange determination and the relevant parity conditions. A brief literature review on carry trade studies will be summarized in chapter 3. The empirical analysis follows in chapter 4, where applied methodology will be explained alongside the analysis. In the end, chapter 5 provides a conclusion of the main results discussed in the empirical analysis.

2. Theoretic background

This chapter will try to provide the necessary theoretic background needed to understand the scope of this thesis. Since the carry trade is based on the exchange rates between the relevant currencies, a detailed introduction of the main foreign exchange determination models is needed. It includes macro based models based on UIP, and an alternative approach that includes a risk premium. The framework for both CIP and UIP will be presented, and the differences between these two will be explained. The exchange rates will be expressed as the domestic price of the foreign currency, namely $S^{d/f}$. A review of the relative PPP will also be included in this chapter.

2.1 Foreign exchange rate determination

The main models in foreign exchange determination can be divided into two categories; macro-based and micro-based approaches. According to Evans and Rime (2012), the approaches are based on different assumptions. The first one is that macro models assume that all participants in the financial market have the same information, while the micro-based models assume that participants have different views on the market. Secondly, macro models often assume that there does not exist a risk premium. This indicates that macro based models often assume that UIP hold.

It is important to explain the forward premium puzzle, since it should not be underestimated in any successful exchange rate model. The puzzle explains why currencies with high interest rates tend to generate excess returns in carry trades. According to Engel (2011), foreign exchange determination models should also explain why empirical findings states that high interest rate currencies tend to appreciate relative to lower interest rate currencies. This is a violation of the UIP condition and complicates any model that is based on it.

The macro models also assumes that the structure of the foreign exchange market has no impact on the exchange rates (Rime, 2003). Macro models pay little attention to trading in foreign exchange markets, because the patterns of currency trading are ignored. On the other hand, micro models assume that participants can use the information received from these patterns (Evans and

Rime, 2012). These specific patterns are not relevant for the research question since trading strategies and therefore this thesis will therefore only summarize the main macro-based models.

In the following subsections the most familiar models will be examined and explained. The models based on the assumption of perfect capital substitutability will be explained first, followed by an alternative model which includes a risk premium. The following sections will focus on how the different models explain changes in nominal exchange rates (s_t). Since these models are based on several equations and econometric relationships, the review is reduced to a minimum.

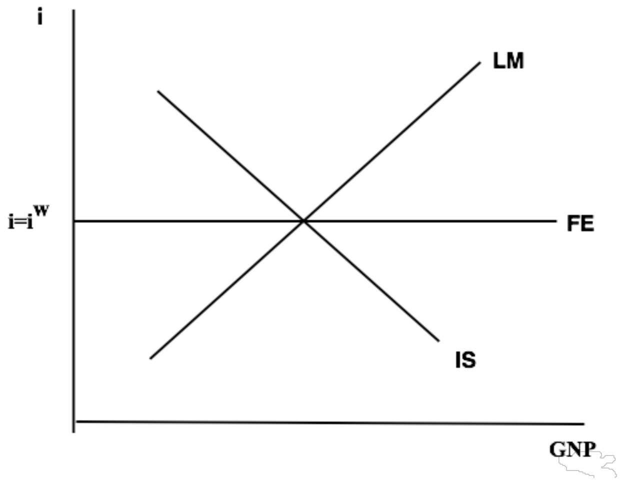
2.1.1 Macro models based on UIP

2.1.1.1 Mundell-Fleming model

The Mundell-Fleming model is used to analyse changes in macroeconomic outputs in a small, open economy. The model concentrates on the equilibrium in three markets; commodity market, domestic financial market, and the currency market. A small economy leads to an intuition that foreign interest rate is exogenous and cannot be influenced by a domestic economy. The model assumes available capacity in the economy, perfect capital mobility and just two goods. If the capital mobility is perfect, the expected return on currencies cannot be different from each other. In other words, the UIP will be applied (Moosa and Bhatti, 2009). The parity conditions will be further explained in detail in section 2.2.

The model is specifically used to examine the effects of macroeconomic changes on monetary- and fiscal policies under two different government regimes; fixed- and flexible exchange rates (Gärtner, 2006). Only floating exchange rate are discussed later, since it is not relevant for this thesis. Let us first introduce the basic setup of a basic Mundell-Fleming model. The horizontal axis is the gross national product (GNP) and the vertical axis is the interest rate (i). All curves are represented in the same diagram, as shown in graph 1 under (Gärtner, 2006):

Graph 1: Mundell-Fleming model



IS-LM-FE curves in the Mundell-Fleming model

The two first curves of the simple Mundell-Fleming model are the IS-curve and the LM-curve. The IS-curve represents the equilibrium in the commodity market, while the LM-curve represents the monetary market. The third and last curve in the model is called the FE-curve and represent the equilibrium of the currency market. With the assumption of perfect capital mobility this curve represents a horizontal line on the graph, because investors will move capital to another country if macroeconomic effects change the interest rate. The FE-curve (1) is often specified in a way so that the domestic interest rate (i^d) is exogenously equal to the worlds interest rate (i^w) plus a change in the exchange rate (Gärtner, 2006):

$$i^d = i^w + \frac{E[S_{t+k}] - S_t}{S_t} \tag{1}$$

The interest rate will be equal in the two different government regimes, since this model assume that the expected exchange rate at time t+k ($E[S_{t+k}]$), equals the exchange rate at time t (S_t). The second expression on the right side will then be zero and the FE-curve will be a horizontal line in both regimes (graph 1).

These curves will change if the government's spending changes (IS) or if the money supply changes (LM). The interest rate will change in response to changes on these curves and the investors will want to move their assets to economies with higher interest rates. This would then have an effect on the exchange rates, since the relationship between supply and demand will result in an appreciation or depreciation of a currency. The governments will need to react with either a fiscal- or monetary policy to put an upward or downward pressure on the interest rate, in order to back to the original starting position.

In a flexible exchange rate regime, where exchange rates are only determined by the market, a similar increase in the IS-curve will not lead to the same response as in a fixed exchange rate regime. The demand for domestic currency will increase, resulting in an appreciation of the currency and the IS-curve will shift upwards to the right. It then becomes more expensive to buy domestic goods with foreign currency and exportation decreases. This will move the IS-curve back to the starting position and fiscal policy will not be able to change GNP. An increase in domestic money supply puts a downward pressure on the interest rates and the domestic currency depreciates. Foreigners buys more domestic goods and exportation increases. The IS-curve will then move upwards to the right and make a new intersection between IS and LM (Gärtner, 2006)

The Mundell-Fleming model provides a relationship between nominal exchange rates and macroeconomic outputs. The interest rate is fixed in the framework of the model and thus the nominal exchange rate is used to obtain equilibrium. The model illustrate how the government can act in relation to different economic results, for example with government spending. As a summary, monetary policy will have no impact in a fixed rate regime and a fiscal policy does not work in a flexible rate regime (Moosa and Bhatti, 2009).

2.1.1.2 The monetary models

The monetary models define the exchange rate as the relative price of two currencies. The relative supply and demand between two currencies are used to determine the exchange rate. The monetary approach of exchange rates can be divided into two; flexible-price version and the sticky-price version. This monetary approach, in addition to the portfolio balance model, have dominated the empirical research after the 1970s (Chinn, 2012).

The flexible-price monetary approach assumes perfect competitive markets and profit-maximising behaviour among agents. The model is based upon several assumptions, for example that both the PPP and UIP holds continuously. The assumption of PPP explains that a good should be prized equally in two countries, otherwise market arbitrage will move the exchange rate. UIP predict that the expected depreciation of the exchange rate should equal the interest rate differential (Neely and Sarno, 2002).

The monetary model treats the spot exchange as a function of relative money supply, relative income, and the interest rate differential. In logarithms (log), the relationship between the exchange rate and the three other factors can be derived as (Chinn, 2012):

$$s_t = \left(m_t^d - m_t^f\right) - \kappa\left(y_t^d - y_t^f\right) + \lambda\left(i_t^d - i_t^f\right) \tag{2}$$

Where *m* is the log of money stock and *y* is log of income. The interest rate is expressed as *i*. The domestic and foreign variables are defined as d and f, respectively. κ and λ are defined as a negative and a positive constant, respectively. These two constants are often assumed to be the same for both countries and are negative (κ) dependent on the income differential (between domestic and foreign) and positive (λ) dependent on the interest rate differential.

An implication of equation (2) is that higher domestic interest rates (relative to foreign interest rate) should result in a weaker domestic currency, this is consistent with the intuition of UIP. This increased interest rate differential results in a higher λ. The exchange rate (domestic currency per unit of foreign currency) increases in value, which means that one unit of foreign currency gets more expensive. Another implication is that the currency will strengthen if income differential increases, since the logarithm of spot exchange rate (s) will decrease and one unit of a foreign currency will be cheaper.

The second version of monetary models is the sticky-price monetary model. According to Neely and Sarno (2002) this model was featured as a respond to the high volatility of exchange rates in the 1970s and the related scepticism of the assumption about continuous PPP. This version of the monetary models allows exchange rates to swing beyond the long-term equilibrium levels. Thus, the assumption of continuous PPP is not used in this model. Such deviations from PPP may be transaction costs, tariffs and other legal barriers. This model also uses UIP as a key component, and the model explains why volatility of exchange rates is so common in the financial world.

An example of the model could be that a decrease in money supply for the domestic country will result in higher interest rates. As the name of the model implies, the prices are sticky (move slowly) in the short run and cannot make rapid jumps. As a result of these sticky prices, the real money supply will primarily fall in the short run. Hence, a capital inflow is apparent because it is assumed that investors would want to invest their assets in economies with higher interest rates relative to their current selection.

At a longer term, the prices will start to adjust and the money supply would eventually be more balanced. The domestic interest rate starts to decline and the interest rate differential would be smaller. The exchange rate will depreciate until it reaches the long-run PPP. This show the main intuition of the model explaining how the exchange rates overshoot (fluctuate beyond) the long-run equilibrium.

As a compensation for sticky prices, jump variables in exchange rates and interest rates are included in the model to balance the money market (Sarno and Taylor, 2002). In the short run, exchange rates overshoot its long-term equilibrium to secure that UIP holds. Therefore, the PPP only hold in the long run, since the prices fail to adjust on a short term basis.

2.1.1.3 Equilibrium model

A generalisation of the monetary model is equilibrium models, which maximises the expected utility for an agent in a model based on two countries. In contrast to the general monetary model, equilibrium models allow for multiple traded goods (Taylor, 1995). A simple equilibrium model may be a two-good model in a world where we assume that only two countries exist (domestic and foreign). The equation below (3) clearly indicates that there are similarities with the monetary model (equation (2)). The relationship between the spot exchange rate and the economic variables are expressed as logarithms and can be viewed as (Sarno and Taylor, 2002):

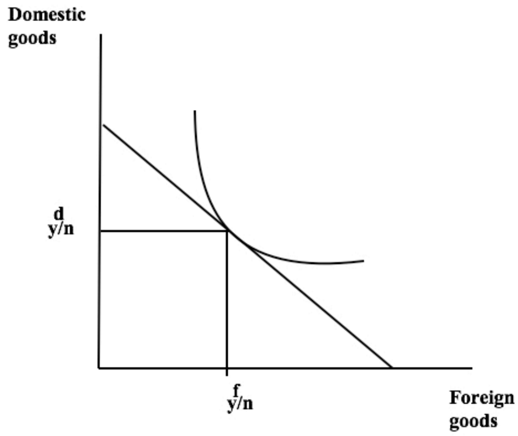
$$s_t = (m_t^d - m_t^f) - \kappa(y_t^d - y_t^f) + \pi_y \tag{3}$$

Here the spot exchange rate at time t (s_t) is expressed as a function of money demand (m_t), income (y_t) and a relative price change (π_y). Notice that the relative price change is dependent on the income differential ($y_t^d - y_t^f$).

This price change depends on the relative income changes. A rise in demand for domestic currency relative to the demand of foreign currency, will result in a depreciation of the domestic currency. This is because a higher spot exchange rate indicates a higher price per unit of foreign currency. This would be in contrast to the monetary models, where a higher income results in a depreciation of the domestic currency (increased spot exchange rate), these models can therefore yield different conclusions. If the income differential increases, it should induce a price change and hence an increased relative price change. These effects can be seen in equation (3).

The relative price increase can be illustrated with graph 2 below, which is similar to the one constructed by Taylor (1995):

Graph 2: "Relative price effect"



This figure illustrates the possible combinations (indifference curve) of domestic and foreign goods. The relative price of foreign output is then the slope of this indifference curve at point $\frac{y^d}{n}, \frac{y^f}{n}$. This "relative price effect" is the first of two effects this income differential has on exchange rates. This effect would increase the spot exchange rate, and thus create a depreciation of the domestic currency.

That being said, an increased income differential would implicate that the "money demand effect" on exchange rate is negative, resulting in an appreciation of the domestic currency. Consequently, the equation yields two different effects and the exchange rate will move in response to this total effect (Taylor, 1995).

To summarize, the intuition of this model is to show that exchange rate would move in response to the substitutability of domestic and foreign goods. As mentioned above, shifts in demand (from foreign to domestic goods or vice versa) will lead to volatility in relative prices and according to the model this can explain the volatility of nominal exchange rates (Taylor, 1995).

2.1.2 Macro model with risk premium

2.1.2.1 Portfolio balance model

In the short run, the portfolio balance model is also based on the demand and supply of financial assets, but the common assumption about perfect substitutability between goods is now more moderate. This implies that a bond might yield different returns because of an included risk premium, which separates the expected depreciation and the interest rate differential (Chinn, 2012).

In addition to money, the portfolio balance model also relies on the demand and supply of bonds to predict the way exchange rate will change in the future. Investors now hold a diversified portfolio, of both domestic and foreign bonds, and their allocation are based on return and risk considerations.

An equation can be used to illustrate the assumptions behind the portfolio balance model. As with the models in previous sections, the assumption of perfect capital mobility holds. The differences however, are the assumption of perfect capital substitutability. In the portfolio balance model the investors will not be indifferent between domestic and foreign bond. Let us consider this equation (Chinn, 2012, Frankel, 1983):

$$\frac{B_t^d}{S_t B_t^f} = \beta(i_t^d - i_t^f - E\left[S_{t+1} - S_t\right]) \tag{4}$$

Where B^d and B^f are net supplies of domestic and foreign bonds at time t. The right side of the equation includes a positive constant β, which is positively dependent on the interest rate differential $(i^d - i^f)$ minus the expected rate of depreciation of the domestic currency $(E_t[s_{t+1} - s_t])$. The intuition of equation (4) is that the beta (β) shows that holding domestic bonds relative to foreign bonds is a positive function of the included risk premium (Chinn, 2012). The right side of the equation shows the deviation from UIP, since an assumption of imperfect substitutes (risk premium) is included in the equation.

Assuming the relative bond demand equation above, it can be written as a linear expression and equation (4) rearranged and in log-form would be (Chinn, 2012):

$$s_t = \alpha_t + \beta(i_t^d - i_t^f - E\left[s_{t+1} - s_t\right]) + b_t^d - b_t^f \tag{5}$$

Where s_t, b_t^d and b_t^f is the logarithm of spot exchange rate (S), supply of domestic bonds (B^d) and supply of foreign bonds (B^f), respectively. The spot exchange would decrease (appreciate) if the supply of foreign bonds increases relatively to the domestic bonds. As a consequence, investors will hold more domestic bonds if they are compensated with a risk premium, which can be an increased interest rate differential or a depreciation of the domestic currency. According to the model, this is because an increase in domestic bonds relative to foreign bonds will cause the domestic currency to depreciate (increased spot exchange rate).

The intuition behind this model is to show that investors in a financial market would not only hold stocks of money, as in the monetary models, but also stocks of bonds. The assumption of imperfect substitutability implies that investors can exploit the included risk premium, which would be a violation of UIP. The model can be important in order to test for an observable risk premium, but the expected rate of depreciation cannot be observed (ex ante) and this complicate the empirical research on portfolio balance models (Taylor, 1995).

2.1.3 Validity of the models

A major part of foreign exchange determination models relies on the international parity conditions. The most important international parity conditions are the CIP, UIP and relative PPP, which we will discuss below. These conditions illustrate how the inflation differentials, interest rate differentials, forward exchange rate, and the changes in spot exchange rates are linked together.

As the thesis will explain later, empirical research on UIP and PPP are unpromising. Deviations from these international parity conditions would affect the importance of interest rate differentials on exchange rate movements. Both the Mundell-Fleming model, the monetary models and the equilibrium models are built on these conditions. These implications issue the validity of these models, since they seem to be built on questionable assumptions. Let us now turn to the most important parity conditions and explain them in detail.

2.2 Parity conditions

The parity conditions assume perfect market conditions and their assumptions can therefore be used to test the market efficiency. UIP is one of the main parity conditions in international finance, in addition to CIP and PPP. In this section a framework of the CIP, UIP and relative PPP will be presented. As for relative PPP, an introduction of the absolute version will be presented before turning to the relative version of PPP. The theory and evidences behind UIP are of particular interest for the rest of this thesis, as the fundamental philosophy behind carry trading is to bet against it.

2.2.1 Covered interest rate parity

CIP is a condition that needs to be in place in order to avoid arbitrage. It states that the foreign exchange forward premium should equal the excess returns earned by the interest rate differential between two currencies (Taylor, 1987). CIP can be expressed as:

$$(1+i_t^d)=(1+i_t^f)\frac{F_t^k}{S_t} \tag{6}$$

Where i^d and i^f is the domestic and foreign nominal interest rate on similar assets. S is the spot exchange rate expressed in domestic price of foreign currency, and F is the forward exchange rate with the same maturity as the interest bearing assets (Akram et al., 2008).

Equation (6) states that the return on a domestic investment should equal the return on a similar investment in the foreign country. If this equation does not hold there would be arbitrage opportunities; however, under the assumption of efficient markets this would eventually be traded away. The law of supply and demand states that arbitrage opportunities will encourage movements in the interest-, spot-, and forward rates until the equation hold.

CIP is an arbitrage condition since the trading happens at the same time, and the risk involved is limited. On the other hand, UIP deals with risk since the participants make a position to profit at a later point. UIP is therefore more relevant for the carry trade and generally the rest of the thesis.

2.2.2 Uncovered interest rate parity

UIP explain a situation where the nominal interest rates, both domestic and foreign, are related to the spot exchange rate and the expected spot rate (Butler, 2012). UIP may be, according to Burda and Wyplosz (2009), expressed as follows:

$$(1+i_t^d)=(1+i_t^f)\frac{E\left[S_{t+k}\right]}{S_t} \tag{7}$$

where i^d and i^f are the nominal interest rate for the domestic and foreign currency. S_t is the nominal spot exchange rate at time t (domestic price of foreign currency) and $E[S_{t+k}]$ is the expected spot exchange rate at time t+k.

Equation (7) states that the income from foreign interest income (in domestic currency) should equal income from the the domestic interest rate. This is because the UIP condition implies that the higher interest rate currency should depreciate in a way that compensates for the interest differentials. The expected spot rate at time $t+1$ should be lower than spot rate today, at time t. If so, the high interest rate currency is at a forward discount. When rearranging equation (7) it can be illustrated as (Ullenes, 2012):

$$\frac{E\left[S_{t+k}\right]-S_t}{S_t}=\frac{i_t^d-i_t^f}{1+i_t^f} \tag{8}$$

It follows from the hypothesis that the forward exchange rate should be an unbiased predictor of the expected spot exchange rate in the future. In that case, currency trading strategies like the carry trade should be expected to deliver zero excess returns and investors should get the same return on an investment in domestic currency as in foreign currency.

2.2.3 Testing CIP and UIP

When both CIP and UIP hold, the following relation can be expressed by dividing the UIP equation (7) by the CIP equation (6) (Sarno and Taylor, 2002):

$$1=\frac{E\left[S_{t+k}\right]}{F_t^k} \tag{9}$$

Since the right side of the equation equals unity, the forward exchange rate at time t should equal the expected spot rate at time t+k:

$$F_t^k=E\left[S_{t+k}\right] \tag{10}$$

Under the assumptions of risk-neutrality, rational expectations and no risk premium, this equation states that the expected future spot rate should equal the corresponding forward rate. Researchers refers to this as the “unbiased hypothesis”.

Although, there are some major differences in the framework of CIP and UIP. The CIP eliminate risk, because all of the variables in the equation are known. In UIP on the other hand, the expected spot rate is unknown at time t, and participants in the foreign exchange market are exposed to currency risk. In the equations mentioned earlier (6 and 7) the differences can be seen on the right side. The forward rate (F) is known, but the expected spot rate ($E[S_{t+1}]$) is unknown at time t. This currency risk might be looked upon as the downside of a carry trade strategy.

Researchers assume that CIP hold, and use empirical tests on UIP to explain “the unbiased hypothesis”; however, CIP might also be tested. According to Sarno and Taylor (2002) the following equation have been used to conduct an empirical test of CIP:

$$f_t^k - s_t = \alpha + \beta\left(i_t^d - i_i^f\right) + \mu_t \tag{11}$$

The lower case characters of F and S above means that logarithms are used. f_t^k is the logarithm of the k-period forward exchange rate at time t and s_t is the logarithm of the spot exchange rate at time t. μ_t is the regression error. If the CIP holds, the α and β should be insignificantly different from zero and unity, respectively. If that is the case, the forward premium (or the forward discount) should equal the interest rate differential. In cases where CIP holds, both the interest rate differential and the forward premium (forward discount) can be used as an independent variable to test the UIP.

If the CIP condition does not hold, it will be possible to make a risk free profit. This kind of profit would be arbitrage and in efficient markets, where information about this would be available for all participants, this would be exploited and eventually traded away. According to Sarno (2005) most research on efficient foreign exchange markets assume that CIP holds, and therefore that UIP plays a major role in testing the efficiency of the market. That said, tests on CIP can be useful on exchange rate modelling.

According to a study done by Taylor (1987) there is no real opportunity for arbitrage when it comes to CIP. In his paper he used data from the London foreign exchange market from the 11th, 12th and 13th of November 1985, his data was sampled at ten minute intervals from 09:00 to 16:50. He collected the spot exchange rate for the US dollar – UK sterling and US dollar – German mark; the forward exchange rate for dollar-mark and dollar-sterling; and Euro deposit interest rates for sterling, dollar and mark. All of his data was collected for one, three, six and twelve-months maturities.

His test was simple yet efficient, Taylor simply counted the number of times he would have been able to produce a profit with covered arbitrage by borrowing dollar and lending marks (or vice versa), and the same with dollar-sterling. In his paper Taylor (1987) concludes with seemingly no possibilities for profitable arbitrage. There was only one opportunity that presented itself, which was the dollar-mark (borrow mark, lend dollar) for twelve-months maturity; however, there was only a $\frac{3}{16}$ of one percent deviation from the rest of the market. The mark was offered at 5 per cent at 11:00 and 11:20 on November 12th, while at 11:10 a broker offered mark at $4\frac{13}{16}$ per cent. Even though Taylor didn't have the longest data sample we believe that it is a good indicator that CIP holds. Taylor could only find one deviation in his sample of 3456 covered arbitrage calculations it would seem that, as he also concludes, there are little to no opportunities for arbitrage.

By replacing the forward premium (left side of equation (11)) with the expected change in spot exchange rates, and the interest rate differential (right side of the equation (11)) with the forward premium, the following equation can be used in a regression analysis of the UIP (Sarno and Taylor, 2002):

$$s_{t+k} - s_t = \alpha + \beta\left(f_t^k - s_t\right) + \eta_t \tag{12}$$

The null hypothesis of this test is similar to the CIP equation, with alpha equals zero and beta equals unity. This would imply that the expected spot rate at time $t + k$ should equal the k-period forward exchange rate known at time t.

By introducing "the unbiasedness hypothesis" equation (10), several studies have used it to test whether the UIP holds. By using linear regression, Fama (1984) contributed to one of the first major researches on this topic. In his paper from 1984, Fama formulated a regression analysis and found negative coefficients on the changes in spot exchange rates on the difference between current forward exchange rate and spot exchange rate.

Several studies find violations of UIP in their data samples and relate it to a risk premium (Aysun and Lee, 2014, Menkhoff et al., 2012, Wagner, 2012). There is some problem in empirical research regarding the test of whether UIP holds. This is because researchers in this area have been arguing over whether the deviations from UIP is because of an observed risk premium or if the assumptions about rational expectations is violated (Froot and Frankel, 1989).

Fama (1984) is the most classical paper studying the evidences of a risk premium in explain the forward premium puzzle. On the other hand, Bilson's study from 1981 (cited in (Froot and Frankel, 1989)) assume no risk premium and find the deviation from UIP as a rejection of rational expectations and that forward discounts expresses an investors expectations. A rejection of the null hypothesis is interpreted in such a way that investors should expect less exchange rate changes than initially anticipated. Wagner (2012) concludes that the violation of UIP is not necessarily the whole story, whereas he thinks that the forward bias puzzle comes from the omission of a risk premium in the standard test of UIP.

2.2.4 Purchasing power parity and the Fisher effect

PPP determine what the exchange rate between two countries should be if the purchasing power of one unit of currency is supposed to be equal (Taylor, 2003). This form of PPP is known as absolute PPP, and is based on the argument concerning the law of one price. Converting the relationship with response to the spot exchange rate, it corresponds to the PPP between the two countries (Melvin and Norrbin, 2012):

$$S_t^{d/f} = \frac{P^d}{P^f} \tag{13}$$

An alternative view of the PPP is the relative PPP. This condition state that changes in exchange rates equals the changes in relative prices between the domestic and foreign price, all changes measured in per cent. The actual exchange rates and the prices (inflation) is not important in this statement, since we are looking at the changes. Relative PPP can hold even though the absolute version fails, but not vice versa. A rewritten expression of this parity can be shown below (Melvin and Norrbin, 2012):

$$\Delta S_t^{d/f} = \Delta P^d - \Delta P^f \tag{14}$$

The equation states that expected change in spot exchange rate (domestic price of foreign currency, $\Delta S_t^{d/f}$) should equal the percentage change in domestic price level (ΔP^d) minus the percentage change of the foreign price level (ΔP^f). The relative PPP implies that any currency with a higher interest rate should be reflected by a higher inflation rate relative to a currency with a lower interest rate. Relative PPP assume that the currency with higher inflation rate, and thereby higher interest rate, should depreciate relative to the currency with lower inflation rate. Then, the equation above (14) shows that relative PPP can be considered as a special case of UIP.

Since the inflation and the expected spot exchange rate in the future are not known, since they are just assumptions and the relative PPP will therefore only hold on average (Butler, 2012). Then, an explanation of the Fisher Effect is important. This relation first presented by the economist Irving Fisher views the inflation rate as the key determinant of nominal interest rates. The nominal interest rate equals the real interest rate plus the inflation rate. This illustrates the point in relative PPP stating that higher inflation rate tends to increase the nominal interest rate (Melvin and Norrbin, 2013).

By combining the Fischer effect and the relative PPP we can define another important theory in international finance, namely the International Fisher Effect. This theory uses the interest rate differential between two countries to explain changes in spot exchange rates, and thereby a similar solution as the UIP. It is also connected to the relative PPP, because the interest rates are closely correlated to the inflation rates (Oana, 2012).

3. Literature review

The vast amount of literature on carry trades, UIP and risk premium spans over a rather long time period, from classical papers like that of Fama (1984) to more recent studies from researchers like Sarno, Brunnermeier and Lustig. The literature review will be constructed in a way where we go from early findings to more recent papers and their differences.

Numerous findings relate to the classical study on UIP provided by Fama (1984) and tests the efficiency of the foreign exchange market. Fama's study is one of the many classical papers focused on this area, among other early researches we can mention Bilson (1981). Fama (1984) test the UIP condition by the regression seen below (15), to see whether the beta coefficient equals unity. He found that time varying risk premium can be one of the most likely explanations of the forward premium puzzle found in his data sample. In his paper he uses this exact notation, which has been commonly referred to in later literature and is similar to equation (12):

$$s_{t+1} - s_t = \alpha + \beta\left(f_t - s_t\right) + \varepsilon_{t+1} \tag{15}$$

The left side of equation (15) are observed at time t+1. Since the expected spot rate is unknown, the actual spot rate one period later is used (ex post). Most replications of this study reject the null hypothesis ($\beta = 1$) and often find a negative beta, which can imply a risk premium. This violation of UIP is called the forward premium puzzle, and this is precisely what the carry traders bet on, according to recent research (Brunnermeier et al., 2009).

The possible explanations of beta coefficients significantly different from unity, is further investigated in earlier papers. A large amount of literature agrees upon the failure of UIP, but they are not in complete agreement about the reason behind it. The most common explanation is the presence of a time varying risk premium, which make the foreign assets riskier when foreign interest rate rise (relatively to domestic interest rate). Another reason can be that the exchange rate is diversifiable or that the participants are risk neutral, which means that the risk premium would be zero (Froot and Thaler, 1990).

Froot and Frankel (1989) states that a risk premium is not the whole reason behind the forward premium puzzle. According to them, this implies that the bias can be due to violations of risk-neutrality and rational expectations. Engel (1996) did a survey that supports this by saying a number of risk premium-based models have failed to explain the puzzle.

In contrast to the UIP, the forward premium puzzle shows that currencies with high interest rate tend to appreciate against the currencies with lower interest rate (Farhi and Gabaix, 2008). These evidences suggest that the interest rate differentials would not give an appropriate proposal to the exchange rate movements in the future.

The forward premium puzzle, which has been examined by a number of researchers, can also be related to other earlier studies. Meese and Rogoff (1983) found evidences stating that a random walk model could predict the exchange rate changes as good as any other structural model. Speculators, like carry traders, can then make a profitable position by taking advantage of the interest rate differential, because the expected exchange rate does not change correspondingly with the condition of UIP (Brunnermeier et al., 2009).

Recent studies have explored the time variation of the risk premium. Aysun and Lee (2014) find a violation of UIP and states that time varying risk premium can explain a significant share of it. They tested the UIP condition with similar regressions as the one Fama used, and studied if these deviations were due to a risk premium. In contrast to Fama (1984) they used the interest rate differential as an independent variable in their regressions.

In the next sequence of their study they incorporated an ARCH/GARCH-in-mean analysis in order to identify a time varying risk premium as the conditional variance of expected currency returns. Their findings focus on the risk premiums dependence on the data frequency and supports that the time variation explains more of the violation in emerging economies, compared to advanced economies. This is because a larger number of emerging countries had significant values in both their conditional mean and variance equations. At a monthly frequency, the time varying risk premium can explain the excess returns from carry trades. Additionally, in emerging markets, it can also explain the excess returns on a quarterly basis (Aysun and Lee, 2014).

Lustig et al. (2011) argues that investors who take a short position in several low interest rate currencies, and a long position in several high interest rate currencies, eliminate the exposure to specific risks. By doing so, investors are no longer exposed to the common risk factors. Their findings indicated that arbitrage pricing theory could explain the carry trade returns, because higher interest rate currencies are more exposed to an introduced slope factor. This slope factor indicated that higher interest rate currencies are loaded positively, and vice versa for the lower interest rate currencies. They also used the covariation of this slope factor to account for the returns between those currencies.

Lustig et al. (2014) find some interesting results connected to the use of bonds with different maturity when it comes to carry trade returns. The term structure of risk premium in carry trade is downward-sloping and the carry trade return are smaller for bonds with longer maturities. He discovers that strategies based on three-month treasury bills (T-bill) tend to be highly profitable, whilst strategies that uses long-maturity bonds are not.

A number of studies state that the returns from carry trades presents negative skewness. Negative skewness means that large negative returns are more prominent than large positive returns (Hodrick, 2013). Cenedese et al. (2014) provide some evidences of both negative skewness and a kurtosis higher than normal. This kind of statistical results might explain the good historical return from carry trade positions. Brunnermeier et al. (2009) state that this negative skewness led to a broader demand of a risk premium among carry traders because they are exposed to “crash risk”. This is because they found a negative correlation between skewness and interest rate differentials, which mean that carry trades are exposed to the negative skewness of exchange rate movements. They found that Austrlian dollar had the highest negative skewness and the Japanese yen had the highest positive skewness, which might explain why carry trades based on Japanese yen as a funding currency was popular prior to the financial crisis of 2008.

Numerous studies refer to the volatility index of S&P 500 (VIX) in order to explain carry trade activity. Cenedese et al. (2014) provide indications of a negative relationship between return in foreign exchange market and risk. These results indicate that higher volatility, indicated by the VIX, is related to large losses in the return to carry trades. The unwinding of carry trade positions might be related to this volatility index. An unwinding might be seen as an event where the risk tolerance among investors declines as the risk exposure in the market increases (Brunnermeier et al., 2009).

According to Egbers and Swinkels (2015) carry trades generated a positive return per annum between 1996 and 2014, but suffered major losses during the financial crisis in 2008. Their findings suggest that carry trades performs poorly in times with higher risk aversion, like the financial crisis.

Brunnermeier et al. (2009) argues that the unwinding could be one of the reasons behind the skewness explained earlier. In periods with good average excess returns from carry trade activity, an expectation of a decrease in interest rate differential might lead to a possible unwinding of carry trade positions among investors. A threatening depreciation of the investment currency (appreciation of the funding currency) is likely to happen because of the huge activity in carry trades.

Evidences of carry trade returns could be misleading because of omission of low-probability events in the sample, often called peso problems. Peso problems can be seen as situations where asset prices include information about a rare event that are not included in the sample (Burnside et al., 2011). For example, Burnside et al. (2011) state that the payoff of unhedged carry trade reflects a peso problem. By showing that a hedged carry trade is resistant to large losses, they argue that those losses could be associated with peso events. Mainly because the carry trade provides larger payoff. Their findings are also supported by others. For example, Hodrick (2013) mentions the peso problem as one possible reason that the past performances of carry trade returns displays positive excess returns. If the sample includes less negative returns than expected, the average returns would be higher.

Recent research has provided explanations based on risk factors in order to explain the predictability of excess returns in currency portfolios (Lustig et al., 2011). According to Wagner (2012), research from earlier year struggled to explain the ties between exchange rates and interest rates by using traditional models without risk premium. Nevertheless, these models have dominated research since models including a risk premium are more complicated.

Wagner (2012) goes on to criticise other research for focusing too much on the beta coefficient of the Fama-regression from 1984. He argues that most of the earlier research have forgotten the implications of an alpha (constant term) different from zero. If alpha is significantly different from zero, the risk premium is constant. Earlier research has shown varying result on the constant term, but disregarding it might lead to wrong conclusion about the efficiency of speculation and therefore misjudging the value of excess returns. He states that carry traders can collect a risk premium and generate excess returns, but the return is limited.

Olmo and Pilbeam (2009) criticize the traditional regression analysis, done by Fama (1984), and argues that the autocorrelation present in the difference between forward exchange rate and spot exchange rate (forward premium/discount) leads to lower standard deviations. This becomes a problem since the standard deviation in the spot exchange rate changes are much larger than in the forward premium/discount, and therefore the estimated beta coefficients are due to high uncertainty. According to them, a reliable traditional regression analysis is only possible when the standard deviation in the exchange rate changes are really low. They provide an alternative approach based on excess returns, and argue it as a more valid test of UIP. Interestingly, they rejected the UIP based on traditional regressions, but could generally not reject the null hypothesis on the alternative approach.

4. Empirical analysis

4.1 Data description and descriptive statistics

The analyses in this thesis are based on obtained spot- and forward exchange rates from Thompson Reuters DataStream. A list of obtained data are included in appendix 1. Spot- and forward exchange rates are obtained for six currency pairs with US dollar (USD) as the base currency (foreign currency per 1 unit of USD). These currency pairs, relative to the USD, are; Australian dollar (AUD), Japanese yen (JPY), Norwegian krone (NOK), New Zealand dollar (NZD), South African rand (ZAR) and Mexican peso (MXN).

The forward rates for AUD to USD were obtained as the opposite forward rate (USD to AUD) and therefore converted it by taking the inverse (1/x). This was done in order to have this currency pair to match the other forward rates with USD as base currency. The USD was chosen as a base currency since it is one of the most used currencies among carry traders and because the findings would be more comparable with other research on this topic. These currencies, along with descriptive statistics of the change in exchange rate and the forward premium/discount, are provided in table 1.

The analyses are based on monthly observations and the time series data for all six currencies spans from January 1, 2000, to January 1, 2016. In total, the data sample covers 193 observation for each of the six currencies used in the regression analysis. 192 observations of which are valid, since we are looking at the change in spot exchange rate one month ahead relative to the spot exchange rate today. In the remainder of this thesis the denotation t+1 will be used instead of t+k, because it represents the time one month ahead.

Table 1: Summary statistics				
Country (N=192)	$s_{t+1} - s_t$		$f_t - s_t$	
	Change in exchange rate		Forward premium/discount	
	Mean	Std. dev.	Mean	Std. dev.
Australia	-0,0507	3,80887	0,2213	0,12590
Japan	0,0888	2,77845	-0,1751	0,16996
Norway	0,0557	3,35499	0,1107	0,16008
New Zealand	-0,1393	4,13248	0,2382	0,35019
South Africa	0,4838	4,81074	0,5359	0,20382
Mexico	0,3168	2,90251	0,4238	0,23994

Table 1: Descriptive statistics for dependent (change in exchange rate) and independent variable (forward premium/discount) in the regression analysis. Mean and standard deviation are on a per cent per month basis.

Table 1 provides an overview of the descriptive statistics for the change in exchange rate and the forward premium. In other words, it provides statistics on the variables which are going to be used in the regression tests on the UIP condition. The table illustrates that the USD has depreciated against AUD and NZD over the period, but appreciated against JPY, NOK, ZAR and MXN. The negative mean of the exchange rate depreciation implies that the spot exchange rate at time t+1 has on average been lower than the corresponding spot exchange rate at time t. Thus, in the case of negative mean, one unit of USD cost less and therefore the foreign currency has appreciated against the USD.

The average for the forward premiums show positive values for five out of six currencies. This indicates that the currency, on average, has been at a forward premium. A currency is at a forward premium if the forward exchange rate exceeds the current spot exchange rate. On the other hand, if the current spot exchange rate exceeds the forward exchange rate, the currency is said to be at forward discount. This is the case for the JPY.

Recall that currencies with a positive (negative) average change in the exchange rate, should have an average positive (negative) corresponding forward premium. If the currencies are at a forward premium, the change in exchange rates should also increase and indicate a depreciation of the currencies. This is the case for NOK, ZAR and MXN. Contrary to these currencies, JPY has depreciated against USD and reports a negative average forward premium, which mean that the JPY was on average at a forward discount.

The standard deviation for the two variables illustrates that there is more uncertainty following the changes in the spot exchange rates than for the forward premium (discount). This is illustrated graphically in appendix 2 and the general observation is that the change in the spot exchange rates show high volatility, especially around the financial crisis of 2008-09. On the other hand, the forward premium (discount) varies around its expected value and provide an approximately horizontal line when compared to changes in exchange rates.

4.2 Regression analyses

In order to test the UIP condition, or the forward premium puzzle, the thesis follows the econometric model presented by Fama (1984) that can be tested with a regression analysis in statistical analysis software packages. In this thesis, IBMs software SPSS, have been used to test if the UIP condition holds in reality. Like Fama (1984), regressions have been estimated on the full sample period. In addition, the full sample has been divided into two sub periods to see if the estimated regressions would yield different results. The first sub period spans from January 1, 2000, to December 1, 2007. The second one spans from January 1, 2008, to January 1, 2016. These sub periods have been chosen in order to see if the financial crisis of 2008-09 had an impact on the exchange rates and hence the regression results. This was done in accordance to the results presented by Egbers and Swinkels (2015), which found that carry trades performs poorly in times with higher risk aversion.

Numerous studies have tested if the hypothesis concerning UIP would hold, and has often found deviations from it. As mentioned in the literature review, Aysun and Lee (2014) and Fama (1984) are examples of studies that reject this hypothesis and find that UIP does not hold in their data samples. Aysun and Lee tests the ex post change in spot exchange rate on the interest rate differential between the two countries, while Fama uses the forward premium as an independent variable in the regression analysis. If CIP hold, these two different regression analyses should yield the same conclusions.

Throughout the thesis a significance level of both five and ten per cent have been used rapidly. While the five per cent level is most used in statistical analysis, a ten per cent level is included since the model contains just one independent variable. The models used are already established, and it will not be considered to include more variables. Significant results on a ten per cent level are not as rigorous as a five per cent level, and this need to be accounted for when making conclusions in later sections.

4.2.1 Classical assumptions

When formulating an econometric model, a number of conditions needs to be accounted for in order to get valid results from the ordinary least squares (OLS) regressions (Studenmund, 2014). In time series data a few conditions about the error term needs to be satisfied. First of all, the variables included in the regression analysis need to be linear. The regression model includes variables that are based on differences. These are then transformed to log-variables in order to make the form of the equation linear.

Another condition to take into account is that the variables included in the regression analysis should be stationary. Stationary variables have constant variance and stable properties at any time. Most economic variables are not stationary, but the variables can be made stationary by transforming the variables by either calculating return, taking differences between two periods, or calculating the logarithms. Transforming variables into logarithms also reduce problems of abnormal observations and normal probability (Ringdal, 2013).

The expected value of the error term should be zero and it should be uncorrelated with any of the independent variables. The error term is included to account for the variation in the dependent variable that cannot be explained by the independent variable. This condition may be a problem if any important variables are excluded from the estimated model. However, this will not be accounted for in this regression analysis since it is based on an already established model.

If the observations of the error term change for each range of observations, the variance of the error term increases with higher values of Z and it would be heteroscedastic ($Var(\varepsilon_i) = \sigma^2 Z_i^2$). This kind of Z value will often be one of the independent variables in a regression. When looking at a regression line in situations like this, the actual observations of the error term are further away for larger values of Z. This is a violation of the assumption about constant variance, which is known as homoscedasticity ($Var(\varepsilon_i) = \sigma^2$) (Studenmund, 2014).

In cases of no autocorrelation, the error terms are not correlated with each other. This is another condition to be aware of, especially for time series data. In cases where there is autocorrelation in the residuals, the standard errors in the model might be unreliable and would make the t-values and hence the p-values inaccurate. This can be accounted for by testing the Durbin-Watson value against critical value, or graphically by looking at correlograms (Studenmund, 2014).

Any deviations from these conditions will be thoroughly analyzed if they become relevant as the results and the implications are presented. It would be especially necessary to test for autocorrelation and heteroscedasticity in the residuals, and to see if the variables are stationary.

4.2.2 Econometric model for regression analysis

In this thesis, the regression relationship follow the same principle and formulations as Fama (1984). This equation has been mentioned earlier, but for simplicity it will be reproduced under:

$$s_{t+1} - s_t = \alpha + \beta\left(f_t - s_t\right) + \varepsilon_{t+1} \tag{16}$$

Again, it is important to notice that the lower cases, s and f, above illustrate that logarithms have been taken of spot exchange rate (S) and forward exchange rate (F). By taking the logarithms and differences of the variables, they tend to become stationary. Appendix 2 illustrate that these variables are fairly stationary because it shows an approximately constant mean. The analysis is independent of whether the exchange rates are expressed as domestic per foreign currency or foreign currency per domestic currency (Fama, 1984). Before running the regressions, these two variables are multiplied by 100 and thus the changes are on a per cent per month basis.

In earlier research both the forward premium and interest rate differential between two currencies have been used as independent variable. This comes from the assumption that CIP hold and this following expression can be used:

$$f_t^1 - s_t = i_t^d - i_t^f \tag{17}$$

Equation (17) states that the difference between the forward exchange rate and the spot exchange rate at time t is equal to the interest rate differential between two currencies. If there exist a risk premium in the forward rate, this must also be explained by the interest rate differential (Fama, 1984).

This regression (16) tests the change in spot exchange rate (ex post depreciation) on the forward premium. If UIP holds, the beta coefficient in this equation should equal unity ($\beta = 1$). Under this hypothesis, the log of the forward rate provides an unbiased forecast on the log of the expected spot exchange rate in the future. If beta equals unity, the change in the forward premium equals the change in the spot exchange rate and implies that a carry trade strategy should yield no excess returns. If the beta coefficient does not equal unity, the actual change in the forward premium does not equal the change of the spot exchange rates between time t and t+1. Then there should be a possibility for excess returns.

The excess return can easily be induced by equation (16). The excess return is defined as the forward premium (discount) minus the one-month change in the exchange rate.

$$ER_t = f_t - s_t - (s_{t+1} - s_t) \tag{18}$$

In later sections graphs has been constructed for both the full sample period and the two sub periods. These graphs show the cumulative excess returns of the time series data over the mentioned periods and illustrate the variation in excess returns for all the six currencies when borrowing in USD. As we will see, the riskiness of carry trades is obvious, especially around the financial crisis of 2008-09.

4.2.3 Regression results

The estimated coefficients and t-values in table 2 are based on the econometric model explained in section 4.2.2. A more detailed output from the regression analyses are presented in appendix 3.

Table 2: Regression results - 01.01.2000 to 01.12.2015					
Country (currency per USD)	$\boldsymbol{\alpha\ (SE)}$	**T-value** $\boldsymbol{H_0: \alpha = 0}$	$\boldsymbol{\beta (SE)}$	**T-value** $\boldsymbol{H_0: \beta = 1}$	$\boldsymbol{R^2}$
Australia	0,262 (0,558)	0,470	-1,415 (2,192)	-1,102	0,002
Japan	0,055 (0,289)	0,190	-0,193 (1,186)	-1,006	0,0001
Norway	0,066 (0,295)	0,225	-0,096 (1,52)	-0,721	0,000021
New Zealand	-0,005 (0,362)	-0,015	-0,562 (0,855)	-1,827*	0,002
South Africa	2,635 (0,967)	2,724***	-4,013 (1,687)	-2,972***	0,029
Mexico	0,599 (0,426)	1,404	-0,665 (0,876)	1,901*	0,003

Table 2: Regression results for the full sample obtained by estimating: $s_{t+1} - s_t = \alpha + \beta(f_t - s_t) + \varepsilon_t$. **, ** and *** denote the statistical signifance at 10%, 5%, and 1%, respectively. Critical values for two sided t-test: 1,645 (10%), 1,96(5%) and 2,576(1%). The standard errors of the estimated regression coefficients are in parentheses.*

The estimated regression results for the full time period shows that all currencies have negative beta coefficients, ranging from -4,013 for ZAR to -0,096 in NOK. Findings of a negative beta coefficient ($\beta < 0$) for all currencies (only three significant) indicate that an increased forward premium will result in a decline of the expected change in exchange rates. This indicate that the six currencies appreciate, rather than an expected depreciation. Though, the estimated t-values for $\beta = 1$ are not significant at any of the three different significance levels for AUD, JPY and NOK. NZD and MXN reports beta coefficient significantly different from unity at a 10% level. ZAR reports a significant beta coefficient at a 1% level. In our case, significant values indicate that the change in the forward premium is significantly different from the changes in the exchange rate.

Both ZAR and MXN are significant at five- and ten per cent level respectively. They are seen as emerging market economies and hence riskier to hold than currencies in more advanced economies like Australia, Japan and Norway. This may lead to significant deviations from UIP, because of both an increased- and more volatile risk premium.

The standard errors for these estimated coefficients are fairly high, and this affects the estimated t-values. One of the conditions in OLS is that the error terms should not correlate with each other. If they are correlated, we deal with autocorrelation. This can be accounted for by looking at the Durbin-Watson (DW) estimate, which is included for all currencies along with the regression output in appendix 3.

The Durbin-Watson statistics from the regressions, range from 1,774 (MXN) to 2,006 (NZD). Five out of six currencies show values lower than two, and the standard critical values for d_L and d_U are retrieved from a critical table. Critical values for 200 observations and one independent variable have been chosen (since N=192 and K=1). The critical values are then 1,76 and 1,78. Four out of five currencies with DW under two are above the upper limit, and the hypothesis about no autocorrelation cannot be rejected. MXN reports a DW value of 1,774, which mean that the test is inconclusive since the value lies between lower and upper limit.

For NZD with a value of 2,006 a test for negative autocorrelation is needed, since the value exceeds two. Critical values are now four minus the upper and lower critical values, which results in 2,22 and 2,24 respectively. The test value is below the lower limit and the hypothesis cannot be rejected. None of the six currencies have significant autocorrelation, and the error terms seem to be uncorrelated with each other. Although, the test for MXN is inclusive and therefore no autocorrelation is assumed.

The coefficients of determination (R^2) are low for the all six currencies, and this can be related to the descriptive statistics (table 1) on the standard deviation for the two included variables. The low R^2 are because of the variations in the forward premium (discount) are much lower than for the changes in exchange rate. It implies that the forward premium (discount) cannot explain a major part of the variation in changes for exchange rates. This is because the model includes just one independent variable, and more variables would most likely have increased the explanatory power. However, as mentioned this thesis uses an already established model, and this will not be taken into consideration. Instead, the t-values (indirectly the p-values) can be used to measure the goodness of fit.

The residual plots provided in appendix 3, which shows the predicted values against the fitted values, report signs of heteroscedasticity for NZD and MXN. This is a violation of the assumption about constant variance for the error terms, which might contribute to different results because of a violation of the different assumptions in OLS. The findings of non-constant variance for these currencies does not affect the estimated coefficients, but the standard errors might be underestimated and it need to be accounted in conclusions about significance.

Although most of the literature on the forward premium puzzle exclusively focuses on the negative beta coefficient, it would also be useful to look at the constant term alpha (α) and test the hypothesis stating that it is zero. These values are included in the tables for both the full sample period and the two sub periods. The estimated results show that it is significantly different from zero for ZAR in the full period, but reported coefficients for the other currencies show alphas insignificantly different from zero. In the estimated regressions the alpha coefficients are fairly high because the changes in exchange rate and the forward premium (discount) are multiplied with 100 before the estimation, but the t-values and thus the test of the null hypothesis are similar to regressions without the multiplication.

In table 1 the standard deviation from the changes in spot exchange rates are much larger than for the forward premium for both periods. As a consequence, the amount of uncertainty connected to the coefficients for the traditional regression would increase. This may be one of the reasons why the beta coefficients for the full sample period are generally non-significant.

It can be clearly seen in the regressions from table 2 that there is a lack of violations from the UIP condition for most of the currencies. As seen above, ZAR reported a significant beta coefficient at a one per cent level. This is a strong violation of UIP and is a sign of a risk premium. ZAR also reported an alpha coefficient significantly different from zero on the same significance level. This would further validate the existence of a risk premium for ZAR.

Two additional currencies, MXN and NZD, also display signs of a risk premium. These currencies only show a violation of the UIP condition at a ten per cent significance level and only for the beta coefficients. However, these two currencies showed signs of heteroscedasticity and therefore they may need to be treated as non-significant.

These results are odd, since there are so few violations of UIP, and especially when it is almost universally considered by researchers that the UIP condition does not hold. Therefore, it is necessary to be critical to the results presented so far, and it might be necessary to look upon the sub periods to validate these results. As mentioned earlier, this thesis has followed Fama (1984) and divided its data sample into two sub periods and will test for deviations from the UIP condition. The sub periods have been divided into pre crisis and post crisis, in order to see if the financial crisis and the recent crash in oil prices might have impacted the data analysis.

4.2.4 Sub period results

4.2.4.1 Sub period 1

The descriptive statistics for the first sub period (appendix 4) show that USD has depreciated against AUD (negative mean of exchange rate depreciation), but appreciated against JPY. Together, these means predict a depreciation of JPY relative to AUD, which is consistent with findings presented by Brunnermeier et al. (2009). According to them, carry traders may have exploited the interest rate differentials between JPY to AUD to earn excess returns. AUD has provided high interest rates, and JPY on the other hand, has delivered low interest rates. Summarizing, the descriptive statistics seem to be consistent with conclusions made by Brunnermeier et al. (2009) prior to the financial crisis of 2008-09.

Table 3: Regression results for the first sub period – 01.01.2000 to 01.12.2007					
Country (currency per USD)	$\alpha\ (SE)$	**T-value** $H_0: \alpha = 0$	$\beta (SE)$	**T-value** $H_0: \beta = 1$	R^2
Australia	0,376 (0,522)	0,736	-4,203 (2,447)	-2,126**	0,031
Japan	-0,646 (0,596)	-1,085	-2,492 (1,79)	-1,951*	0,020
Norway	-0,283 (0,329)	-0,861	-1,203 (1,422)	-1,549	0,008
New Zealand	-0,071 (0,436)	-0,163	-1,344 (0,961)	-2,439**	0,021
South Africa	2,35 (1,081)	2,174**	-4,277 (1,854)	-2,846***	0,054
Mexico	0,654 (0,413)	1,581	-0,951 (0,705)	-2,767***	0,019

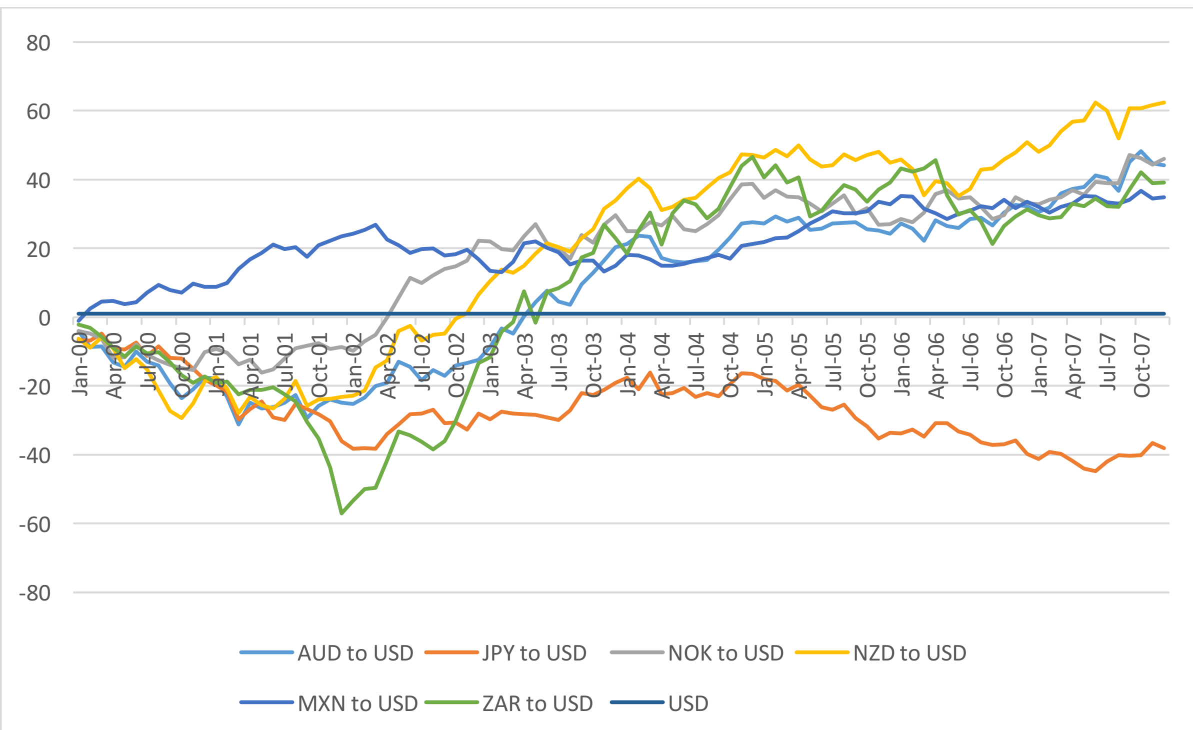
*Table 3: Regression results for the first sub period. *, ** and *** denote statistical significance at 10%, 5%, and 1%, respectively. Critical values for two sided t-test: 1,66 (10%), 1,984 (5%) and 2,626 (1%). The standard errors of the estimated regression coefficients are in parentheses.*

The first sub period spans from the beginning of 2000 to end of 2007 and the beta coefficients are negative and significant for five out of six currencies. However, JPY report a significant beta coefficient at a ten per cent level. It is worth mentioning that even though there is an increased number of significant currencies, there is still only ZAR which shows a significant rejection of the alpha hypothesis. The change in the forward premium (discount) are significantly different from the change in the spot exchange rate.

Since the forward premium (discount) is comparable to the interest rate differential, a negative beta coefficient that is significantly different from unity would imply that the higher interest rate currency should appreciate. A carry trade strategy would make profit from the appreciation, in addition to the interest rate differential. This is a deviation from the UIP condition. According to Fama (1984) this might be due to a time varying risk premium. This could then be the case for four out of six currencies at a five per cent level, and additionally for JPY at a ten per cent level.

By using the definition of excess return explained in equation (18) the following graph (3) is provided to give a further understanding of risk and return associated with carry trades.

Graph 3: Cumulative excess return sub period 1



Graph 3: Represents cumulative excess return in US Dollar from investing in foreign currency, and reinvesting it throughout the period: 01.01.2000 – 01.12.2007.

By looking at graph 3 it is possible to see the graphical representation of the cumulative excess return earned from investing in x amount of foreign currencies and reinvesting the return on a monthly basis throughout sub period 1. When the graph is above the blue line (which represents US domestic return = 1), an investor will make positive return from investing in the foreign currency. In other words, when the curve is above the USD line, the investment in foreign currency has outperformed the domestic rate of return. This also implies that when the curve is below, investing in the foreign currency has underperformed in relation to the US domestic return. Note that this means the carry trade would be profitable when turned around and investors borrow foreign currency and invests in USD.

By taking a closer look at the graph, it should be fairly obvious that there has existed a possibility to gain excess returns, especially from mid 2003 and towards the end of 2007 for all of our currencies. For JPY, it would be profitable by reversing the strategy. This gives us further indicators that the UIP condition generally does not hold for the first sub period.

Sub period 1, as mentioned above, present a different result than the full period. This gives a strong indicator that the results presented table 2 might be influenced by events that happened during sub period 2. To understand the contradictory findings between the results provided table 2 and 3, it is necessary to look towards sub period 2 to find possible reasons behind this.

4.2.4.2 Sub period 2

Table 4: Regression results for the second sub period – 01.01.2008 to 01.12.2015					
Country (currency per USD)	$\alpha\ (SE)$	**T-value** $H_0: \alpha = 0$	$\beta(SE)$	**T-value** $H_0: \beta = 1$	R^2
Australia	0,26 (1,521)	0,171	-0,23 (5,185)	-0,237	0,000021
Japan	0,673 (0,362)	1,842*	11,073 (4,218)	2,388**	0,068
Norway	-0,522 (0,984)	-0,531	7,416 (6,548)	0,980	0,013
New Zealand	-0,017 (0,585)	-0,029	0,612 (1,507)	-0,257	0,002
South Africa	2,83 (2,19)	1,293	-3.606 (3,887)	-1,185	0,009
Mexico	0,193 (0,876)	0,221	0,865 (2,402)	-0,056	0,001

*Table 4: Regression results for the second sub period. *, ** and *** denote the statistical significance at 10%, 5%, and 1%, respectively. Critical values for two sided t-test: 1,66 (10%), 1,984 (5%) and 2,626 (1%). The standard errors of the estimated regression coefficients are in parentheses.*

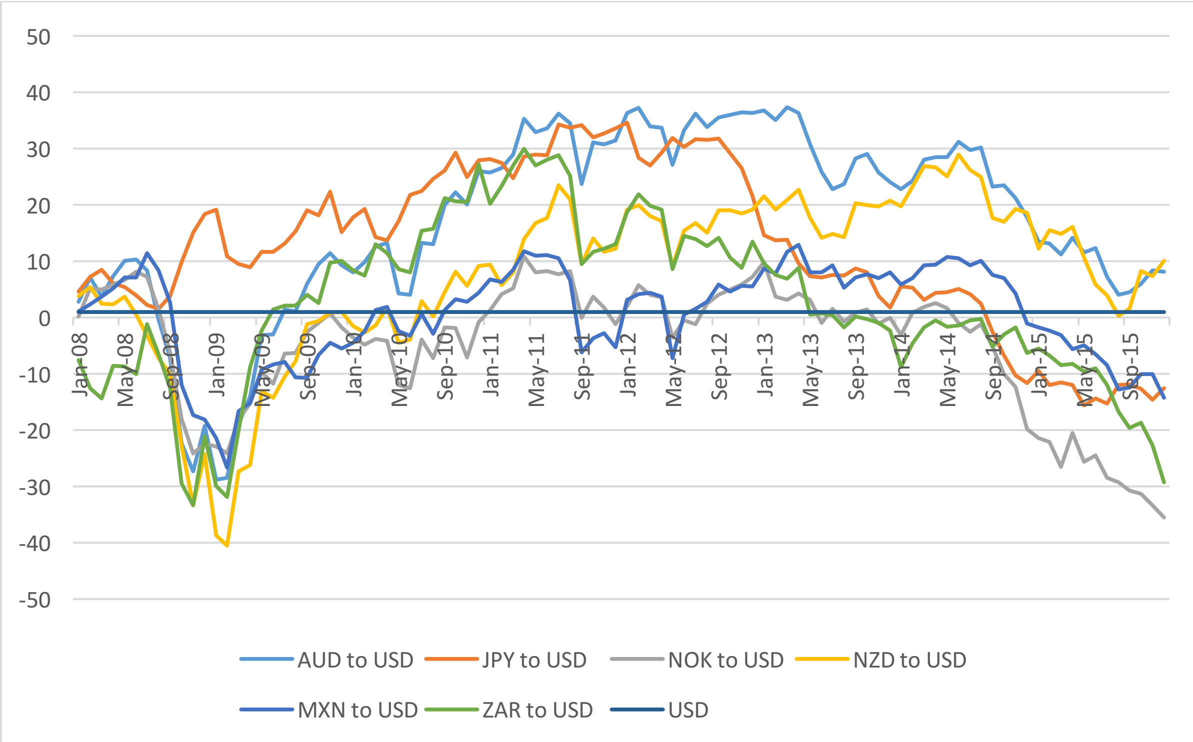
The second sub period, from the beginning of 2008 to the beginning of 2016, report interesting results. There is just one significant beta coefficient, which is for JPY. Interestingly this estimated coefficient is not negative, but highly positive with a value of 11,073. The number of currencies with negative beta coefficients are smaller for the second sub period. The differences in the beta coefficients between the two sub periods are large and it switches from negative to positive values for the currencies JPY, NOK, NZD and MXN.

One possible reason for the changes from negative beta coefficients in sub period 1 to positive coefficients in sub period 2 might be that currencies strengthened due to greater capital inflows. An example of these high capital inflows is the safe haven effect. Ranaldo and Söderlind (2010) define safe haven currencies are currencies that benefits from negative risk exposure, as it appreciates when market risk and volatility increases. They argue that JPY are among the currencies that moved inversely with international markets and foreign exchange volatility. This can be relatable to the results, where the estimated beta coefficients show that JPY is the currency that changes most between the sub periods. Another reason might be that the government implicated an expansionary fiscal policy, which made interest rates decrease.

It is important to notice that sub period 2 stretches through the financial crisis and the recent crisis in the oil prices, which has caused sharp changes in the exchange rates during this period. In this period, the profitability of carry trade strategies was greatly reduced compared to earlier years (sub period 1). This can be due to unwinding of the carry trade, which happens in times with increased risk exposure. This can be related to the findings done by Egbers and Swinkels (2015).

The differences between the beta coefficients from the different sub periods show that carry trades are exposed to crash risk through “flight to quality” or “flight to liquidity”. In times of uncertainty in financial markets, investors would want to move their assets to more secure investments. This is similar to an unwinding of carry trade positions, which often happen in times with high volatility in the financial market. Appendix 2 illustrates this high volatility and the uncertainty about future spot exchange rate, and it is especially high in 2008 and 2009 for all currencies relative to the USD.

Graph 4: Cumulative excess return sub period 2



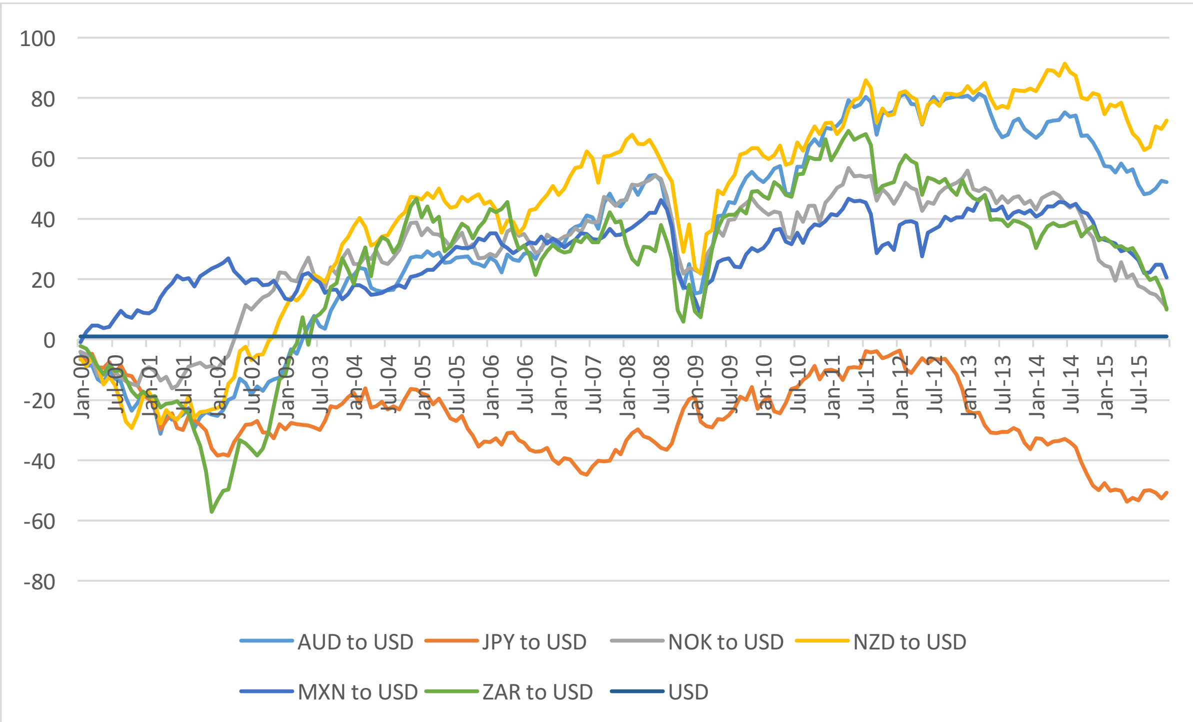
Graph 4: Represents cumulative excess return in USD from investing in foreign currency, and reinvesting it throughout the period: 01.01.2008 – 01.12.2015.

The differences between the two sub periods might be best illustrated when looking at graph 4 in relation to graph 3 from sub period 1. When looking at graph 3 we could clearly see the possibility of generating excess returns, whilst in graph 4 there seems to be less possibilities to generate the same excess returns. The cumulative excess return for most currencies changes between positive and negative values very frequently for some currencies during this time period. This would seemingly make a carry trade strategy more exposed to risk, and might explain the upset in the regression analyses.

In order to understand the results presented in the sub periods, the next section will try to explain the implications and provide a graphical overview of excess returns based on the full data sample.

4.2.5 Implications of sub period results

Graph 5: Cumulative excess return



Graph 5: Represents cumulative excess return in USD from investing in foreign currency, and reinvesting it throughout the period: 01.01.2000 – 01.12.2015.

Graph 5 represent the same cumulative excess return, but now for the whole sample period. As seen from the graph there seems to exist a possibility for a profitable carry trade strategy, especially from around April 2003. For many of the currencies; however, there seems to be an unwinding of the carry trades profitability around the financial crisis. There also seems to be a similar loss of profitability for MXN, NOK, and ZAR around the oil price crisis from late 2014 and throughout our sample period.

This unwinding of carry trades seems to be the reason behind the drastically different regression results presented in the sub periods. The differences between the two sub periods can therefore have influenced the results from the full data sample. By looking at graph 5 it is possible to see that the different curves changes in similar ways compared to the USD.

ZAR changes a lot during the period, which implies that the risk premium varies throughout the full sample. When looking at graph 5 this also seems to be the case for most of the other currencies. This might imply that there is a time varying risk premium that is not identified by the regression analysis. It will therefore be conducted a test to try to identify a time varying risk premium on all of the currencies. This test will be conducted on the full sample period, but not on either of the sub periods.

Speculations on what kind of strategies would generate profits, will however not be discussed further as this falls outside the scope of this thesis.

4.3 Model for time varying risk premium

4.3.1 Excess return

The different regression results from the two sub periods imply that it could be a time varying risk premium, since the beta coefficients for several currencies change a lot from sub period 1 to sub period 2. This may be the reason why the UIP condition could not be rejected for the full sample period. The cumulative excess return diagram (graph 5) illustrate this by showing a correction in the return around the period of 2008-09.

Olmo and Pilbeam (2009) proposed that the traditional econometric regression test based on Fama (1984) may be unreliable. This is because of the large differences in the standard deviations (volatility) between the changes in exchange rates and the forward premium (discount). They follow a similar approach as Aysun and Lee (2014) and construct a test based on excess return. This thesis implement the approach presented by Aysun and Lee (2014) in order to test for the possibility of time variation in the risk premium. Risk neutrality between participants in the foreign exchange market are seen as lenient, but rational expectations are assumed to hold.

Based on the UIP condition illustrated in the work done by Fama (1984), and Aysun and Lee (2014), a definition of the expected excess return on currency strategies like carry trades can be made. Aysun and Lee (2014) expresses this definition as:

$$ER_t = i_t^d - i_t^f - (s_{t+1} - s_t) \tag{19}$$

Since the regression analyses on UIP follows Fama (1984) and since information on forward rates is more readily available than interest rates (e.g. while there are many interest rates variables it is almost possible to obtain trader specific interest rates), it is assumed that CIP hold (equation (17)) and therefore the excess return variable is rearranged as:

$$ER_t = f_t - s_t - (s_{t+1} - s_t) \tag{20}$$

Where the forward premium $(f_t - s_t)$ has replaced the interest rate differential between the domestic and foreign currency $(i_t^d - i_d^f)$. This equation (20) can also be expressed the other way, where the excess returns equals the change in the spot exchange rates minus the forward premium. This would yield the same absolute return, but with opposite sign.

If the current spot exchange rate is removed from both the forward premium and change in spot exchange rate, it is comparable to buying a foreign currency at a forward contract at time t and sell it in the spot market one period later:

$$ER_t = f_t - s_{t+1} \tag{21}$$

The excess returns can be interpreted as a carry trade strategy that uses the USD as funding currency and foreign currency as the investment currency. According to UIP, this excess return should not be forecastable and is expected to be zero (Brunnermeier et al., 2009):

$$E\left[ER_t\right] = 0 \tag{22}$$

The descriptive statistics for the excess return are provided in table 5. All the currencies, except JPY, has on average offered positive excess return against the USD.

Table 5: Descriptive statistics on excess returns						
Country	**Mean**	**Std. dev**	**Skewness**	**Kurtosis**	**Jarque-Bera**	**P-value**
Australia	0,272050	3,816827	-0,428816	4,350285	20,47042**	0,0000
Japan	-0,263913	2,785651	-0,281576	3,040225	2,550062	0,2794
Norway	0,055058	3,359545	-0,217538	3,390430	2,7338	0,2549
New Zealand	0,377534	4,163871	-0,368498	4,292032	17,7001**	0,0001
South Africa	0,052036	4,849561	-0,322372	3,924715	10,16634**	0,0062
Mexico	0,106917	2,925523	-1,096538	8,725901	300,7642**	0,0000

*Table 5: Descriptive statistics for the monthly excess returns. Sample period from January 2000 to January 2016. * and ** denote statistical significance at 10% and 5%, respectively.*

The test value of Jarque-Bera (table 5) and the corresponding p-values show that four currencies are significant. The Jarque-Bera test the null hypothesis that skewness and kurtosis are zero, which in case implies a normal distribution. The excess return is normally distributed for all currencies, except JPY and NOK. For these four currencies the Borrelslev-Wooldridge heteroscedastic consistent covariance matrix have been used when conducting further analysis. This will make sure the results are not biased because of the non-normality found from the Jarque-Bera statistics. For the two non-significant currencies ordinary covariance matrix is used.

In order to test the time varying risk premium, a test for generalized autoregressive conditional heteroscedasticity (GARCH) is useful. Specifically, the GARCH-in-mean model (GARCH-M) is used because it allows the conditional variance to affect the mean of excess returns (Engle et al., 1987).

Such tests are common in financial time series data and especially where the error term of a model may be non-constant, related to the classical assumptions mentioned in section 4.2.1. In this thesis, a GARCH-M model is helpful to verify if the residuals of excess returns are heteroscedastic, and thus may indicate a time varying risk premium in excess returns of currency trading strategies like carry trade.

Before estimating the GARCH-M model for the excess return on the six currencies, it is necessary to look for ARCH-effects in the residuals of the specified model. Significant ARCH-effects indicate that the residuals are heteroscedastic and therefore might affect the mean of excess returns. It is necessary to specify the regression of ER_t as a constant term (ϕ) in addition to an error term (ε_t):

$$ER_t = \phi + \varepsilon_t \tag{23}$$

The constant term is simply the expected value of excess return, defined as the average return of the sample period ($\phi = \overline{ER}_t$). Olmo and Pilbeam (2009) and Brunnermeier et al. (2009) argues that similar tests based on excess returns are a good empirical alternatives to test the UIP condition. Equation (23) can be tested by a OLS regression to test whether the constant term, or the average excess return over the sample periods, is significantly different from zero. This would imply a risk premium. This thesis only uses equation (23) in order to examine the residuals and later include the conditional variance as an independent variable in the GARCH-M.

The next step is to use equation (23) to test for heteroscedasticity in the residuals. The estimated residuals are the actual excess return for each period minus the average return over the sample period:

$$\varepsilon_t = ER_t - \overline{ER}_t \tag{24}$$

The usual method to test the heteroscedasticity in the error terms are the ARCH-test. In the next section a detailed overview of this test, in addition to the results will be provided.

4.3.2 Testing for ARCH-effects

A test regression for the residuals is constructed in order to identify possible ARCH-effects. The variance in the residuals is dependent on its lagged variables for p periods. This thesis follow Aysun and Lee (2014) and construct a test regression with 5 lags. The general model with p lags are derived as:

$$\varepsilon_t^2 = \delta_0 + \delta_1\varepsilon_{t-1}^2 + \delta_2\varepsilon_{t-2}^2 + \ldots + \delta_p\varepsilon_{t-p}^2 \tag{25}$$

Where the squared residuals have been used as a denotation for the variance of the residuals. The independent variables in equation (25) are the lagged variables of the squared residuals from equation (24). If the residuals indicate ARCH-effects, the variance of the error term is heteroscedastic. The null hypothesis of this test regression is that $\delta_1 = \delta_2 = \cdots = \delta_p = 0$. If the hypothesis is rejected, that one of the slope coefficient is significantly different from zero, the residuals contains ARCH-effects.

Below (table 6) the equation (25) has been estimated by OLS and residual diagnostics on the error term has been used to test whether the residuals contain ARCH-effects. It has been constructed based on five lags. The squared residuals from the main excess return equation depends on the squared residuals from the five previous periods. These results are also included in appendix 5.

Table 6: Testing for ARCH- effects						
Number of lags	**1**	**2**	**3**	**4**	**5**	**t-value LM TEST**
Australia	0,171	0,000	0,723	0,468	0,026	26,722***
Japan	0,537	0,243	0,154	0,904	0,260	5,538
Norway	0,075	0,086	0,066	0,686	0,223	9,753*
New Zealand	0,580	0,000	0,502	0,223	0,784	38,196***
South Africa	0,161	0,348	0,193	0,963	0,086	9,998*
Mexico	0,060	0,684	0,789	0,013	0,054	16,708***

*Table 6: The t-values from the Lagrange multiplier test are given as TR^2, where observations (T) are multiplied with R^2 from equation (24). It follows a chi squared distribution ($\chi^2(q)$) with q lags. 10%, 5% and 1% statistical significance are denoted as *, **, and ***, respectively.*

In cases of currencies with ARCH-effects, the model can be further developed to test the significance of both a constant- and time varying risk premium. However, this thesis will focus primarily on the significance of the time varying risk premium. The numbers presented the first columns in the table 6 are the p-values. In the last column, the t-value of the Lagrange multiplier test show that three currencies have significant ARCH-effects on a one per cent level. This is the case for AUD, NZD and MXN. NOK and ZAR are significant at a ten per cent level. Since JPY is insignificant at all three levels, it will be excluded from the following analysis. Significant ARCH-effects can also be seen by the estimated p-values, since they are under 0,05 or 0,1 for one of the five lags. Although a ten per cent significance level is not statistically strong, a GARCH-M model will still be constructed for all currencies that are significant at this level.

4.3.3 GARCH-in-mean model

In the continued model excess return depends on its own conditional variance, now denoted ht, and allows the volatility to change over time. The specification of conditional variance ht are defined in various ways when it comes to an ARCH-in-mean and GARCH-M model. According to Aysun and Lee (2014) a GARCH-M model may be more successful results, and therefore the following analysis is based on GARCH-M (1,1). The variance equation, which is the first of two important equations, can be expressed as follows:

$$h_t = \delta_0 + \delta_1 \varepsilon_{t-1}^2 + \delta_2 h_{t-1} \tag{26}$$

Where the conditional variance is a linear function of a constant term, one ARCH-term (past squared errors) and one GARCH-term (past conditional variance).

The logarithm of the conditional variance, estimated from the variance equation (26), is allowed to be included in the mean equation (27) as an independent variable. According to Engle et al. (1987), taking the log of the estimated conditional variance from the variance equation is found to be more successful in empirical research. The excess return is now dependent on a mean, a variance component and a "white noise" process:

$$ER_t = \phi_0 + \phi_1 \ln ht + \varepsilon_t \tag{27}$$

The excess return is now dependent on a time varying risk premium ($\phi_1 lnht$), in addition to the constant risk premium (ϕ_0). The main idea behind the formulation is to test if the excess returns is an increasing function of the time varying risk premium, which in this analysis is its own conditional variance. If both the risk premium coefficients are insignificantly different from zero, it implies a nonexistent risk premium in the data sample. If either the constant- or time varying risk premium is significantly different from zero, there exists a risk premium. If the sign of the estimated coefficients is positive, this indicate a positive relationship between currency excess returns and volatility. Potential return will then rise with an increased volatility (risk).

In table 7 the estimated coefficient from the GARCH-M (1,1) are shown. The coefficients from the mean equation are presented in the first two columns, while the last three presents the variance equation. A more detailed overview of the results is presented in appendix 6.

Table 7: GARCH-M estimates						
	GARCH	$\boldsymbol{\phi_0}$	$\boldsymbol{\phi_1}$	$\boldsymbol{\delta_0}$	$\boldsymbol{\delta_1}$	$\boldsymbol{\delta_2}$
AUD	GARCH (1,1)	-3,691	1,554	2.364	0,131	0,701**
	SE	3,750	1,456	1,535	0,107	0,167
	P-value	0,3249	0,2860	0,1236	0,2216	0,0000
NOK	GARCH (1,1)	60,289	-25,106	9,058	0,008	0,168
	SE	370,394	254,234	7,470	0,050	0,168
	P-value	0,8707	0,8707	0,2254	0,8658	0,8090
NZD	GARCH (1,1)	-1,761	0,826	3,671	0,140	0,635**
	SE	3,802	1,406	2,640	0,089	0,195
	P-value	0,6433	0,5568	0,1644	0,1154	0,0011
ZAR	GARCH (1,1)	-7,369**	2,485**	1,274*	0,113**	0,834**
	SE	2,129	0,766	0,725	0,051	0,062
	P-value	0,0005	0,0012	0,0789	0,0269	0,0000
MXN	GARCH (1,1)	1,095	-0,459	0,736	0,336	0,640**
	SE	0,690	0,394	0,613	0,253	0,201
	P-value	0,1124	0,2446	0,2301	0,1844	0,0015

Table 7: Results from estimating GARCH-M (1,1). Mean equation: $ER_t = \phi_0 + \phi_1 lnht$. *Variance equation:* $h_t = \delta_0 + \delta_1 \varepsilon_{t-1}^2 + \delta_2 h_{t-1}$. *Table provides coefficients, standard errors (SE) and p-values. 10% and 5% statistical significance are denoted as * and **, respectively.*

While the test for ARCH-effects showed that the error term was heteroscedastic for five out of six currencies at a ten per cent level, the GARCH-M (1,1) fails to find evidences of both constant and time varying risk premium except in the case for ZAR.

The results from GARCH-M analysis show that the time varying risk premium does a good job in explaining the deviation from the UIP condition for ZAR. The results show statistical significant terms on both the mean equation and the variance equation. For the other currencies, there is just significant coefficients in the variance equation.

Both the constant (ϕ_0)- and time varying risk premium (ϕ_1) are significant at a 5%-level for ZAR, but the results for the other four currencies are different. The model provides statistical significant terms on the conditional variance equation for AUD, NZD and MXN, but not in the mean equation. This indicate that the GARCH-specification is supported by these three currencies, but the results does not provide any signs of a constant- or time varying risk premium.

ZAR also showed statistical significance in the estimated results from table 2, and table 1 show that the currency had the highest volatility of the spot exchange rate over the sample period. Appendix 4 show that ZAR also had highest volatility in both sub periods. In the GARCH-M (1,1)-model the mean equation reports both significant constant risk premium and time varying risk premium. The positive time varying risk premium in ZAR indicates that the excess return is positively related to its volatility, showing a risk-return tradeoff. The illustration of the cumulative return in graph 5 illustrates that ZAR had the largest negative value, and among the currencies with largest cumulative return during the sample period.

The findings in the case of ZAR is consistent with the findings from Aysun and Lee (2014), in such a way that this thesis also found a negative constant risk premium and a positive time varying risk premium. The main idea of this approach was to look at the time varying risk premium, since it has been named as the reason behind the rejection of UIP. According to this, the time varying risk premium did a good job explaining the rejection of UIP for ZAR between 2000 and 2016.

The conditional variances, which is included as an independent variable, are illustrated in appendix 7. The conditional variance (volatility) from the fitted GARCH (1,1) does a good job capturing the volatility clustering in excess returns. As for ZAR, the conditional volatility varies more correlated with the excess returns than the other currencies. This is consistent with the finding of time varying risk premium.

In the cases for AUD, NZD and ZAR the constant risk premium reports negative signs, which implicate that investing in riskier currencies actually pays lower premium than in a safe investment. Though, the risk premium is not significantly different from zero for AUD and NZD. The fluctuations in the market around the financial crisis of 2008-09 may have caused this negative signs, because of the unwinding of carry trades due to the high volatility in the market.

The rejection of UIP for NZD and MXN in the traditional regressions, on a ten per cent level, could not be explained by the time varying risk component in the GARCH-M analysis. This implicate that the slightly deviations of UIP for these two currencies are not induced by a time varying risk premium. This may be because of the rejection of the hypothesis about rational expectations Froot and Thaler (1990) or the findings of heteroscedasticity in the residuals explained in section 4.2.3.

An estimated GARCH-M (1,1) model can be evaluated using graphical or statistical techniques. According to Zivot (2008), the residuals of the estimated GARCH-M (1,1) should not display any heteroscedasticity or autocorrelation.

NOK reports unusual coefficients in both mean equation and in the conditional variance equation of the GARCH-M (1,1). By formulating a test for remaining ARCH-effects in the residuals and in addition a test for autocorrelation, it can be shown that the estimated residuals display autocorrelation. Appendix 6 provide graphs for autocorrelation in squared residuals. The graphs indicate significant autocorrelation for the analysis on NOK, but not for the other four currencies. The results from remaining ARCH-effects are consistent with the correlograms and show significance just for NOK.

5. Conclusion

In this thesis it has been tested whether or not it is possible to identify a risk premium in trading strategies like carry trades, and if it is possible to find a time varying risk premium. This has been done by collecting time series data for six different currencies in relation to USD, and analysed these in order to see if UIP holds. Literature has often found that a rejection of UIP might be a sign of risk premium.

The traditional regression analyses could not reject the condition of UIP, on a five per cent level, for five out of six currencies. The only rejection of UIP was for ZAR and therefore the only currency that showed sign of a risk premium.

The time series data used in this thesis spans from the beginning of 2000 to the end of 2015. The data sample was divided into two sub periods to see if the financial crisis affected the estimations. The first sub period showed significant rejections of UIP for most of the currencies, while the latter generally provided non-significant results.

Even though the full sample period showed generally non-significant results, the sub periods indicate that events as of 2008 had a strong influence on the results. The changes from negative- to positive beta coefficients between the sub periods might indicate the presence of a time varying risk premium that is not identified by the traditional regression analysis.

The second part of the research question raised the issue on whether or not the risk premium was time varying. Each of the currencies was analysed, except for JPY, because it did not show any signs of heteroscedasticity in the residuals of excess return. The estimated results from the GARCH-M (1,1) analysis generally found no evidences for time varying risk premium during the period from 2000 to the end of 2015. The only exception was for ZAR and the fact that there is still only ZAR that is significant strengthen the results we got from the original regression, and that there is generally not possible to identify a constant or time varying risk premium for this time period.

The reason why this thesis could generally not identify a constant- or time varying risk premium, might be because the data sample is too short to withstand the impact that the financial crisis and the recent crash in oil prices might have had upon it. By reproducing the analyses with a longer data sample, the results might have been more consistent with earlier research. However, this does not change the conclusion about generally non-significant evidences of a constant- or time varying risk premium from the beginning of this millennium and until the end of 2015.

References

AKRAM, Q. F., RIME, D. & SARNO, L. 2008. Arbitrage in the foreign exchange market: Turning on the microscope. *Journal of International Economics,* 76**,** 237-253.

AYSUN, U. & LEE, S. 2014. Can time-varying risk premiums explain the excess returns in the interest rate parity condition? *Emerging Markets Review,* 18**,** 78-100.

BILSON, J. F. O. 1981. The "Speculative Efficiency" Hypothesis. *The Journal of Business,* 54**,** 435-451.

BRUNNERMEIER, M. K., NAGEL, S. & PEDERSEN, L. H. 2009. Carry trades and currency crashes. *NBER Macroeconomics Annual,* 23**,** 313-347.

BURDA, M. & WYPLOSZ, C. 2009. *Macroeconomics : a European text,* Oxford, Oxford University Press.

BURNSIDE, C., EICHENBAUM, M., KLESHCHELSKI, I. & REBELO, S. 2011. Do Peso Problems Explain the Returns to the Carry Trade? *The Review of Financial Studies,* 24**,** 853-891.

BUTLER, K. C. 2012. The International Parity Conditions and Their Consequences. *Multinational Finance : Evaluating Opportunities, Costs, and Risks of Operations.* 5th ed ed. Somerset: John Wiley & Sons.

CENEDESE, G., SARNO, L. & TSIAKAS, I. 2014. Foreign exchange risk and the predictability of carry trade returns. *Journal of Banking and Finance,* 42**,** 302-313.

CHINN, M. D. 2012. Macro Approaches to Foreign Exchange Determination. *Wiley Handbooks in Financial Engineering and Econometrics : Handbook of Exchange Rates.* John Wiley & Sons.

EGBERS, T. & SWINKELS, L. 2015. Can implied volatility predict returns on the currency carry trade? *Journal of Banking & Finance,* 59**,** 14.

ENGEL, C. 1996. The forward discount anomaly and the risk premium: A survey of recent evidence. *Journal of Empirical Finance,* 3**,** 123-192.

ENGEL, C. 2011. The Real Exchange Rate, Real Interest Rates, and the Risk Premium. National Bureau of Economic Research, Inc.

ENGLE, R. F., LILIEN, D. M. & ROBINS, R. P. 1987. Estimating Time Varying Risk Premia in the Term Structure: The Arch-M Model. *Econometrica,* 55**,** 391-407.

EVANS, M. D. D. & RIME, D. 2012. *Micro Approaches to Foreign Exchange Determination*.

FAMA, E. F. 1984. Forward and Spot Exchange Rates. *Journal of Monetary Economics,* 14**,** 319-338.

FARHI, E. & GABAIX, X. 2008. Rare Disasters and Exchange Rates. *National Bureau of Economic Research,* 13805.

FRANKEL, J. A. 1983. Monetary and Portfolio-Balance Models of Exchange Rate Determination. *In:* BHANDARI, J. S. & PUTNAMPP, B. H. (eds.) *Economic Interdependence and Flexible Exchange Rates.* Cambridge: MIT Press.

FROOT, K. A. & FRANKEL, J. A. 1989. Forward Discount Bias: Is it an Exchange Risk Premium? *The Quarterly Journal of Economics,* 104**,** 139-161.

FROOT, K. A. & THALER, R. H. 1990. Anomalies: Foreign Exchange. *Journal of Economic Perspectives,* 4**,** 179-192.

GÄRTNER, M. 2006. *Macroeconomics,* Harlow, FT Prentice Hall.

HODRICK, R. J. 2013. Assessing the Efficiency of Asset Markets through Analysis of the Currency Carry Trade. *Stanford Institute for Economic Policy Research.* Stanford University.

LUSTIG, H., ROUSSANOV, N. & VERDELHAN, A. 2011. Common Risk Factors in Currency Markets. *The Review of Financial Studies,* 24**,** 3731-3777.

LUSTIG, H., STATHOPOLOUS, A. & VERDELHAN, A. 2014. The Term Structure of Currency Carry Trade Risk Premia. 837.

MEESE, R. A. & ROGOFF, K. 1983. Empirical Exchange Rate Models of the Seventies: Do they fit out of sample? *Journal of International Economics,* 14.

MELVIN, M. & NORRBIN, S. C. 2012. Chapter 7 - Prices and Exchange Rates: Purchasing Power Parity. *International Money and Finance.* 8th ed. ed.: United States: Academic Press.

MELVIN, M. & NORRBIN, S. C. 2013. Chapter 6 - Exchange Rates, Interest Rates, and Interest Parity. *International Money and Finance (Eighth Edition).* Academic Press.

MENKHOFF, L., SARNO, L., SCHMELING, M. & SCHRIMPF, A. 2012. Carry Trades and Global Foreign Exchange Volatility. *Journal of Finance,* 67**,** 681-718.

MOOSA, I. A. & BHATTI, R. 2009. *Theory and Empirics of Exchange Rates,* Singapore, Singapore, SGP: World Scientific Publishing Co.

NEELY, C. J. & SARNO, L. 2002. How well do monetary fundamentals forecast exchange rates?(Statistical Data Included). *Federal Reserve Bank of St. Louis Review,* 84**,** 51.

OANA, M. 2012. The Influence of International Parity on the Exchange Rate: Purchasing Power Parity and International Fisher Effect. *Acta Universitatis Danubius : Oeconomica,* 8**,** 60-81.

OLMO, J. & PILBEAM, K. 2009. Uncovered Interest Parity: Are Empirical Rejections of It Valid? *Journal of Economic Integration,* 24**,** 369-384.

RANALDO, A. & SÖDERLIND, P. 2010. Safe haven currencies. *Review of Finance,* 14**,** 385-407.

RIME, D. 2003. Hva kan vi lære om valutakurser av finansiell økonomi?

RINGDAL, K. 2013. *Enhet og mangfold : samfunnsvitenskapelig forskning og kvantitativ metode,* Bergen, Fagbokforl.

SARNO, L. 2005. Towards a Solution to the Puzzles in Exchange Rate Economics: Where Do We Stand? *Journal of Economics***,** 673-708.

SARNO, L. & TAYLOR, M. P. 2002. *The Economics of Exchange Rates,* Cambridge, U.K., Cambridge University Press.

SHAMAH, S. 2013. The Foreign Exchange Market. *A Currency Option Primer.* Oxford, UK: John Wiley & Sons Ltd.

STUDENMUND, A. H. 2014. *Using econometrics : a practical guide,* Harlow, Pearson Education.

TAYLOR, M. P. 1987. Covered Interest Parity: A High-Frequency, High-Quality Data Study. *Economica,* 54**,** 429-438.

TAYLOR, M. P. 1995. The Economics of Exchange Rates. *Journal of Economic Literature,* 33**,** 13-47.

TAYLOR, M. P. 2003. Purchasing Power Parity. *Review of International Economics,* 11**,** 436-452.

ULLENES, B. T. 2012. *Uncovered interest parity and the forward premium puzzle : implications for market efficiency and carry trade.*

WAGNER, C. 2012. Risk-premia, carry-trade dynamics, and economic value of currency speculation. *Journal of International Money and Finance,* 31**,** 1195-1219.

ZIVOT, E. 2008. Practical Issues in the Analysis of Univariate GARCH Models. University of Washington, Department of Economics.

Appendix

Appendix 1 – Data obtained from DataStream

Spot exchange rates:

Country	Observations	Data Code	Source
Australian $ to US $	1-month	Y74550	WM/Reuters
Japanese Yen to US $	1-month	S90246	WM/Reuters
Norwegian Krone to US $	1-month	S90257	WM/Reuters
New Zealand $ to US $	1-month	Y74553	WM/Reuters
South Africa Rand to US $	1-month	S90278	WM/Reuters
Mexican Peso to US $	1-month	S90253	WM/Reuters

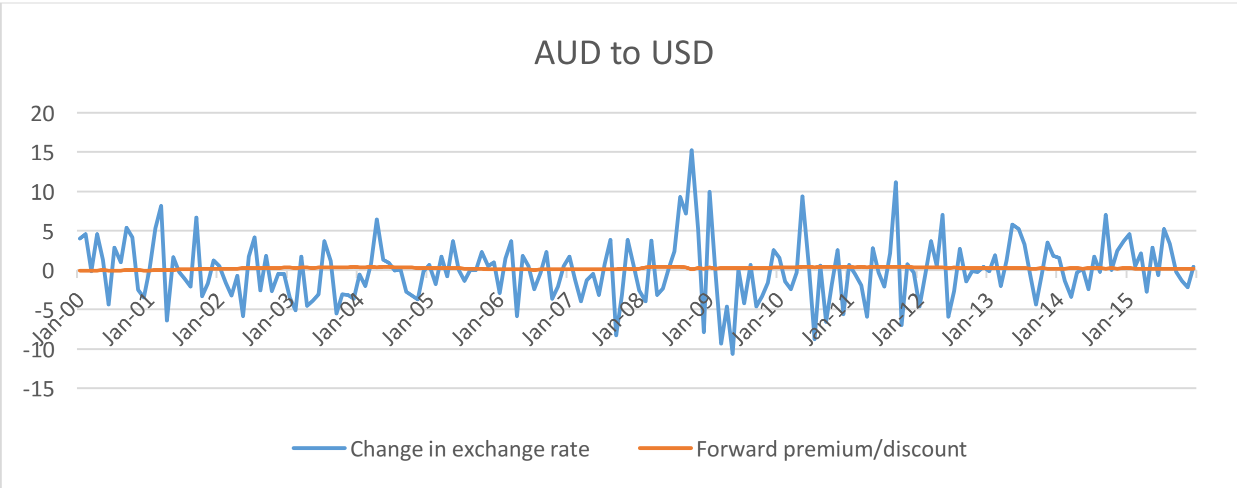
Forward exchange rates:

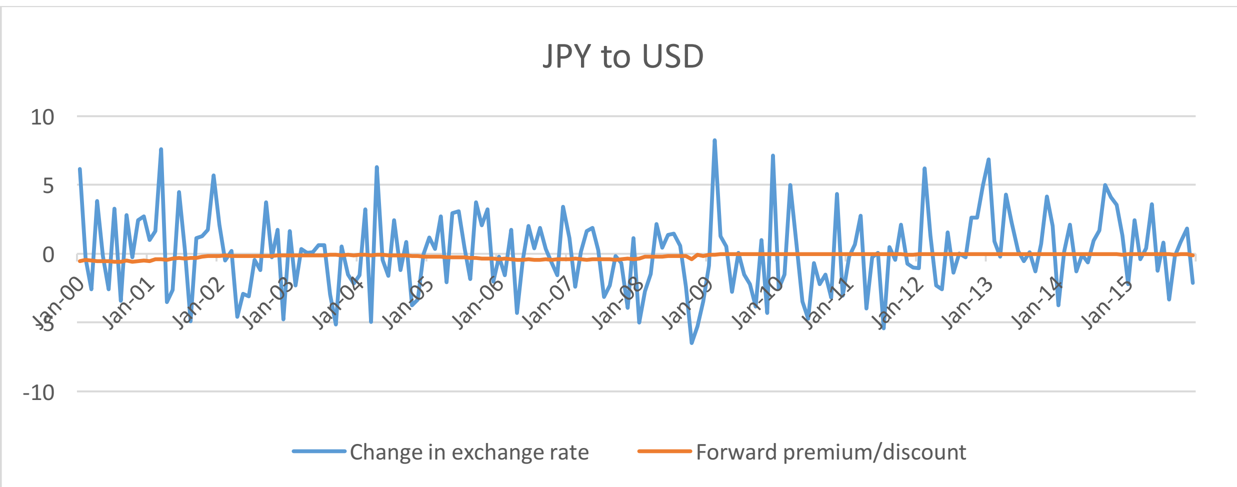
Country	Type	Data Code	Source
US $ to Australian $	1-month	S19543	WM/Reuters
Japanese Yen to US $	1-month	S19792	WM/Reuters
Norwegian Krone to US $	1-month	S99739	WM/Reuters
New Zealand $ to US $	1-month	S00631	Barclays Bank PLC
South Africa Rand to US $	1-month	S20012	WM/Reuters
Mexican Peso to US $	1-month	Y79894	WM/Reuters

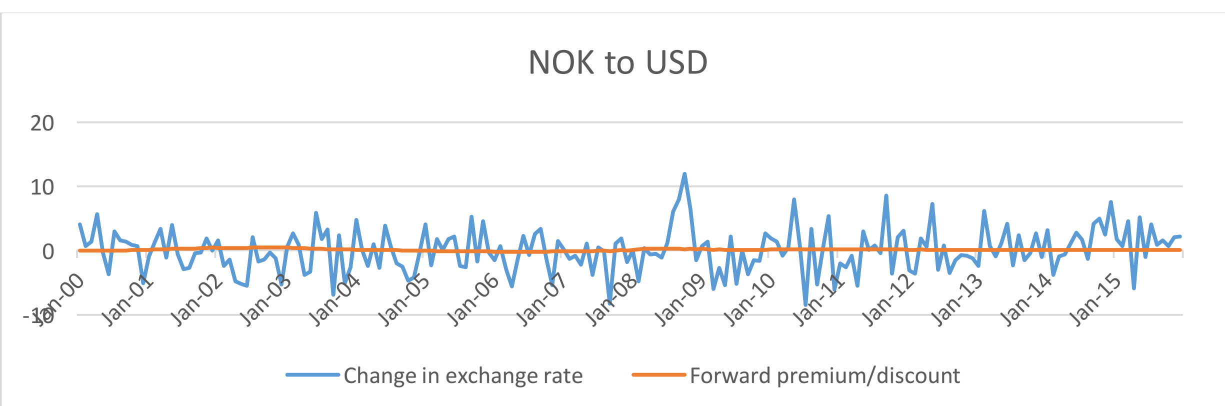
Note: Australian $ to US $ has been inverted in our analysis, but was gathered as USD to AUD based on lack of data on AUD to USD.

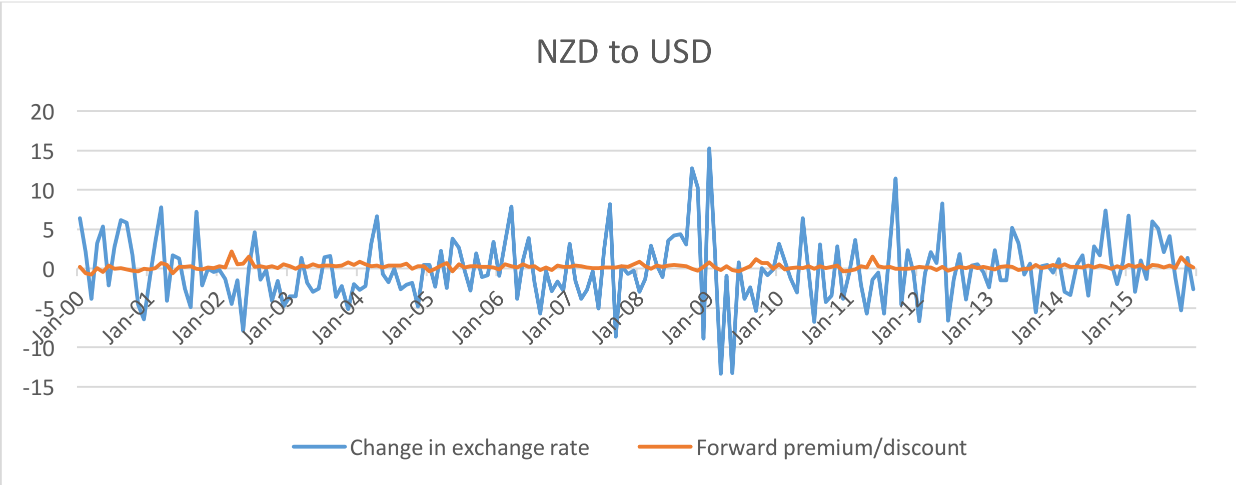
Appendix 2 – Volatilities of regression variables

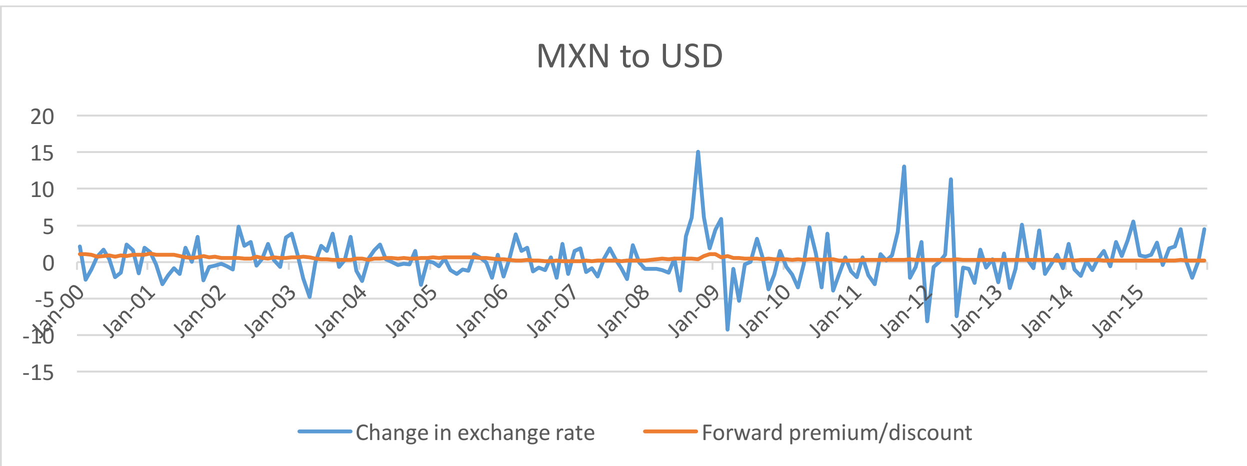
Volatilities for changes in exchange rate and the forward premium/discount for all six currencies.

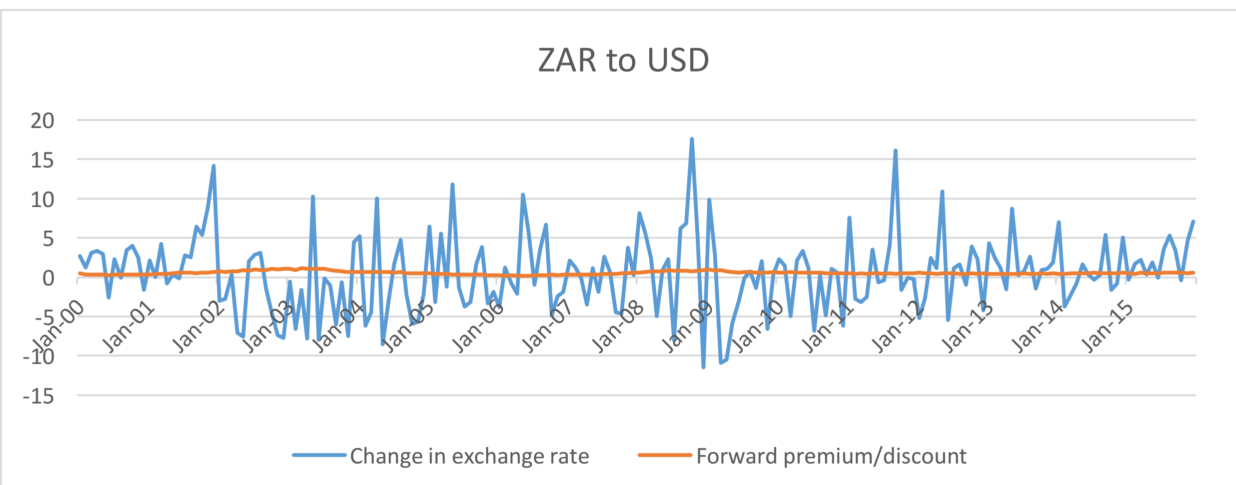







NZD to USD
20
15
10
5
0
-5
-10
-15
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Change in exchange rate
Forward premium/discount


MXN to USD
20
15
10
5
0
-5
-10
-15
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Change in exchange rate
Forward premium/discount


ZAR to USD
20
15
10
5
0
-5
-10
-15
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Change in exchange rate
Forward premium/discount

Appendix 3 – Output from regression analysis

Appendix 4.1 – Full sample period

<u>Australian dollar to US dollar</u>

Model Summary[b]

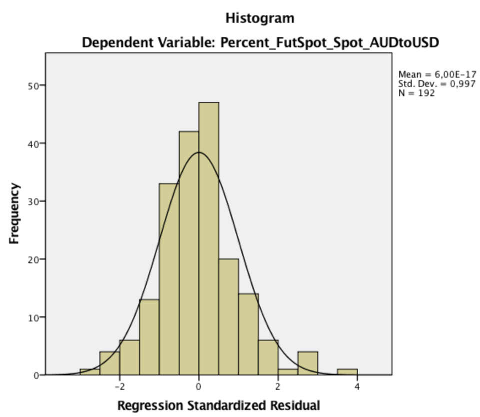
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,047[a]	,002	-,003	3,81470	1,833

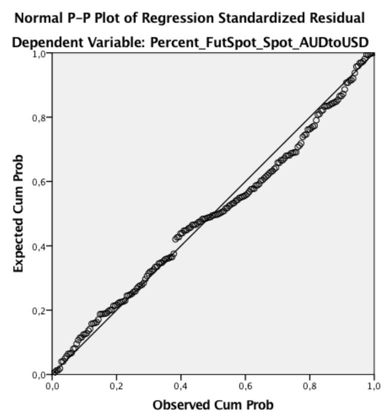
a. Predictors: (Constant), Percent_Forward_Spot_AUDtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_AUDtoUSD

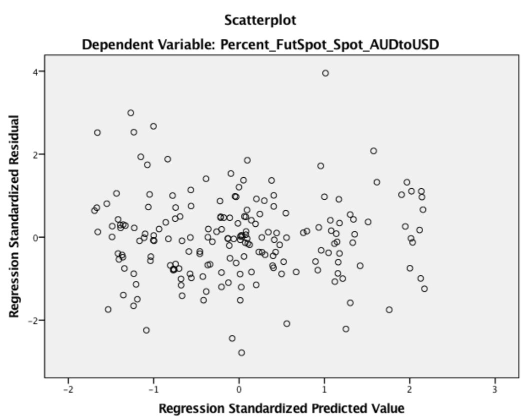
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,262	,558		,470	,639
	Percent_Forward_Spot_AUDtoUSD	-1,415	2,192	-,047	-,645	,520

a. Dependent Variable: Percent_FutSpot_Spot_AUDtoUSD







Japanese yen to US dollar

Model Summary[b]

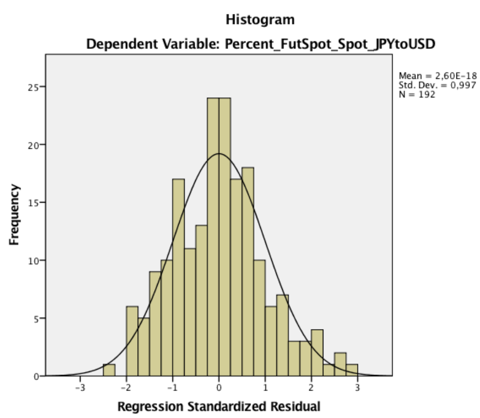
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,012[a]	,000	-,005	2,78556	1,895

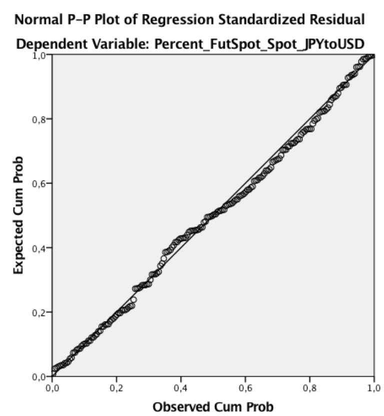
a. Predictors: (Constant), Percent_Forward_Spot_JPYtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_JPYtoUSD

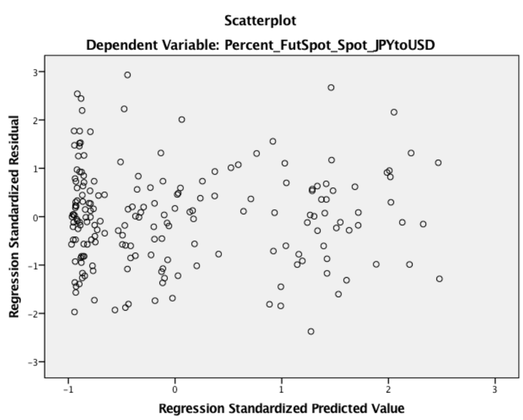
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	,055	,289		,190	,849
	Percent_Forward_Spot_JPYtoUSD	-,193	1,186	-,012	-,163	,871

a. Dependent Variable: Percent_FutSpot_Spot_JPYtoUSD







Norwegian krone to US dollar

Model Summary[b]

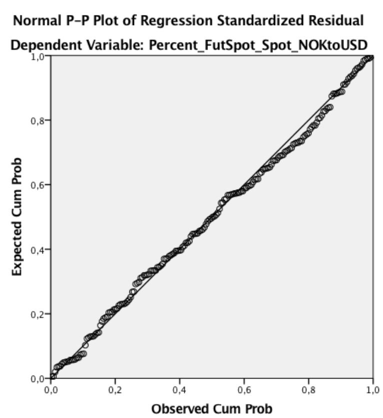
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,005[a]	,000	-,005	3,36378	1,906

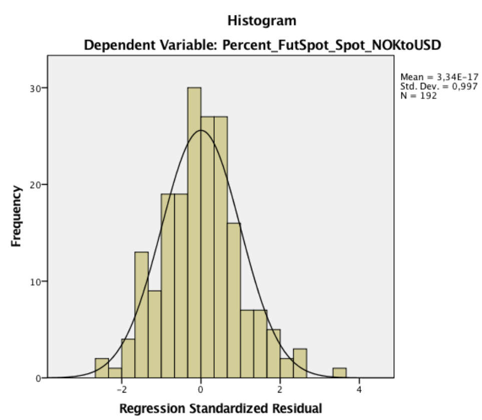
a. Predictors: (Constant), Percent_Forward_Spot_NOKtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_NOKtoUSD

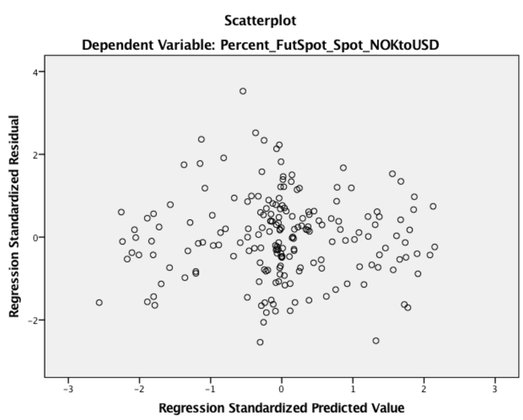
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,066	,295		,225	,823
	Percent_Forward_Spot_NOKtoUSD	-,096	1,520	-,005	-,063	,950

a. Dependent Variable: Percent_FutSpot_Spot_NOKtoUSD







New Zealand dollar to US dollar

Model Summary[b]

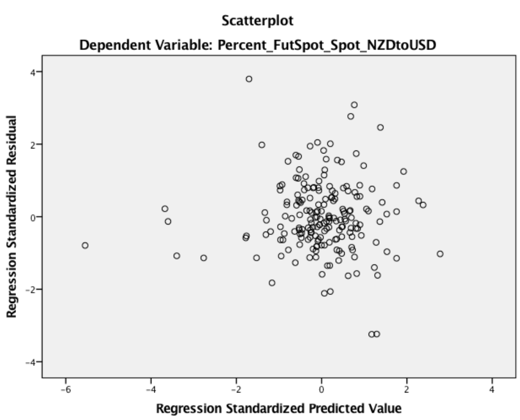
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,048[a]	,002	-,003	4,13864	2,006

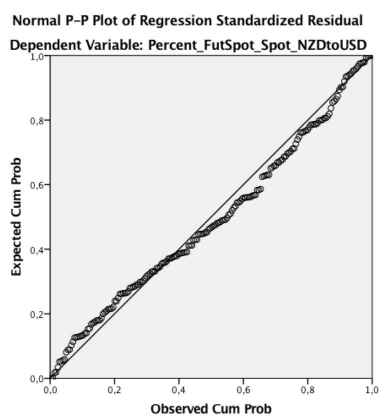
a. Predictors: (Constant), Percent_Forward_Spot_NZDtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_NZDtoUSD

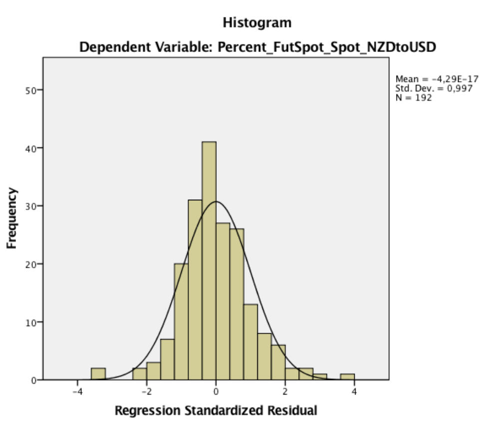
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-,005	,362		-,015	,988
	Percent_Forward_Spot_NZDtoUSD	-,562	,855	-,048	-,657	,512

a. Dependent Variable: Percent_FutSpot_Spot_NZDtoUSD







South African rand to US dollar

Model Summary[b]

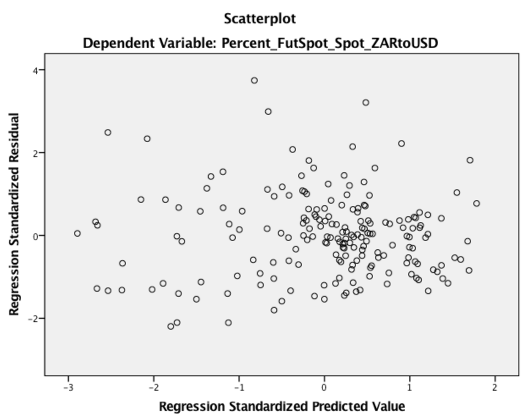
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,170[a]	,029	,024	4,75315	1,925

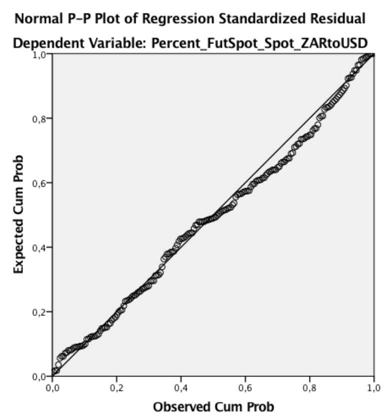
a. Predictors: (Constant), Percent_Forward_Spot_ZARtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_ZARtoUSD

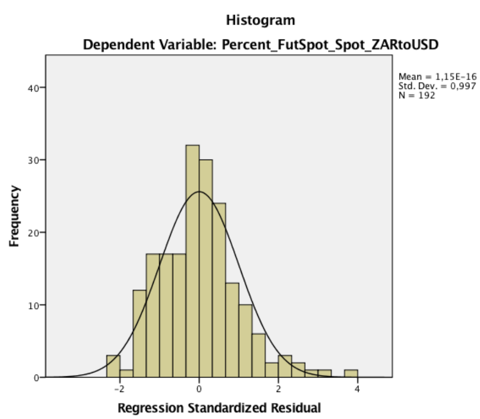
Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2,635	,967		2,724	,007
Percent_Forward_Spot_ZARtoUSD	-4,013	1,687	-,170	-2,378	,018

a. Dependent Variable: Percent_FutSpot_Spot_ZARtoUSD







Mexican peso US dollar

Model Summary[b]

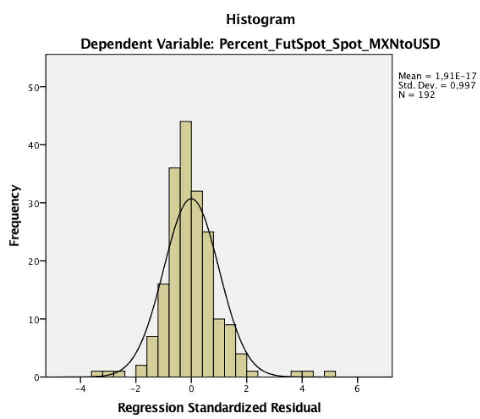
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,055[a]	,003	-,002	2,90573	1,774

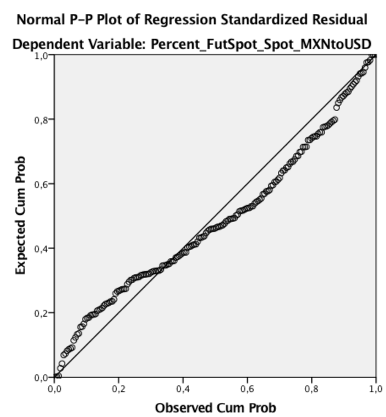
a. Predictors: (Constant), Percent_Forward_Spot_MXNtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_MXNtoUSD

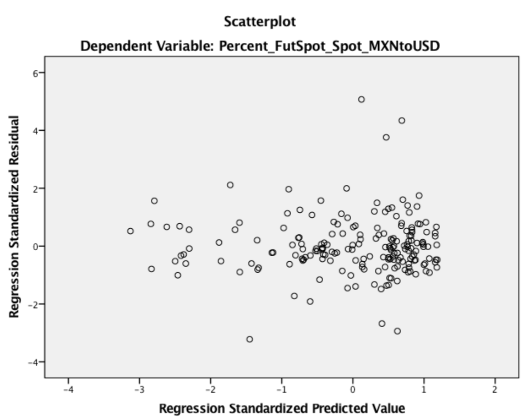
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,599	,426		1,404	,162
	Percent_Forward_Spot_MXNtoUSD	-,665	,876	-,055	-,759	,449

a. Dependent Variable: Percent_FutSpot_Spot_MXNtoUSD
b.







Appendix 4.2 – Sub period 1

Australian dollar to US dollar

Model Summary[b]

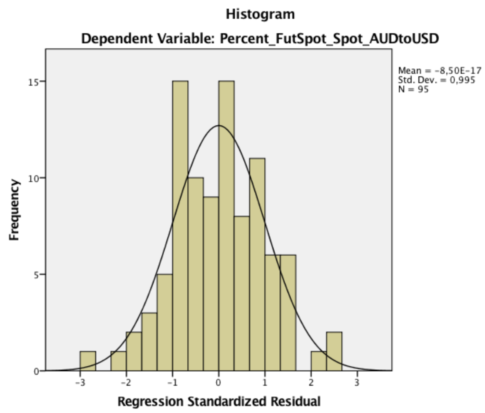
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,175[a]	,031	,020	3,12967	2,030

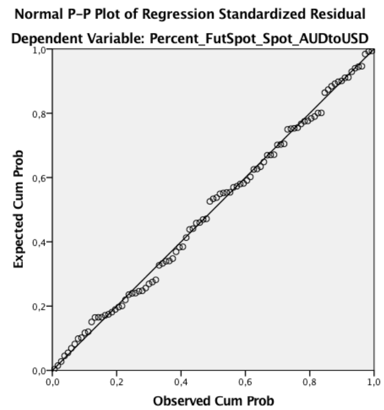
a. Predictors: (Constant), Percent_Forward_Spot_AUDtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_AUDtoUSD

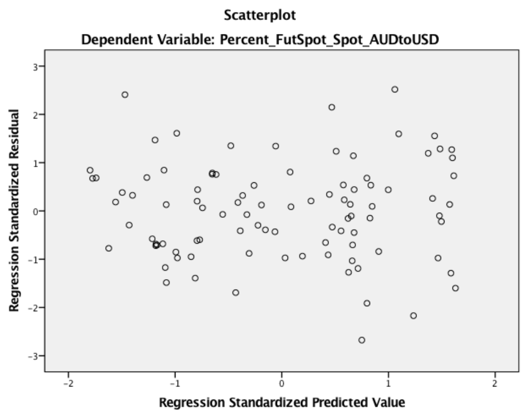
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,376	,511		,736	,464
	Percent_Forward_Spot_AUDtoUSD	-4,203	2,447	-,175	-1,718	,089

a. Dependent Variable: Percent_FutSpot_Spot_AUDtoUSD







Japanese yen to US dollar

Model Summary[b]

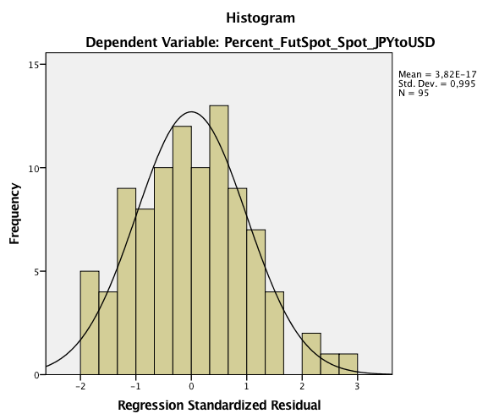
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,143[a]	,020	,010	2,67615	2,163

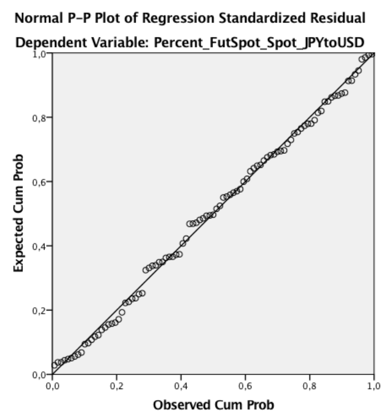
a. Predictors: (Constant), Percent_Forward_Spot_JPYtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_JPYtoUSD

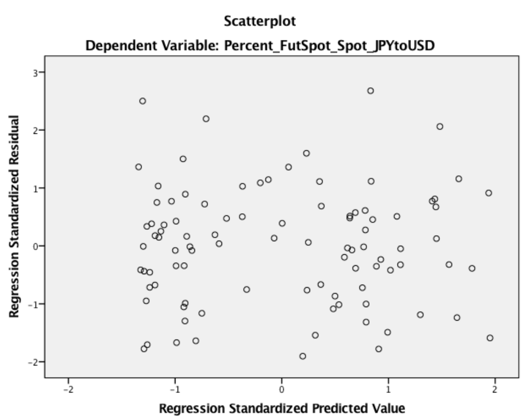
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-,646	,596		-1,085	,281
	Percent_Forward_Spot_JPYtoUSD	-2,492	1,790	-,143	-1,393	,167

a. Dependent Variable: Percent_FutSpot_Spot_JPYtoUSD







Norwegian krone to US dollar

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,087[a]	,008	-,003	2,99171	1,998

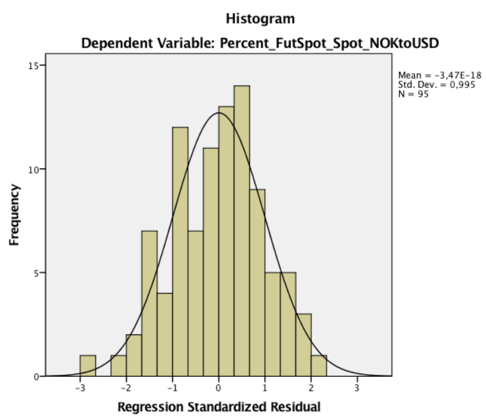
a. Predictors: (Constant), Percent_Forward_Spot_NOKtoUSD

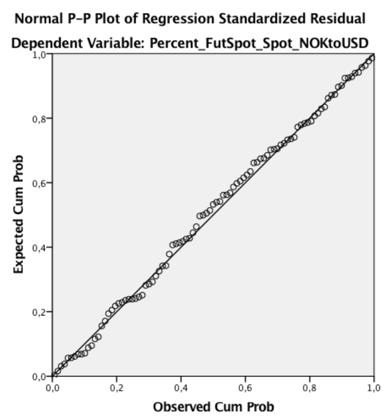
b. Dependent Variable: Percent_FutSpot_Spot_NOKtoUSD

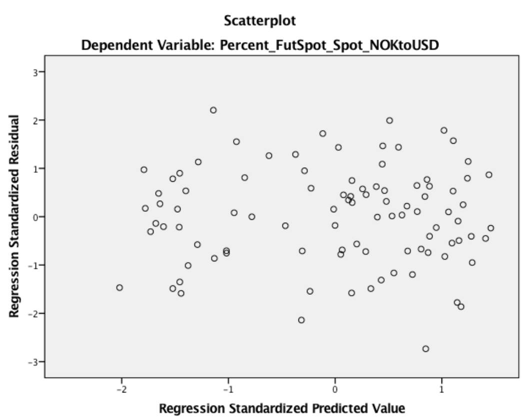
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-,283	,329		-,861	,391
	Percent_Forward_Spot_NOKtoUSD	-1,203	1,422	-,087	-,846	,400

a. Dependent Variable: Percent_FutSpot_Spot_NOKtoUSD







New Zealand dollar to US dollar

Model Summary[b]

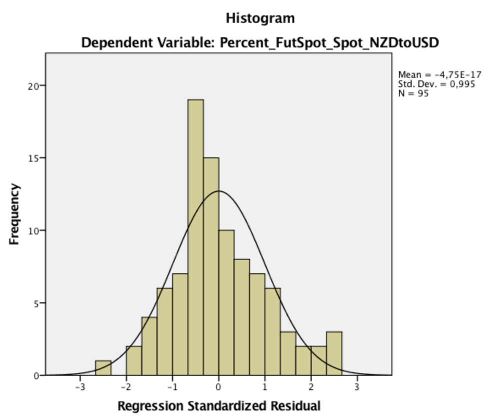
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,144[a]	,021	,010	3,56357	1,899

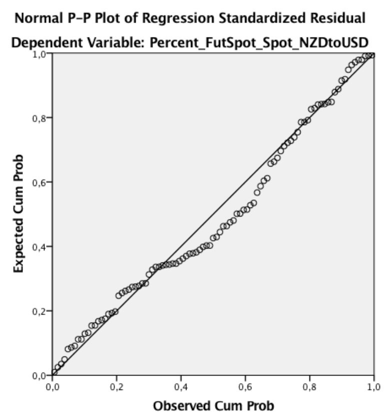
a. Predictors: (Constant), Percent_Forward_Spot_NZDtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_NZDtoUSD

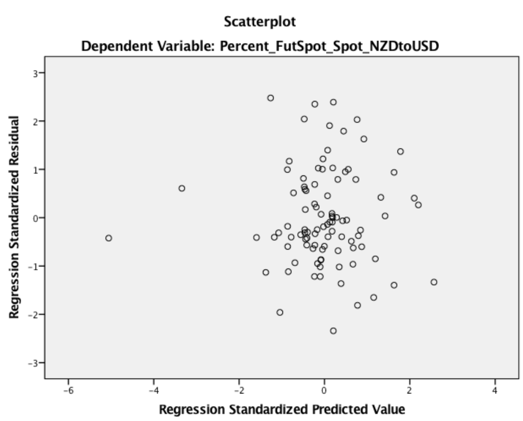
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-,071	,436		-,163	,871
	Percent_Forward_Spot_NZDtoUSD	-1,344	,961	-,144	-1,399	,165

a. Dependent Variable: Percent_FutSpot_Spot_NZDtoUSD







South African rand to US dollar

Model Summary[b]

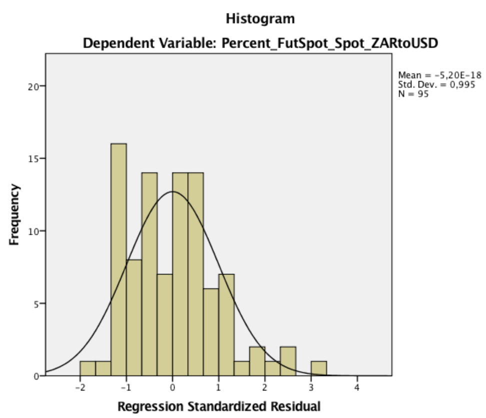
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,233[a]	,054	,044	4,66303	1,991

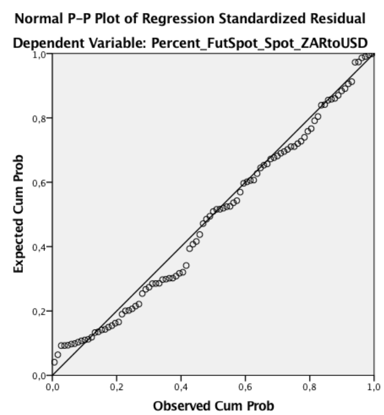
a. Predictors: (Constant), Percent_Forward_Spot_ZARtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_ZARtoUSD

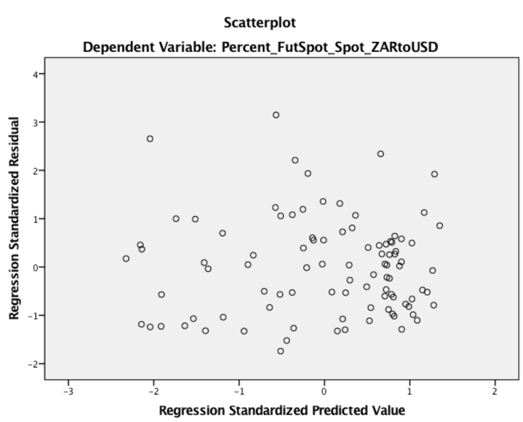
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,350	1,081		2,174	,032
	Percent_Forward_Spot_ZARtoUSD	-4,277	1,854	-,233	-2,307	,023

a. Dependent Variable: Percent_FutSpot_Spot_ZARtoUSD







Mexican peso to US dollar

Model Summary[b]

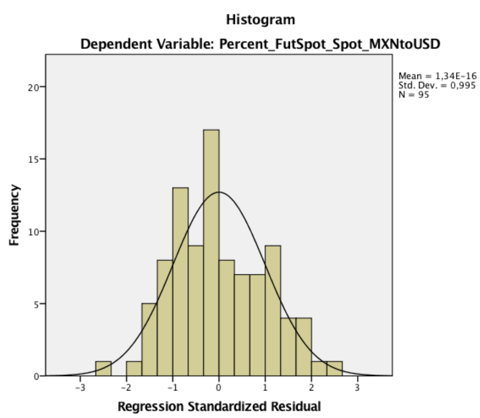
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,139[a]	,019	,009	1,84204	1,784

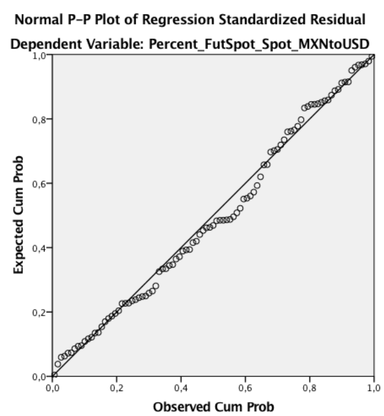
a. Predictors: (Constant), Percent_Forward_Spot_MXNtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_MXNtoUSD

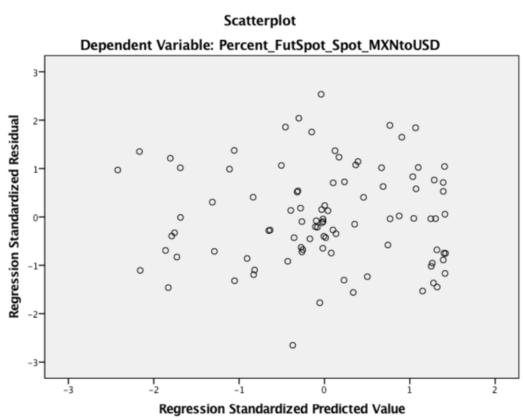
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,654	,413		1,581	,117
	Percent_Forward_Spot_MXNtoUSD	-,951	,705	-,139	-1,349	,181

a. Dependent Variable: Percent_FutSpot_Spot_MXNtoUSD







Appendix 4.3 – Sub period 2

Australian dollar to US dollar

Model Summary[b]

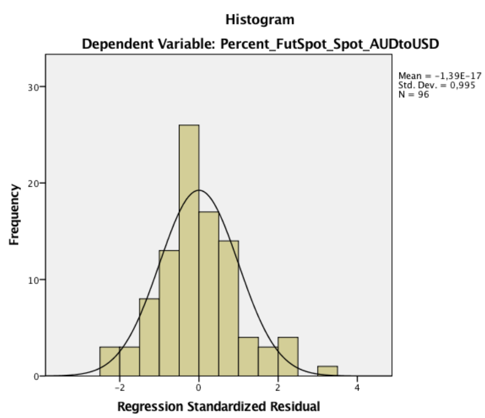
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,005[a]	,000	-,011	4,39837	1,761

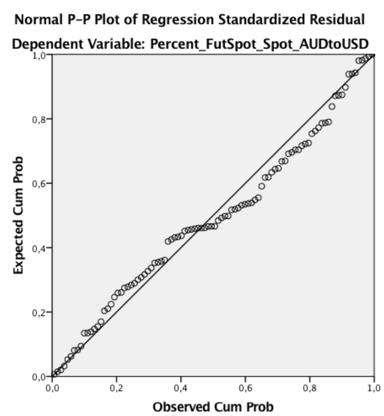
a. Predictors: (Constant), Percent_Forward_Spot_AUDtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_AUDtoUSD

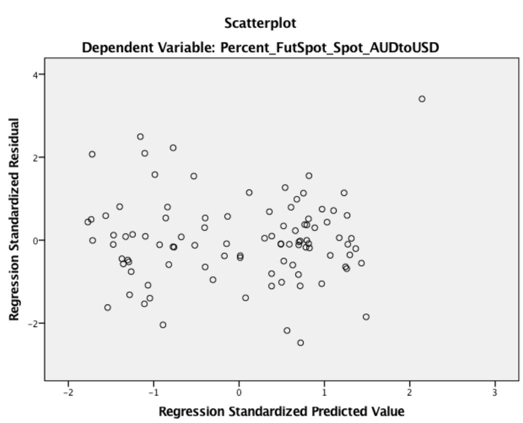
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,260	1,521		,171	,865
	Percent_Forward_Spot_AUDtoUSD	-,230	5,185	-,005	-,044	,965

a. Dependent Variable: Percent_FutSpot_Spot_AUDtoUSD







Japanese yen to US dollar

Model Summary[b]

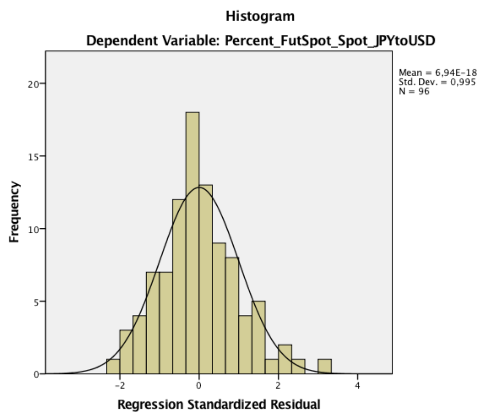
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,261[a]	,068	,058	2,80437	1,741

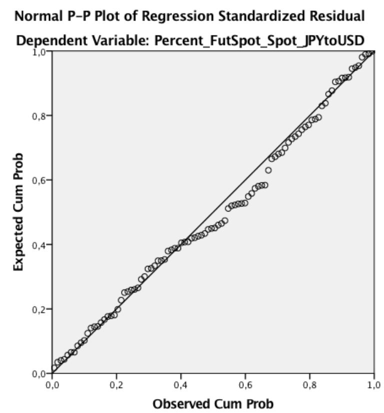
a. Predictors: (Constant), Percent_Forward_Spot_JPYtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_JPYtoUSD

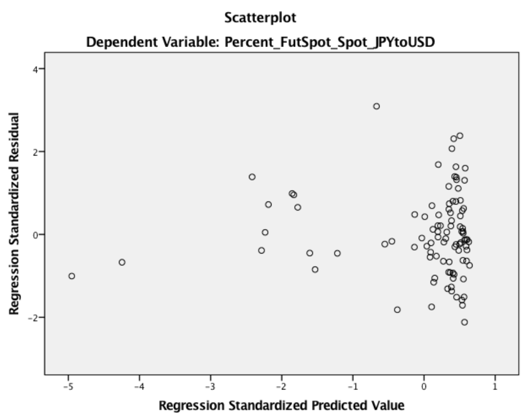
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,673	,365		1,842	,069
	Percent_Forward_Spot_JPYtoUSD	11,073	4,218	,261	2,625	,010

a. Dependent Variable: Percent_FutSpot_Spot_JPYtoUSD







Norwegian krone to US dollar

Model Summary[b]

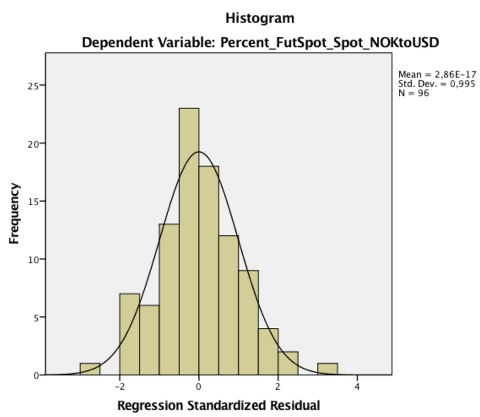
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,116[a]	,013	,003	3,65047	1,928

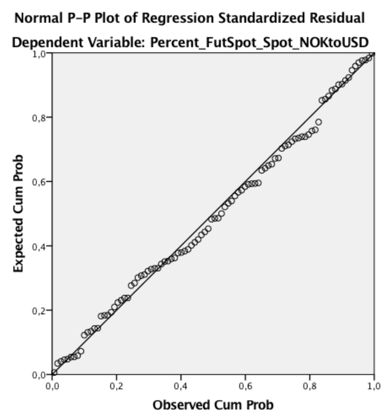
a. Predictors: (Constant), Percent_Forward_Spot_NOKtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_NOKtoUSD

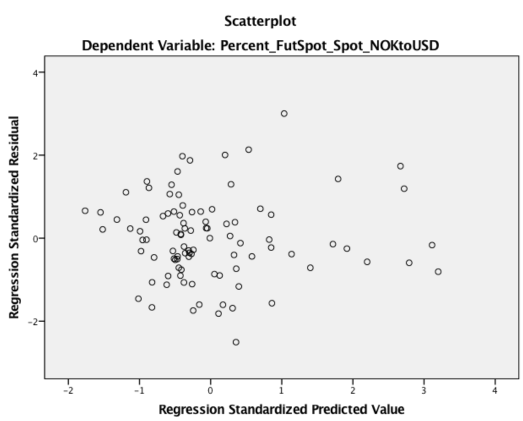
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-,522	,984		-,531	,597
	Percent_Forward_Spot_NOKtoUSD	7,416	6,548	,116	1,133	,260

a. Dependent Variable: Percent_FutSpot_Spot_NOKtoUSD







New Zealand dollar to US dollar

Model Summary[b]

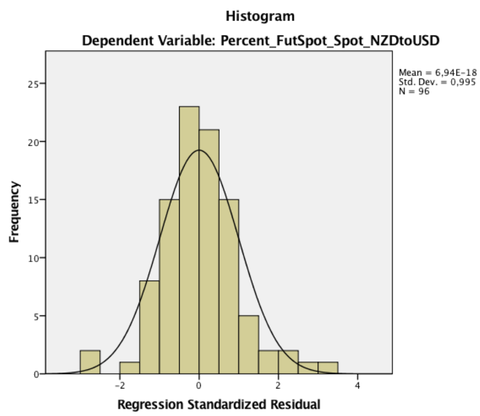
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,042[a]	,002	-,009	4,65766	2,064

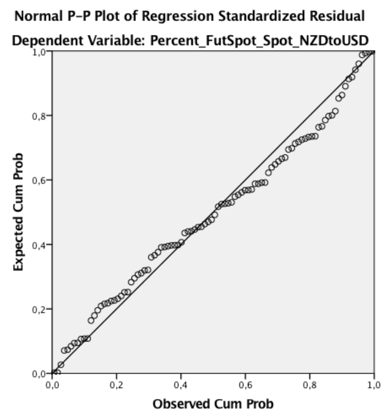
a. Predictors: (Constant), Percent_Forward_Spot_NZDtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_NZDtoUSD

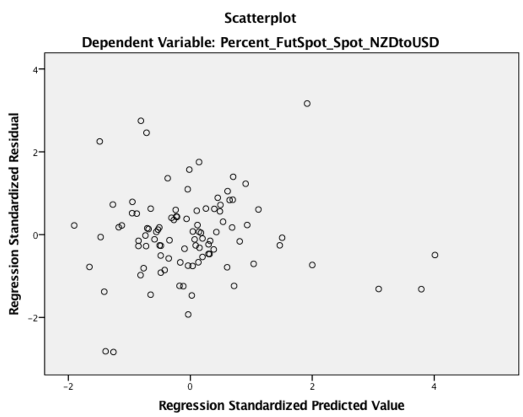
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-,017	,585		-,029	,977
	Percent_Forward_Spot_NZDtoUSD	,612	1,507	,042	,406	,685

a. Dependent Variable: Percent_FutSpot_Spot_NZDtoUSD







South African rand to US dollar

Model Summary[b]

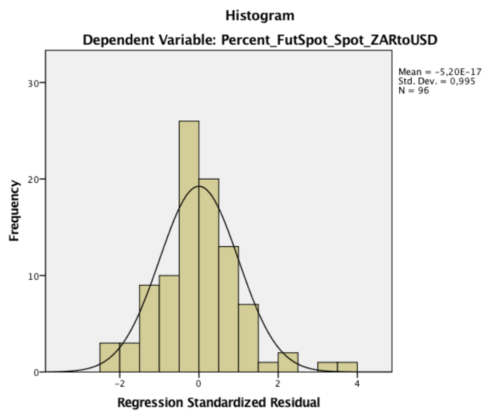
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,095[a]	,009	-,001	4,87701	1,865

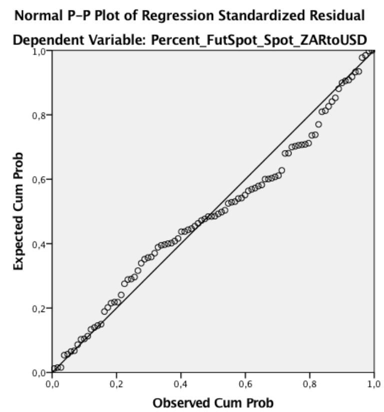
a. Predictors: (Constant), Percent_Forward_Spot_ZARtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_ZARtoUSD

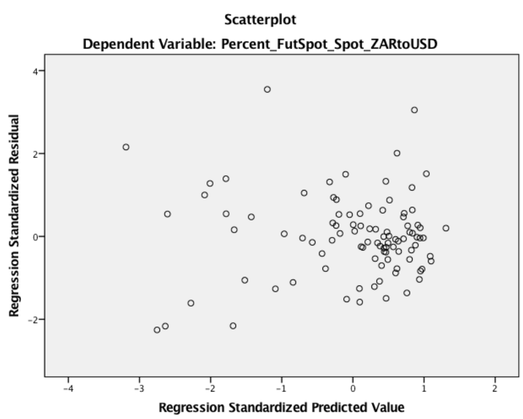
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,830	2,190		1,293	,199
	Percent_Forward_Spot_ZARtoUSD	-3,606	3,887	-,095	-,928	,356

a. Dependent Variable: Percent_FutSpot_Spot_ZARtoUSD







Mexican peso to US dollar

Model Summary[b]

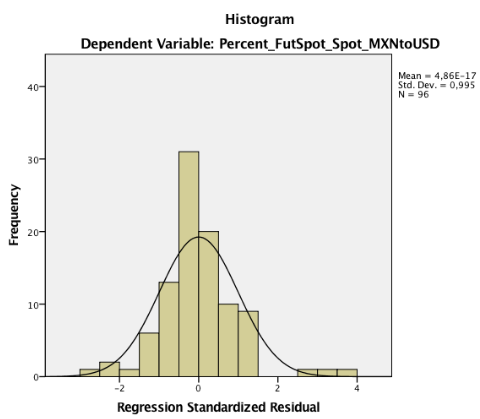
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,037[a]	,001	-,009	3,69093	1,803

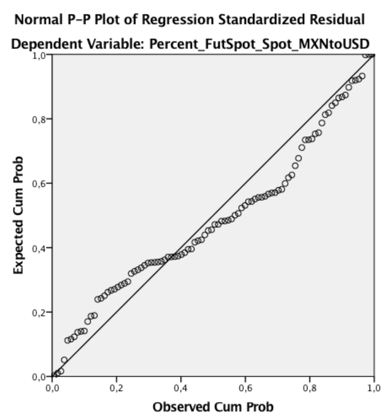
a. Predictors: (Constant), Percent_Forward_Spot_MXNtoUSD
b. Dependent Variable: Percent_FutSpot_Spot_MXNtoUSD

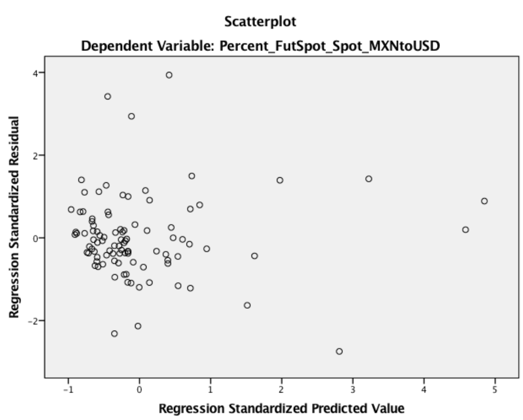
Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	,193	,876		,221	,826
	Percent_Forward_Spot_MXNtoUSD	,865	2,402	,037	,360	,720

a. Dependent Variable: Percent_FutSpot_Spot_MXNtoUSD







Appendix 4 - Descriptive statistics for sub periods

Means and standard deviations on a per cent per month basis.

Sub period 1:

Country N=95	$s_{t+1} - s_t$		$f_t - s_t$	
	Exchange rate depreciation		**Forward premium**	
	Mean	Std. dev	Mean	Std. dev
Australia	-0,3073	3,16197	0,1626	0,13192
Japan	0,0897	2,68948	-0,2953	0,15424
Norway	-0,3832	2,98717	0,0831	0,21699
New Zealand	-0,4021	3,58166	0,2465	0,38255
South Africa	0,1137	4,76909	0,5228	0,25946
Mexico	0,1577	1,85005	0,5215	0,26949

Sub period 2:

Country N=96	$s_{t+1} - s_t$		$f_t - s_t$	
	Exchange rate depreciation		**Forward premium**	
	Mean	Std. dev	Mean	Std. dev
Australia	0,1959	4,37521	0,2804	0,08704
Japan	0,0771	2,89002	-0,0538	0,06821
Norway	0,5090	3.65589	0,1390	0,05720
New Zealand	0,1218	4,63715	0,2269	0,31719
South Africa	0,8527	4,87342	0,5485	0,12872
Mexico	0,4781	3,67398	0,3293	0,15766

Appendix 5 – ARCH-effects

Australia

Heteroskedasticity Test: ARCH

F-statistic	6.035431	Prob. F(5,181)	0.0000
Obs*R-squared	26.72225	Prob. Chi-Square(5)	0.0001

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.139504	2.528722	2.823364	0.0053
RESID^2(-1)	0.100666	0.073317	1.373029	0.1714
RESID^2(-2)	0.319059	0.073569	4.336861	0.0000
RESID^2(-3)	-0.027395	0.077222	-0.354759	0.7232
RESID^2(-4)	-0.053561	0.073543	-0.728284	0.4674
RESID^2(-5)	0.164729	0.073290	2.247637	0.0258

Japan

Heteroskedasticity Test: ARCH

F-statistic	1.104694	Prob. F(5,181)	0.3595
Obs*R-squared	5.537581	Prob. Chi-Square(5)	0.3538

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.795838	1.474289	5.287864	0.0000
RESID^2(-1)	0.045769	0.073997	0.618516	0.5370
RESID^2(-2)	-0.086747	0.074084	-1.170919	0.2432
RESID^2(-3)	0.105803	0.073905	1.431610	0.1540
RESID^2(-4)	-0.008917	0.074018	-0.120466	0.9042
RESID^2(-5)	-0.081610	0.072285	-1.129001	0.2604

Norway

Heteroskedasticity Test: ARCH

F-statistic	1.991969	Prob. F(5,181)	0.0819
Obs*R-squared	9.753314	Prob. Chi-Square(5)	0.0825

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.173126	2.087603	4.394094	0.0000
RESID^2(-1)	0.132333	0.073911	1.790443	0.0751
RESID^2(-2)	0.127666	0.074044	1.724197	0.0864
RESID^2(-3)	-0.136841	0.073984	-1.849621	0.0660
RESID^2(-4)	-0.029951	0.074006	-0.404712	0.6862
RESID^2(-5)	0.089865	0.073506	1.222554	0.2231

New Zealand

Heteroskedasticity Test: ARCH

F-statistic	9.291972	Prob. F(5,181)	0.0000
Obs*R-squared	38.19572	Prob. Chi-Square(5)	0.0000

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.997550	2.787927	2.509948	0.0130
RESID^2(-1)	0.041169	0.074266	0.554352	0.5800
RESID^2(-2)	0.378882	0.074013	5.119163	0.0000
RESID^2(-3)	0.053238	0.079140	0.672703	0.5020
RESID^2(-4)	0.090745	0.074179	1.223322	0.2228
RESID^2(-5)	0.020331	0.074218	0.273934	0.7844

South Africa

Heteroskedasticity Test: ARCH

F-statistic	2.044752	Prob. F(5,181)	0.0745
Obs*R-squared	9.997938	Prob. Chi-Square(5)	0.0753

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	14.54947	4.293691	3.388569	0.0009
RESID^2(-1)	0.103852	0.073780	1.407583	0.1610
RESID^2(-2)	0.069805	0.074180	0.941026	0.3479
RESID^2(-3)	0.096842	0.074045	1.307879	0.1926
RESID^2(-4)	-0.003440	0.074186	-0.046366	0.9631
RESID^2(-5)	0.127181	0.073748	1.724537	0.0863

Mexico

Heteroskedasticity Test: ARCH

F-statistic	3.551776	Prob. F(5,181)	0.0044
Obs*R-squared	16.70824	Prob. Chi-Square(5)	0.0051

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.086513	2.065195	2.462969	0.0147
RESID^2(-1)	0.139534	0.073589	1.896138	0.0595
RESID^2(-2)	-0.029809	0.073091	-0.407840	0.6839
RESID^2(-3)	-0.019576	0.073106	-0.267772	0.7892
RESID^2(-4)	0.182722	0.073114	2.499149	0.0133
RESID^2(-5)	0.143082	0.073635	1.943122	0.0536

Appendix 6 – Output from GARCH-M (1,1) analysis in EViews

Australia

Dependent Variable: ERTAUD
Method: ML ARCH - Normal distribution (OPG - BHHH / Marquardt steps)
Date: 05/02/16 Time: 12:51
Sample: 1 192
Included observations: 192
Convergence achieved after 46 iterations
Coefficient covariance computed using Bollerslev-Wooldridge QML
sandwich with expected Hessian
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LOG(GARCH)	1.553817	1.456300	1.066962	0.2860
C	-3.691145	3.749878	-0.984338	0.3249
		Variance Equation		
C	2.364234	1.535343	1.539873	0.1236
RESID(-1)^2	0.130774	0.106998	1.222215	0.2216
GARCH(-1)	0.700974	0.166685	4.205377	0.0000

R-squared	0.009588	Mean dependent var	0.272050
Adjusted R-squared	0.004375	S.D. dependent var	3.816827
S.E. of regression	3.808469	Akaike info criterion	5.469598
Sum squared resid	2755.842	Schwarz criterion	5.554428
Log likelihood	-520.0814	Hannan-Quinn criter.	5.503955
Durbin-Watson stat	1.797890		

Correlogram squared residuals

Lag	AC	PAC	Q-Stat	Prob*
1	0.011	0.011	0.0234	0.879
2	0.120	0.120	2.8592	0.239
3	-0.062	-0.065	3.6107	0.307
4	-0.062	-0.077	4.3834	0.357
5	0.035	0.054	4.6292	0.463
6	0.001	0.013	4.6292	0.592
7	0.016	-0.005	4.6780	0.699
8	-0.020	-0.022	4.7614	0.783
9	-0.010	-0.004	4.7827	0.853
10	-0.107	-0.104	7.1079	0.715
11	0.053	0.058	7.6880	0.741
12	0.033	0.057	7.9169	0.792

*Probabilities may not be valid for this equation specification.

Remaining ARCH-effects

Heteroskedasticity Test: ARCH

F-statistic	1.006800	Prob. F(5,181)	0.4151
Obs*R-squared	5.060141	Prob. Chi-Square(5)	0.4086

Norway

Dependent Variable: ERTNOK
Method: ML ARCH - Normal distribution (OPG - BHHH / Marquardt steps)
Date: 05/02/16 Time: 12:52
Sample: 1 192
Included observations: 192
Convergence not achieved after 500 iterations
Coefficient covariance computed using outer product of gradients
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LOG(GARCH)	-25.10646	154.2336	-0.162782	0.8707
C	60.28907	370.3939	0.162770	0.8707
		Variance Equation		
C	9.055739	7.469968	1.212286	0.2254
RESID(-1)^2	0.008469	0.050120	0.168971	0.8658
GARCH(-1)	0.167829	0.694462	0.241667	0.8090

R-squared	0.019679	Mean dependent var	0.055058
Adjusted R-squared	0.014519	S.D. dependent var	3.359545
S.E. of regression	3.335067	Akaike info criterion	5.288215
Sum squared resid	2113.308	Schwarz criterion	5.373045
Log likelihood	-502.6686	Hannan-Quinn criter.	5.322572
Durbin-Watson stat	1.931659		

Correlogram squared residuals

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.743	0.743	107.56	0.000
		2	0.553	0.003	167.53	0.000
		3	0.315	-0.216	187.08	0.000
		4	0.146	-0.041	191.28	0.000
		5	0.028	0.002	191.43	0.000
		6	-0.042	-0.015	191.79	0.000
		7	-0.020	0.119	191.87	0.000
		8	-0.028	-0.067	192.03	0.000
		9	-0.008	-0.006	192.04	0.000
		10	-0.022	-0.039	192.14	0.000
		11	-0.027	-0.006	192.29	0.000
		12	-0.014	0.056	192.33	0.000

*Probabilities may not be valid for this equation specification.

Remaining ARCH-effects

Heteroskedasticity Test: ARCH

F-statistic	4.874666	Prob. F(5,181)	0.0003
Obs*R-squared	22.19282	Prob. Chi-Square(5)	0.0005

New Zealand

Dependent Variable: ERTNZD
Method: ML ARCH - Normal distribution (OPG - BHHH / Marquardt steps)
Date: 05/02/16 Time: 12:52
Sample: 1 192
Included observations: 192
Convergence achieved after 33 iterations
Coefficient covariance computed using Bollerslev-Wooldridge QML
sandwich with expected Hessian
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LOG(GARCH)	0.826023	1.405880	0.587549	0.5568
C	-1.760666	3.801618	-0.463136	0.6433
		Variance Equation		
C	3.670868	2.640076	1.390440	0.1644
RESID(-1)^2	0.139770	0.088780	1.574344	0.1154
GARCH(-1)	0.634883	0.194968	3.256341	0.0011

R-squared	0.002390	Mean dependent var	0.377534
Adjusted R-squared	-0.002861	S.D. dependent var	4.163871
S.E. of regression	4.169823	Akaike info criterion	5.648599
Sum squared resid	3303.610	Schwarz criterion	5.733430
Log likelihood	-537.2655	Hannan-Quinn criter.	5.682956
Durbin-Watson stat	1.945143		

Correlogram squared residuals

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	-0.021	-0.021	0.0894	0.765
		2	0.066	0.065	0.9368	0.626
		3	0.024	0.026	1.0461	0.790
		4	0.071	0.068	2.0445	0.728
		5	0.005	0.005	2.0499	0.842
		6	-0.085	-0.096	3.5113	0.742
		7	0.041	0.033	3.8455	0.797
		8	-0.009	-0.000	3.8607	0.869
		9	-0.046	-0.048	4.2950	0.891
		10	-0.086	-0.078	5.7943	0.832
		11	-0.085	-0.089	7.2879	0.775
		12	0.003	0.004	7.2899	0.838

*Probabilities may not be valid for this equation specification.

Remaining ARCH-effects

Heteroskedasticity Test: ARCH

F-statistic	0.367929	Prob. F(5,181)	0.8701
Obs*R-squared	1.881505	Prob. Chi-Square(5)	0.8653

South Africa

Dependent Variable: ERTZAR
Method: ML ARCH - Normal distribution (OPG - BHHH / Marquardt steps)
Date: 05/02/16 Time: 12:53
Sample: 1 192
Included observations: 192
Convergence achieved after 27 iterations
Coefficient covariance computed using Bollerslev-Wooldridge QML
sandwich with expected Hessian
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LOG(GARCH)	2.484500	0.766407	3.241748	0.0012
C	-7.368808	2.129146	-3.460922	0.0005
Variance Equation				
C	1.274108	0.725019	1.757346	0.0789
RESID(-1)^2	0.112782	0.050972	2.212608	0.0269
GARCH(-1)	0.834220	0.062332	13.38354	0.0000

R-squared	0.080194	Mean dependent var	0.052036
Adjusted R-squared	0.075353	S.D. dependent var	4.849561
S.E. of regression	4.663269	Akaike info criterion	5.876771
Sum squared resid	4131.756	Schwarz criterion	5.961601
Log likelihood	-559.1700	Hannan-Quinn criter.	5.911128
Durbin-Watson stat	1.948316		

Correlogram squared residuals

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.039	0.039	0.2984	0.585
		2	-0.050	-0.052	0.7879	0.674
		3	0.023	0.027	0.8886	0.828
		4	-0.014	-0.019	0.9264	0.921
		5	-0.012	-0.008	0.9546	0.966
		6	0.011	0.010	0.9788	0.986
		7	-0.082	-0.084	2.3433	0.938
		8	0.100	0.110	4.3828	0.821
		9	0.029	0.009	4.5516	0.872
		10	-0.116	-0.105	7.3092	0.696
		11	-0.052	-0.047	7.8658	0.725
		12	0.117	0.115	10.679	0.557

*Probabilities may not be valid for this equation specification.

Remaining ARCH-effects

Heteroskedasticity Test: ARCH

F-statistic	0.192237	Prob. F(5,181)	0.9652
Obs*R-squared	0.987803	Prob. Chi-Square(5)	0.9635

Mexico

Dependent Variable: ERTMXN
Method: ML ARCH - Normal distribution (OPG - BHHH / Marquardt steps)
Date: 05/02/16 Time: 12:53
Sample: 1 192
Included observations: 192
Convergence achieved after 55 iterations
Coefficient covariance computed using Bollerslev-Wooldridge QML
sandwich with expected Hessian
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
LOG(GARCH)	-0.458679	0.394224	-1.163499	0.2446
C	1.094837	0.689724	1.587356	0.1124
Variance Equation				
C	0.735989	0.613280	1.200087	0.2301
RESID(-1)^2	0.336066	0.253205	1.327251	0.1844
GARCH(-1)	0.639759	0.201022	3.182534	0.0015

R-squared	-0.010102	Mean dependent var	0.106917
Adjusted R-squared	-0.015419	S.D. dependent var	2.925523
S.E. of regression	2.947991	Akaike info criterion	4.839951
Sum squared resid	1651.223	Schwarz criterion	4.924782
Log likelihood	-459.6353	Hannan-Quinn criter.	4.874308
Durbin-Watson stat	1.792046		

Correlogram squared residuals

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob*
		1	0.064	0.064	0.8017	0.371
		2	-0.071	-0.075	1.7802	0.411
		3	-0.051	-0.042	2.2976	0.513
		4	0.059	0.061	2.9964	0.558
		5	0.013	-0.002	3.0306	0.695
		6	-0.098	-0.094	4.9416	0.551
		7	-0.060	-0.041	5.6581	0.580
		8	0.216	0.213	15.062	0.058
		9	-0.013	-0.063	15.095	0.088
		10	-0.081	-0.052	16.453	0.087
		11	-0.069	-0.034	17.422	0.096
		12	0.079	0.054	18.719	0.096

*Probabilities may not be valid for this equation specification.

Remaining ARCH-effects

Heteroskedasticity Test: ARCH

F-statistic	0.560944	Prob. F(5,181)	0.7298
Obs*R-squared	2.853480	Prob. Chi-Square(5)	0.7226

Appendix 7 – Excess return and volatility for fitted GARCH (1,1)