
$F_t^1 = E_t[S_{t+1}]$
$S_t(1+i) = F_t^k(1+i^*)$
$S_t(1+i) = E_t[S_{t+1}](1+i^*)$
$s_{t+1} - s_t = \alpha + \beta(f_t^1 - s_t) + \mu_{t+1}$

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Uncovered Interest Parity and the Forward Premium Puzzle: Implications for market efficiency and carry trade

Master thesis within the main profile of Finance

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Abstract

Uncovered interest parity is a fundamental concept in foreign exchange and implies that the same deposit placed at home or abroad should yield equal returns. The forward premium puzzle refers to a well known empirical failure of the uncovered interest parity relation. Under the forward premium puzzle, currencies that are expected to depreciate, in fact tend to appreciate.

This puzzling fact have been interpreted as a failure of the efficient market hypothesis in the foreign exchange market, and has served as a theoretical foundation for earning excess returns from the currency speculation known as carry trade. According to uncovered interest parity, no excess return from such speculation should be possible.

This thesis tests for the appearance of the forward premium puzzle in recent data through the conventional approach of regressing the change in spot prices on the forward premium. In addition, two excess return based trading strategies are analyzed as a more practical and direct approach to testing the efficient market hypothesis and uncovered interest parity.

My findings regarding the puzzle are consistent with existing literature in the sense that the forward premium puzzle is identified for all eight currency pairs which are included in the regression. However, the estimated coefficients are statistically insignificant, and it is therefore difficult to draw definitive conclusions from the analysis.

On the other hand, results from testing the excess return based strategies shows that the apparent presence of the forward premium puzzle not necessarily indicates that there are excess return possibilities in the foreign exchange market. Excess return is only identified for the Norwegian krone and Australian dollar against US dollar parities, but test results remain inconclusive due to violations of the conditions under the ordinary least squares methodology in regression analysis.

Preface

This thesis has been written as part of the Master degree program at NHH and was inspired by the topics covered in International Finance. It was at first only intended to cover the two related topics of uncovered interest parity and the forward premium puzzle, but was eventually expanded to focus more on the implications of the puzzle, such as profitable currency speculation.

It has proven difficult both to obtain data of longer time series and to obtain data from the same source, and this has especially been the case for the forward exchange rates. It also has been challenging to analyse the results and draw conclusions due to statistically insignificant results, and violations of required statistical properties in the data.

In retrospect, I should have included the effect of transaction costs under the section on empirical testing, although it doesn’t seem that it would have produced different outcomes or conclusions.

I want to thank my parents, Eirik Ask and Tone Einarsen for the support and encouragement in writing this thesis.

All results, conclusions and remaining errors are mine, and mine alone.

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Introduction

The foreign exchange market has grown both in size and importance over the last few decades. Increased international trade combined with the deregulation of financial markets in countries such as the US and Japan has caused the foreign exchange trade to skyrocket in recent years (Krugman et al 2012). In April 1989 the average total value of global foreign exchange trading was just short of $600 million a day. By April 2010 that number had increased to an average of almost $4 trillion (BIS 2010).

A fundamental concept in foreign exchange trade is the interest parity relation first introduced by the economist Irving Fisher. The basic idea behind interest parity is that the same deposit placed at home or abroad should generate the same return. That is, any returns from interest differentials should be equalized through exchange rate movements.

Interest parity is said to be covered when it refers to the closed relation between the spot and *forward* rate of a currency pair, as opposed to the uncovered version which is an open relation between today’s spot rate and the *expected* future spot rate.

Uncovered interest parity (UIP) is a classic topic of international finance, and a critical building block of most theoretical models in addition to being a dismal empirical failure. The relation predicts that countries with high interest rates should, on average, have depreciating currencies. Instead such currencies tend to have appreciated (Flood and Rose 2001).

A currency is said to be at a forward discount when the future spot rate is expected to depreciate below the current spot rate, and conversely at a forward premium when we expect the opposite. The finding of a forward premium when we expect a forward discount is what is usually referred to as the forward premium puzzle.

Central to the finding of a forward premium puzzle is the failure of the unbiased forward rate hypothesis (UFRH), which implies that the forward rate is an unbiased estimate of the future exchange rate. However, early work showed that forward exchange rates have little power as forecasters of future spot rates (Fama 1984).

Several explanations have been offered to explain this puzzle including but not limited to the presence of a time-varying risk premia attached to future spot rates, unexpected market events, statistical forecast errors and irrational investors (see Al-Zoubi 2011, Lewis 1995)

The forward premium puzzle anomaly has served as the theoretical foundation of positive returns from currency speculation known as carry trade (Xanthopoulos 2011). Carry trade is a strategy that exploits that the forward exchange rate is a biased forecaster of the future spot exchange rate. It involves selling currencies forward that are at a premium and buying currencies forward that are at forward discount.

According to UIP no excess returns from investing in the high interest rate currency should be possible. It follows that if UIP hold, the expected returns are zero, forward rates predict future spot rates and the hypothesis of market efficiency is not rejected (Xanthopoulos 2011). In the alternative, the carry trader can pocket both the interest rate differential and appreciation of the target currency, with zero capital (Li 2010). However, as Xanthopoulos (2011) notes, market corrections may reverse some of the profits.

Nominal interest rates reflect investor expectations about future inflation (Burnside et al 2011a). If investors rationally forecast inflation, then (assuming perfect markets and risk neutrality) the high interest rate currency should depreciate as predicted by UIP. In the opposite, if inflation is not rationally forecasted, the forward premium might be present together with the possibility for excess returns.

James et al (2009) show that the UIP holds in the early years after the break-up of Bretton Woods[1] progressively weakens during the 80s and the 90s before it completely breaks down between 2002-2007, when most of the carry profits came from spot moves. According to the article it was at the time too early to tell whether the 2007 and onwards increase in carry losses would represent a return to the UIP condition

[1] Bretton Woods monetary system officially ended when the United States terminated convertibility of the dollar to gold on August 15, 1971. http://en.wikipedia.org/wiki/Bretton_Woods_system#cite_note-0

This thesis has two main objectives. The first objective is to test whether the latest data supports UIP or in the alternative presents evidence in favour of the forward premium puzzle. The premier motivation for this part is the suggestion from James et al (2009) that recent increases in carry losses might represent a return to the UIP condition. A simple linear regression model will be used to test the UIP condition which is based on the classical approach applied by amongst others, Fama (1984) and Bansal and Dalquist (2000).

The second objective is to test the efficient market hypothesis through two profit based excess return strategies. Olmo and Pilbeam (2009, 2011) argue that the testing of profit based strategies is a more direct and meaningful test of market efficiency and with it the UIP condition.

The final results from the two approaches to testing market efficiency and UIP will be compared to see whether they agree or produce contradictive results. In the latter it will be difficult to draw any definitive conclusions on whether UIP and market efficiency prevails. On the other hand, if the two approaches do agree it should be possible to either confirm that UIP holds and there is market efficiency or that it fails and excess returns are possible from currency speculation.

The remainder of this thesis is structured as follows: Section one provides an overview of previous studies on the subject of UIP and carry trade. In section two, a general outline of underlying theory and econometric models for testing both the UIP condition and the excess return hypothesis are described in detail. Section three contains empirical testing and results, both from the UIP regression and the excess return strategies. The final section includes concluding remarks and suggestions for possible future research.

1.0 Prior studies

Al-Zoubi (2011) summarizes to date explanations for the Forward Premium Puzzle in two broad categories. The forecast error category has several explanations for the forward biasedness such as peso problems, learning problems and/or irrational investors. The second class of studies attributes the puzzle to a time-varying risk premium which according to Burnside et al (2007) is emphasized in the literature.

Fama (1984) is a classical and a frequently referenced study which test the UIP condition by decomposing the forward rate into two components; the expected future spot rate and a premium. Fama shows that both components vary through time, and that most of the variation is attributable to the premium, and that the premium and expected future spot rate are negatively correlated. This leads to the negative coefficient in the regression defined as the premium puzzle.

A number of later studies however, discount the fact that a time-varying risk premium can explain the puzzle. Froot and Frankel (1989) find that the systematic portion of forward discount prediction errors does not capture a time-varying risk premium. In addition, Froot and Frankel (1989) also reject the claim that the risk premium is more volatile than the expected depreciation.

In a survey, Engel (1996) concludes that the empirical tests [for the UIP condition] routinely reject the hypothesis that the forward rate is an unbiased predictor of the future spot exchange rate and that models of the risk premium have been unsuccessful at explaining the magnitude of this failure of unbiasedness.

Baillie and Bollerslev (2001) state that the forward premium puzzle may be viewed as a statistical phenomenon from having small sample sizes together with the presence of persistent autocorrelation in the forward premium. Baillie and Bollerslev (2001) also states that if a time-varying risk premium does exist, the available evidence suggests that it is extremely small at the monthly level. In a classic study by Meese and Rogoff (1983) it is actually shown that none of the estimated models outperforms a random walk model.

Flood and Rose (2001) look at the UIP using data from 23 developing and developed countries in the period of multiple currency crisis' in the 1900s. UIP may work better for countries in crisis, where both exchange rates and interest rates are more volatile. Despite a considerable amount of heterogeneity in the results, Flood and Rose (2001) conclude that UIP works better in the analyzed period in the sense that high interest rate countries at least tend to have depreciating currencies, although not equal to the interest rate differential.

Bekaert and Hodrick (1993) look at several sources of bias which could mitigate the burden on a time varying risk premium in explaining the failure of the unbiased forward rate hypothesis. Firstly, measurement error from either incorrect sampling or the failure to account for bid-ask spreads, where both show little significance. Omitted variables, also pointed out by Olmo and Pilbeam (2009, 2011), due to conditional heteroskedasticity in the data is also shown to have little effect in explaining empirical results.

The question then arises whether rational expectations theory can account for the extremely variable forward market risk premium implied by the finding of negative slope coefficient. According to Bekaert and Hodrick (1993) rational agents might need time to react to changes in policy regimes, which can lead to systematic forecast errors. Such rational "learning" is also explored as a possible explanation by Lewis (1995).

A peso problem is defined by Lewis (1995) as the case where market participants expect a future shift in policy that is not present within the sample period examined. Lewis (1995) finds that the puzzle may in part be caused by peso problems, but that peso problems alone cannot account for all predicted excess returns. Kaminski (1993) find some support for the peso problem hypothesis in the dollar/pound exchange rate analyzing data between 1976 and 1987.

Bansal (1997) and Bansal and Dalquist (2001) provides empirical evidence that further deepens the forward premium puzzle. In these models, a state dependent regression is considered, capturing the sign of the interest rate differential. Their findings suggest that the slope coefficient is strongly related to the interest rate differential, and that the puzzle is more probable when the US interest rate is lower than foreign nominal interest rates.

In more recent studies there has been increasing focus on irrational investors and nonlinearities in the data as an explanation for the forward premium puzzle in addition to the use of increasingly more sophisticated econometric models (Olmo and Pilbeam 2011). Xanthopoulos (2011) notes that the spot exchange rates may consist of both a linear relation to interest rates and the correcting effect of large capital flows (non-linear effect).

Al-Zoubi (2011) examines the forward premium puzzle by decomposing spot and forward rates into (permanent) nonlinear trend components and (transitory) stationary components. It is argued in the article that the rejection of the hypothesis of the unbiased forward rate as predictor of the future spot rate is due to the failure of *the transitory* component of the forward rate to fully predict *the transitory* component of the future spot rate.

Furthermore, Al-Zoubi (2011) shows that the permanent component of the forward rate which is modelled as a non linear deterministic trend, can fully predict the nonlinear deterministic trend component of the corresponding future spot rate. Also Sarno et al (2006) finds significant nonlinearities in the relationship between spot and forward exchange rates and show that deviations from UIP detected using linear regression can be misleading.

On the other hand, Burnside et al (2007) approaches the puzzle from yet a different angle where they conclude that adverse selection problems between participants in foreign exchange markets can account for the forward premium puzzle. In another article by Burnside et al (2011a), an explanation is offered for the forward premium puzzle in investor over confidence.

The work is motivated by evidence from psychology in relation to individual judgment. Their main conclusion is that investors overreact to information about future inflation, which causes greater overshooting in the forward rate than the spot rate. Thus the forward premium reflects the overreaction in the spot rate and predicts its subsequent correction. The presented model can explain the magnitude of the forward premium bias and is consistent with the availability of profitable carry trade strategies.

The existing literature seems to offer a variety of possible solutions to what has become known as the Forward Premium Puzzle. Al-Zoubi (2011) notes that (p599):

> "The hypothesis that forward exchange rates are unbiased predictors of future spot rates is empirically far from conclusive"

Isard (2006) states in the ending remarks (p9) that:

> "Regardless of the usefulness of UIP as an ex ante hypothesis for macroeconomic modelling, it is quite clear that UIP by itself provides a very inaccurate framework for predicting the changes in exchange rates that are observed ex post."

Econometric rejections of UIP have been taken as evidence in the literature as indicating that the foreign exchange market is inefficient or contains a risk premium which then implies the possibility for excess return in currency speculation.

There have not been many in-depth studies of whether the failure of UIP can be applied to earn excess returns in the foreign exchange market (Olmo and Pilbeam 2011), but Burnside et al (2006) are in fact able to show significant excess return over time. They however include the following in the ending remarks (p23):

"While the statistical failure of UIP is very sharp, the amount of money that can be made from this failure, at least with our currency speculation strategies, seems relatively small."

Similarly, Sarno et al (2006) find that when the potential profit is large enough to attract speculative capital, the spot-forward relationship quickly reverts towards the UIP condition.

On the other hand, James et al (2009) shows that carry has been a robust trading strategy that has returned profits for three decades. Furthermore, with falling interest rate differentials they also show that the source of the carry trade profits has increasingly tilted towards exchange rate moves, demonstrating a further move away from UIP.

In line with the findings of James et al (2009), Burnside et al (2011b) find that carry trade strategy applied to portfolios of currencies yields high average payoffs. The most natural explanation according to their article is that the investor is compensated for risk. At the same time conventional risk measures fail to explain the payoffs to carry (and the forward premium puzzle).

Burnside et al (2011b) in fact argue that the positive average payoff to the unhedged carry trade reflects peso event risk. By comparing an unhedged carry trade strategy to a hedged strategy involving currency options to mitigate adverse effects of peso events, they find that the payoff of the hedged strategy is smaller than the unhedged carry trade. This finding is consistent with the view that the average payoff to the unhedged carry trade reflects a peso problem.

Olmo and Pilbeam (2009, 2011) takes the conventional econometrical failure of the UIP as a given, and explores the implications of deviations from UIP for the profitability of trading in the foreign exchange market. They find that a breakdown of UIP not necessarily means that excess returns are present and that over time returns are similar to what UIP would predict. The article is not conclusive, because the dollar-pound currency pair shows some signs of excess returns.

The argument is that traditional econometric rejections of UIP are only indirect tests of the efficient market hypothesis. Excess profitability is according to Olmo and Pilbeam (2009) a more direct and economically meaningful test of uncovered interest parity and with it market efficiency.

This thesis will be limited to test whether the latest data support UIP or in the alternative, show characteristics normally associated with the forward premium puzzle. In addition to the conventional approach of testing UIP, I will apply two excess return strategies to test the efficient market hypothesis under the framework of Olmo and Pilbeam (2009, 2011).

In the event a forward premium puzzle is identified in the conventional approach, providing explanations for the puzzle, e.g. relating it to time-varying risk premiums or peso problems or test whether is confined to developed economies, will fall outside the scope of this thesis.

Furthermore, this thesis will not go into details on exchange rate fundamentals and the formation of currency prices. Nor will it take into account transaction costs or other barriers that might influence market efficiency or the free flow of capital in the empirical testing.

2.0 Theoretical foundation

A fundamental concept, both in international finance and as underlying theory to the forward premium puzzle is the theory of interest rate parity. The basic idea behind this relation is that the same deposit should generate the same return, irrespectively of whether it is placed at home or abroad.

Interest rate parity can be divided into two main relations, namely covered and uncovered interest parity. Covered interest parity relates to hedged exchange rate transactions, whereas the uncovered interest parity relation applies to unhedged transactions. The details of these two relations are described below.

2.1 *The theory*

2.1.1 A framework for covered interest parity

Covered interest parity is a closed relation between the spot and forward rates of a currency pair, and the nominal interest rates associated with the respective currencies. All variables are known with certainty today so there is no risk involved. The CIP can be expressed as follows:

$$S_t(1+i) = \mathrm{F}_\mathrm{t}^\mathrm{k}(1+i^*) \tag{1}$$

Where S_t represents today's spot rate, F_t^k is today's forward rate k periods from now. i and i^* is the domestic and foreign nominal interest rate, respectively. It follows from equation (1) that the domestic return equals the foreign return on investment. If equation (1) does not hold there are arbitrage opportunities, which under the efficient market hypothesis would quickly be traded away.

Rearranging and subtracting one from each side of equation (1) will yield the following expression:

$$\frac{F_t^k - S_t}{S_t} = \frac{i - i^*}{1 + i^*} \quad (2)$$

The left hand side represents the forward premium percentage, also referred to as the normalized forward premium. The normalized forward premium is approximately[2] equal to the interest rate differential and will be used interchangeably, see Bansal and Dalquist (2000)

A forward discount exists when the forward rate is below the spot rate. Conversely, when the forward rate is above the spot rate, there is a forward premium. It follows from equation (2) that a high interest currency is expected to be at a forward discount.

2.1.2 A framework for uncovered interest parity

Unlike covered interest parity, the uncovered interest parity relation does not eliminate risk. The uncovered interest parity is an open relation between spot and *expected future spot rates*, domestic and foreign nominal interest rates. The UIP relation is also known as the international Fischer effect[3]. The uncovered interest parity relation can be expressed as follows:

$$S_t(1 + i) = E_t[S_{t+1}](1 + i^*) \quad (3)$$

Where S_t represents the spot rate today, and $E_t[S_{t+1}]$ is the expected future spot rate, conditional of information at time t. As with the covered interest parity relation, i and i^* denotes the domestic and foreign nominal interest rates respectively.

By utilizing the same procedure as above of subtracting one from each side of equation (3), and rearranging we get:

$$\frac{E_t[S_{t+1}] - S_t}{S_t} = \frac{i - i^*}{1 + i^*} \quad (4)$$

[2] The denominator $1 + i^*$ is relatively small and often omitted in CIP
[3] Introduced by the economist Irving Fisher

The expected exchange rate depreciation equals the interest rate differential[4]. The country with the higher nominal interest rate is expected to depreciate against the low interest currency, because higher nominal interest rates reflect the expectation of inflation (Madura 2007).

2.1.3 The unbiased forward rate condition

A central concept to the theory of interest rate parity is investor expectations, which were introduced in the previous section (UIP). The future spot rate is not completely predictable, and may differ from the forward rate. Market equilibrium occurs when

$$\mathrm{F}_{\mathrm{t}}^{1} = E_t[S_{t+1}] \tag{5}$$

Equation (5) is also known as the unbiased forward rate condition[5]. This condition states that the forward rate must be a true and unbiased estimate of the future spot rate, conditional on information available today. If a currency is expected to depreciate, investors will sell the currency forward at a cheaper rate, until the forward rate $\mathrm{F}_{\mathrm{t}}^{1}$ again equals the expected future spot rate, $E_t[S_{t+1}]$.

When this does not hold, it is often explained by the presence of a time varying risk premium attached to the future spot rates (Fama 1984).

2.1.4 Introducing a risk premium

An asset's risk premium is a form of compensation for investors who tolerate extra risk[6]. Investments with higher risk must provide an investor with the potential for larger returns to warrant the risks of the investment.

According to Fama (1984), Bansal and Dalquist (2000) the forward risk premium can be expressed as the difference between the forward contract at time $t + 1$ less the expected future spot rate, divided by today's spot rate

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[4] As for CIP, denominator $1 + i^*$ is relatively small and is often omitted
[5] This relation can also be found by combining covered interest parity and the international Fischer effect, in equations (2) and (4)
[6] From the definition of "risk premium", investopedia.com

$$\frac{F_t^1 - E_t[S_{t+1}]}{S_t} \tag{6}$$

The risk premium will be denoted ρ_t

Specifically, if the UFR condition does not hold, the difference could be explained by adding a risk premium:

$$F_t^1 = E_t[S_{t+1}] + \rho_t \tag{7}$$

Bansal and Dalquist (2000) show that the forward premium (eq 2), the expected depreciation of a currency (eq 4) and the risk premium (eq 6) are closely related[7]:

$$\frac{F_t^k - S_t}{S_t} = \frac{E_t[S_{t+k}] - S_t}{S_t} + \frac{F_t^k - E_t[S_{t+k}]}{S_t} \tag{8}$$

Or

$$x_t = d_t + \rho_t \tag{9}$$

As outlined above, currencies with higher nominal interest rates are expected to depreciate as higher nominal interest rates are indicative of inflation. This implies that the high interest currency should be at a forward discount, i.e. the future spot rate should be lower than today's spot rate.

The finding of a forward premium when we expect a forward discount is what is usually referred to as the forward premium puzzle.

2.1.5 Data characteristics and methodology

Standard statistical tools such as the linear regression have a number of required conditions that must be satisfied for the methods to be valid. A critical component is the error variable, ε_{t+k}. The least squares model requires that the probability distribution of ε_{t+k} is normal, and that the mean of the distribution is zero.

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[7] Equation (8) can be found by adding and subtracting ${S_{t+k}}/{S_t}$ from the forward premium.

Furthermore, that the standard deviation of the error variable is a constant regardless of the value of the independent variable, and that the error variable is uncorrelated to any particular value of the dependent variable, i.e. the error variable is stationary (Keller, G. and Warrack, B. 2003)

Many finance models implicitly assume that the data used are stationary. The failure of this assumption may lead to anomalies or puzzles, such as the forward premium puzzle. As stated above, stationary data are characterized constant mean, variance and covariance.

Making non-stationary data stationary can often be accomplished by either differencing the data or taking logarithms. Taking logarithms also makes the analysis independent of whether a currency is measured in domestic currency per foreign currency or vice versa (Fama 1984).

2.2 The forward premium puzzle

2.2.1 Precise expression of the puzzle

Based on the theory outlined in the previous section we need to develop an econometric model to be able to test for the forward premium puzzle. As a starting point we recall the UFR condition:

$$f_t^k = E_t[s_{t+k}] \tag{10}$$

Note that the lower case characters signal that we have taken the logarithms, so that s_t is defined as the logarithm of the spot exchange rate at time t, and f_t^k is the logarithm of the time t forward rate, to trade the asset k periods from now.

Furthermore, ρ_t is defined as the risk premium on the particular trading position and ε_t is the market's forecast error for the spot exchange rate, given available information at time t.

With rational expectation the actual spot rate tomorrow equals the expected future spot rate today plus the forecast error:

$$s_{t+k} = E_t[s_{t+k}] + \varepsilon_{t+k} \tag{11}$$

Using equation (11) we can rewrite the UFR condition for any k period in the future as:

$$\begin{aligned} f_t^k &= E_t[s_{t+k}] \\ &= s_{t+k} - \varepsilon_{t+k} \end{aligned} \tag{12}$$

Note that it is the use of the forecast error that allows us to work without the expectations operator. Expectations are not observed and are therefore difficult to work with econometrically.

Remembering that if the UFR condition does not hold, this can be explained by a time varying risk premium. Specifically, if the forward premium does not equal the future spot rate (adjusted for the error variable), any difference will be the risk premium:

$$\mathrm{s_{t+k} - f_t^k - \varepsilon_{t+k} = \rho_t} \tag{13}$$

Equation (13) can be rearranged to show the speculative return on a forward contract:

$$s_{t+k} - f_t^k = \rho_t + \varepsilon_{t+k} \tag{14}$$

On the left hand side of equation (14) is the difference between the spot rate k periods from now and the corresponding forward rate at time t. The left hand side represents whatever the unbiased forward rate cannot explain, denoted by the risk premium and the random error term.

To test this equation we follow Fama (1984) and look at the change in the spot rate on the one period forward premium. Subtracting s_t from equation (14), and rearranging results in the following expression[8]:

[8] It can be shown that taking logs to the forward premium, ln ($\mathrm{F_t^k} - S_t / S_t$) equals $f_t^k - s_t$.

$$(s_{t+1} - s_t) = (f_t^1 - s_t) + \rho_t + \varepsilon_t \tag{15}$$

The change in spot rate equals the forward premium in addition to the risk premium and the expectational error. This framework is also consistent with the work of Bansal and Dalquist (2000).

2.2.2 The model

To test this econometrically I perform the following regression, testing the expected depreciation by regressing the change in spot prices on the forward premium:

$$s_{t+1} - s_t = \alpha + \beta(f_t^1 - s_t) + \mu_{t+1} \tag{16}$$

This model has been used extensively to document the forward premium puzzle, and the consequent violations of interest rate parity. The model is useful, because it allows us to test unbiasedness just by looking at the coefficient β. It follows from equation (16) that the unbiased forward rate condition holds when $\beta = 1$. It is the finding of a negative slope-coefficient which indicates the presence of the forward premium puzzle (Bansal and Dalquist 2000).

2.2.3 Economic implications

The finding of $\beta < 0$, referred to as the forward premium puzzle (Fama 1984), has particularly counter-intuitive implications. It leads relatively high domestic nominal interest rates to predict an appreciation of the domestic currency. Specifically, it follows from the regression equation that if the coefficient equals negative one, and the forward rate exceeds the spot rate by 1%, the spot rate would decrease by 1% or more, instead of *increasing* by 1%, and reaching market equilibrium.

There are models that can explain a coefficient which is less than one, but a negative coefficient is difficult to satisfy with frictionless asset markets. This would require that the aggregate risk in the economy must be lower when the level of interest rates is high – a feature that most parametric models find difficult to capture (Bansal and Dalquist 2000).

Another implication is that the failure of UIP could imply that the foreign exchange market is inefficient and that excess return possibilities exist. To test this possibility is one of the main objectives in this thesis.

2.3 Excess return strategies

2.3.1 Strategy 1

According to the UIP condition there should be no excess returns for an investor from holding capital in the domestic or foreign currency. As noted by Olmo and Pilbeam (2009) not many studies, except for Burnside et al. (2006) have investigated whether the econometric failure of the UIP condition can be used to achieve excess returns.

If the foreign market is efficient, then the expected *excess* return of holding capital in foreign currency at the foreign interest rate should be zero. This can be expressed in the following way[9]

$$E[R^*_{t+1}] - E[R_{t+1}] = 0 \tag{17}$$

$E[R^*_{t+1}]$ represents the expected domestic return, conditional upon information at time t, of holding capital in the foreign currency at the foreign rate of interest. On the other side, $E[R_{t+1}]$ is the expected return of holding capital at the domestic interest rate. The domestic return on investing X amounts in the foreign currency is defined as

$$R^*_{t+1} = \frac{S_t}{S_{t+1}}(1 + r^*_t) - 1 \tag{18}$$

Note that $E[R_{t+1}] = r_t$ and by substituting equation (18) into (17), and at the same time multiplying with S_{t+1} yields the following expression:

$$S_t(1 + r^*_t) = E[S_{t+1}](1 + r_t) \tag{19}$$

[9] The notational and theoretical outline is in accordance with the work of Olmo and Pilbeam (2009, 2011)

When CIP holds, $S_t(1 + r_t^*) = F_t(1 + r_t)$ and the foreign exchange market would be efficient if $F_t = E[S_{t+1}]$ (Olmo and Pilbeam 2009).

To test this Olmo and Pilbeam (2009) introduce the following simple econometric test:

$$R_{t+1}^* - R_{t+1} = \alpha + \varepsilon_{t+1} \tag{20}$$

In this model is sufficient under the null hypothesis to look at the coefficient α[10]. When this is zero there is no excess return of holding capital in the foreign currency. Conversely, if α is significantly different from zero, there exists either a risk premium and/or market inefficiency between the currency pair.

2.3.2 Strategy 2

The second strategy builds on the results of conventional regression analysis of the UIP and the finding of the Forward Premium Puzzle. The finding of a negative Beta suggests that the currency that are expected to depreciate due to higher nominal interest rates, in fact tend to appreciate. Investing in the high interest rate currency is a key element of the carry trade

Olmo and Pilbeam (2011) propose a high interest-low interest profitability test that consists of comparing the dollar returns of investing capital in the market with highest nominal interest rates to the dollar return of investing capital in the currency with the lowest nominal interest rate.

The relevant efficiency condition in this case can be stated as follows:

$$E[RH_{t+1}] - E[RL_{t+1}] = 0 \tag{21}$$

where $E[RH_{t+1}]$ is defined as the expected *dollar* return from being invested in the high interest rate currency and $E[RL_{t+1}]$ consequently represents the expected *dollar* return from being invested in the low interest rate currency.

[10] Note that the regression is balanced if $R_{t+1}^* - R_{t+1}$ and the error term is stationary. If this is the case and the error term is a white noise then OLS estimators provide consistent and efficient estimates of the parameters.

The corresponding econometric test is defined by Olmo and Pilbeam (2011) as

$$E[RH_{t+1}] - E[RL_{t+1}] = \alpha + \varepsilon_{t+1} \tag{22}$$

Olmo and Pilbeam (2011) analyze four currency pair, namely the Yen, Swiss-Franc, Euro and Sterling Pound against US Dollars. They find that the yen and Swiss Franc currency pairs pass all four test, while the results for the euro and sterling are somewhat more mixed, failing two of the profitability test (one being the carry trade test described above).

On the basis of the first two tests they argue that the foreign exchange market has been efficient for all four currency pairs. Olmo and Pilbeam (2011) are however cautions to draw this conclusion in general, due to the findings regarding the euro and sterling parities.

2.3.3 Methodology

Since there is no independent variable, the regression line boils down to the average of the calculated excess return, denoted α. The residuals will constitute each observations difference from the sample mean. A standard student t test with corresponding p-value will be applied to test whether α is significantly different from zero. The OLS conditions described under section 2.15 still applies.

In the following section I will perform a regression analysis for eight major currencies in addition to test excess return strategy 1 and 2 on the same currency pairs with the US Dollar as base currency. As this thesis is written in Norway, I will expand the testing for profit strategy 1 and 2 to include five major currencies with NOK as base currency, and compare the two. Since the profit strategies are applied on monthly data, I will test the same strategies using annual data for three major currencies to see whether a different outcome will occur.

3.0 Empirical results

3.1 Data and descriptive statistics

All data used in the regression analysis and all consecutive analysis' are collected from Thompson DataStream. A complete list of collected time series is available in Appendix 3.

For the forward premium regression, monthly spot and forward exchange rates are collected for a total of eight currencies shown in Table 1. The time series span from January 1st 1997 to April 1st 2012 for all currencies with the exception of the Euro. The Euro was first introduced as an accounting currency January 1st 1999 and no data [including forward rates] are available prior to this date. The collected time series thus include 183 observations for all currencies except the Euro, which has 159 observations.

All spot and forward exchange rates are obtained with USD as the base currency (currency to US) with the exception of the spot exchange rate for the British Pound and the one month forward exchange rate for the Australian Dollar. The corresponding "currency to US" spot and forward exchange rate respectively have been obtained by taking the inverse of the US to currency ratio. The US Dollar has been chosen as base currency because it remains the most important currency in the foreign exchange market with a share of 84.9% against the Euro's market share of 39.1% (BIS 2010)[11].

Existing literature on UIP and carry trade utilizes different time horizons on the spot and forward exchange rates. Bansal (1997) and Bansal and Dalquist (2000) use weekly data, while Flood and Rose (2001) use daily data. Al-Zoubi (2011) uses monthly data when testing for the forward premium puzzle, and Olmo and Pilbeam (2011) do the same in their approach. I have therefore chosen to do the same, so that results from the two approaches to testing UIP in this thesis are more easily comparable.

Annual one month interest rates are collected (interbank or equivalent) and converted to monthly interest rate using the ratio (30/360) to get the correct time horizon for the excess return strategy testing. The time series for the profit testing with NOK as base currency span

[11] Of a total sum 200% because each currency trade always involves a currency pair.

from October 1st 2000 until 1st April 2012. The currencies Yen and Swiss Franc exchange rates are divided by 100 to obtain comparable rates. The applied interest rates are the same monthly rates as above.

The longer, annual time series have been analyzed with US Dollar as the base currency and span from 1976 until 2012 for the currencies Yen, Swiss Franc and the British Pound. The British Pound was again only available as "currency to USD", and has therefore been converted as above.

The length of the time series has only been limited by the availability of historical data, as is the case for the Euro. In addition, the availability of forward exchange rates has proven a limiting factor. The length of the time series available varies considerably. I have chosen to limit the data to the second shortest time series to better be able to compare my findings.

Descriptive statistics is shown below for the currencies included in the regression. The logs have been transformed into percent, and converted to annual numbers by multiplying the mean with 12 and the standard deviation by $\sqrt{12}$ respectively.

The US Dollar has, on average, depreciated against all currencies with the exception of the British Pound and the South African Rand. The Swiss Franc and the Japanese Yen has the highest average appreciation against the US dollar of the analyzed currencies.

If the unbiased forward rate hypothesis (eq 5) holds, a currency which is expected to depreciate should be at a forward discount. Currencies with negative average mean should therefore have corresponding negative average forward premiums, i.e. be at a forward discount. As the table below show, this is not the case for the Australian Dollar and the Norwegian krone. Both currencies have on average depreciated, but show a corresponding average forward premium where we expect a forward discount.

This might be an early implication that the parity relations and the unbiased forward rate hypothesis might not hold.

Table 1: Descriptive statistics on data input for FPP regression

		Exchange rate depreciation, dt				Forward premium, x_t				Timeseries	
Country	N	Mean	StDev	95% CI on mean		Mean	StDev	95% CI on mean		Start date	End date
Australia	183	-1,76	13,30	-3,69	0,16	2,05	0,57	1,97	2,14	01.01.1997	01.03.2012
Canada	183	-2,11	8,72	-3,37	-0,85	-0,09	0,30	-0,13	-0,04	01.01.1997	01.03.2012
Switzerland	183	-2,59	11,54	-4,26	-0,92	-2,12	0,46	-2,19	-2,05	01.01.1997	01.03.2012
United Kingdom	183	0,43	9,11	-0,89	1,75	1,05	0,34	1,00	1,09	01.01.1997	01.03.2012
Japan	183	-2,28	11,33	-3,92	-0,64	-3,18	0,62	-3,27	-3,09	01.01.1997	01.03.2012
Norway	183	-0,76	11,40	-2,41	0,90	1,04	0,65	0,95	1,14	01.01.1997	01.03.2012
South Africa	183	3,23	16,79	0,80	5,66	7,48	0,95	7,34	7,62	01.01.1997	01.03.2012
Euro	159	-0,94	10,82	-2,62	0,75	-0,28	0,42	-0,35	-0,22	01.01.1999	01.03.2012

3.2 Regression analysis Forward Premium Puzzle

The table below shows results from regressing the change in spot exchange rates on the corresponding forward premium. The full results from the regression are presented in appendix 4.

Table 2: Regression results for the Forward Premium Puzzle

Countries	N	β	SE-β	p-value β	R-sq	r-sq adj	DW
Australia	181	-2,18	1,73	0,211	0,9 %	0,3 %	1,91
Canada	181	-1,76	2,16	0,418	0,4 %	0,0 %	2,05
Switzerland	181	-2,60	1,84	0,159	1,1 %	0,5 %	2,14
United Kingdom	181	-0,50	2,00	0,803	0,0 %	0,0 %	1,83
Japan	181	-0,95	1,36	0,486	0,3 %	0,0 %	2,19
Norway	181	-0,87	1,30	0,503	0,2 %	0,0 %	1,90
South Africa	181	-1,53	1,32	0,247	0,7 %	0,2 %	1,81
Euro	157	-2,45	2,06	0,236	0,9 %	0,3 %	1,93

The estimated coefficients are reported as negative for all currencies. As explained above, it is the finding of a negative slope coefficient that indicates the presence of the forward premium puzzle (Fama 1984). A closer look at the data however, reveals that the standard errors of the coefficients are fairly high and the calculated p-value[12] shows that the coefficients are not statistically significant at a 95% confidence level.

Bansal and Dalquist (2000) report similar findings with negative coefficient for all these currencies. Norway, South Africa and the Euro are not part of the Bansal and Dalquist (2000) paper. Their findings are also supported by a higher r-squared statistic. The low r-squared statistic is fairly common when analyzing financial data. A low r-squared indicates that other factors not included in the model are influencing the data, but parameters such as the coefficients p-value is a better judgment of the goodness of fit for the regression.

As described under the section on theoretical foundation, the methodology of ordinary least squares requires that certain conditions relating to the error term are satisfied. The error term needs to be normally distributed with an expected mean of zero and have a constant variance (uncorrelated error terms). Autocorrelation violates the ordinary least squares (OLS) assumption that the error terms are uncorrelated. The Durbin-Watson test statistics is a test

[12] The p-value of the coefficient is calculated based on a t-test with a null hypothesis of $\beta = 0$. High p-values indicate that we cannot conclude at the convenient level that the coefficient differs from zero.

commonly used for detecting first-order autocorrelation in the error term and determines whether the error variable is normally distributed and has a constant variance.

When applied to the regression results in this section, all currencies show signs of negative autocorrelation in the error term[13]. While the presence of negative autocorrelation does not affect the OLS coefficient estimates, the standard errors tend to be overestimated and the corresponding t-statistic underestimated. This might contribute fact that the coefficient estimates are statistically insignificant from zero.

A review of the different diagnostic diagrams produced by Minitab also supports these conclusions regarding the error variable. The error variable does not seem to follow a normal distribution according to the histogram for e.g. Norwegian krone and Canadian dollar. The autocorrelation function show clear violations at 5% significance for both the British Pound and the Japanese Yen. The scatter plots of the residuals vs. fitted values also show signs of heteroskedasticity, a violation of the constant variance criteria for OLS.

Although the regression result indicate that the data violate the criteria for OLS and we are unable to draw significant conclusion on the estimates, the estimated β coefficients are reported as negative, which match with the findings of Bansal and Dalquist (2000), Flood and Rose (2001) and Al-Zoubi (2011).

As noted at the beginning of this thesis attributing the finding of a negative slope coefficient to a time-varying risk premium, or exploring other possible explanations for the apparent premium puzzle, is outside the scope of this paper and will not be commented on further.

As Olmo and Pilbeam (2009, 2011) I accept the results at face value, and explore possible implications for market efficiency and the possibilities for excess returns in the foreign exchange market in the remainder of this thesis.

[13] At 95% confidence, the currencies are above the upper limit of 1.69 for the DW test statistic, implying negative autocorrelation presence.

3.3 Strategy 1 (monthly, USD)

According to the argument made by Olmo and Pilbeam (2009, 2011) the standard test for the UIP condition above and the negative findings in prior studies should not be attributed to the failure of market efficiency. As outlined in the introduction, many have interpreted the failure of the UIP condition as a sign of an inefficient foreign exchange market and the possibility of excess return opportunities.

Olmo and Pilbeam (2011) outline four strategies, two of which will be tested below on the same data as used in the classic test for the UIP condition. The first strategy involves comparing returns from holding capital domestically versus investing in the foreign currency, earning the foreign rate of interest. For the purpose of testing these two strategies, the US will be defined as the domestic country.

Table 3: Results for Strategy 1 (monthly, USD)

Variable	Count	α	StDev	t-statistic	*p*-value α	Skewness	Kurtosis	JB	*p*-value
AUD_P1	219	0,004	0,04	1,73	0,085	-0,21	1,27	28,9	0,001
CAD_P1	219	0,002	0,02	1,05	0,295	-0,05	3,11	0,2	0,900
CHF_P1	219	0,001	0,03	0,51	0,607	0,29	1,78	16,7	0,001
GBP_P1	219	0,002	0,03	0,95	0,341	-0,15	2,29	5,4	0,010
JPY_P1	219	0,000	0,03	-0,21	0,837	0,70	3,42	19,5	0,001
NOK_P1	219	0,003	0,03	1,32	0,189	-0,09	0,52	56,4	0,001
ZAR_P1	219	0,003	0,05	0,84	0,401	-0,24	1,43	24,6	0,001
EUR_P1	159	0,001	0,03	0,51	0,610	0,10	0,60	38,4	0,001

Table 3 represents combined descriptive statistics and results from the test of the first strategy. The null hypothesis that $\alpha = 0$ is tested using a standard student t-test, which Minitab then uses to calculate the corresponding α p-value. A complete overview of the results is presented in Appendix 5.

Based on the α p-value the null hypothesis cannot be rejected for any of the currencies. The α value which represents excess return from investing abroad is not statistically different from zero. This is in accordance with the findings of Olmo and Pilbeam (2009, 2011) for this particular trading strategy. This is the complete opposite results compared to the classical regression results described above, and Olmo and Pilbeam interpret this as evidence that the efficient market hypothesis holds, at least for the first strategy.

The kurtosis and skewness for the random error variable forms the foundation for calculation the Jarque-Bera (JB) statistics. This statistic is used to determine whether kurtosis and skewness of the error term follows a normal distribution[14]. Perfect normality implies that the statistic equals zero. The JB statistic follows a Chi-squared distribution, with two degrees of freedom. The corresponding p-value to the JB statistic is shown in the table.

The p-values of the JB statistic show that normality holds for Canadian dollar and the British Pound, but are rejected for all other currencies. This conclusion is supported by the diagnostic diagrams produced with Minitab shown in appendix 5. In addition, several of the currencies show signs of autocorrelation. As described under the previous section, this might influence the standard deviation and consequently t-statistic. This could imply that the null hypothesis of $\alpha = 0$ should have been rejected for the currencies with a lower p-value, such as the Australian dollar and Norwegian krone.

3.3.1 Accumulated return Strategy 1

The following graph provides a visual representation of the strategy. Accumulated returns from investing in the foreign currency is calculated by buying $\mathcal{X}$ amounts of the foreign currency at the beginning of each month, earning the foreign rate of interest and exchanging the invested amount and returns to US dollars at the end of the period. The amount is then reinvested in the same way the following month, and this process is repeated throughout the period.

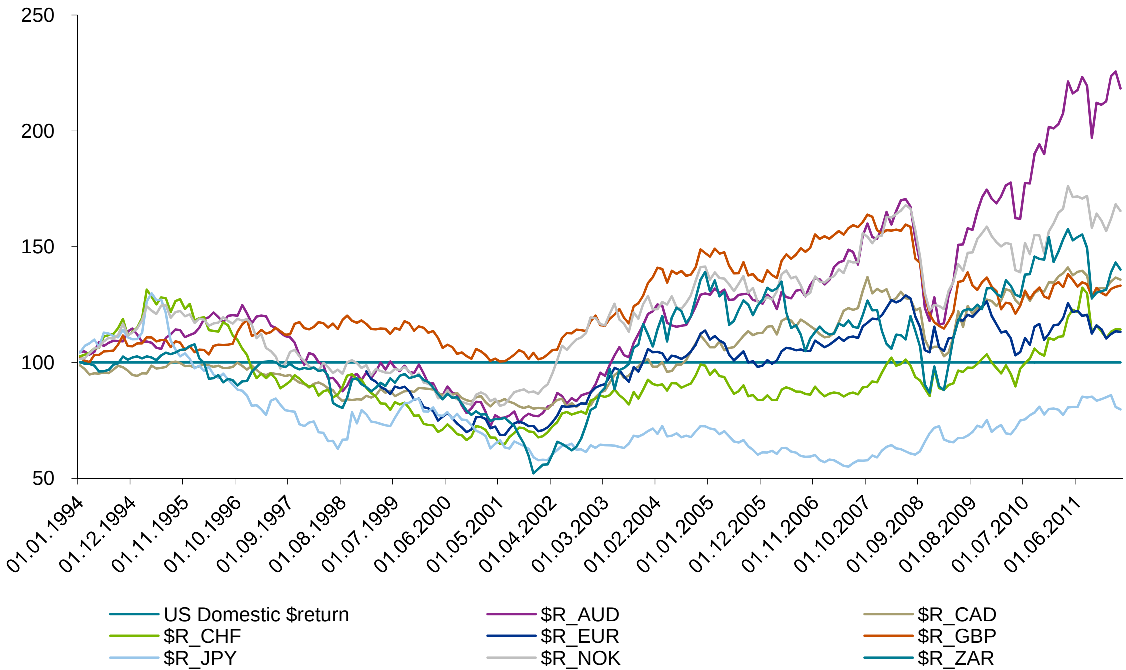
The accumulated dollar return of investing in the foreign currency is shown in *excess* of the equivalent accumulated domestic [US] return. That is, when the return is above the line (US return = 100), investing in the foreign currency has outperformed the domestic rate of return. On the other hand, when the return is below the line, the strategy of investing abroad has underperformed against holding capital at the domestic rate of interest.

At the beginning of the period, the accumulated return seems to be centered around the US return (=100), earning excess returns for the first few years, before taking a slow downward turn and underperforming against the dollar up to around 2002. The exception is the British

[14] The null hypothesis is a joint test of zero kurtosis (K=0) and zero skewness (S=3). At a confidence level of 95% and two degrees of freedom the null hypothesis is rejected for JB greater than 5.99.

Pound which in this period consistently outperforms the dollar before returning towards the US rate of return around 2002.

Graph 1: Strategy 1 - Excess return in US Dollar from investing in the foreign currency



From 2002 and onwards, almost all currencies accumulate excess profit against holding capital at the US rate of return, with the exception of the Yen which consistently underperforms throughout the period. Note that this implies borrowing Yen and investing in dollars would be profitable between 1994 and 2012

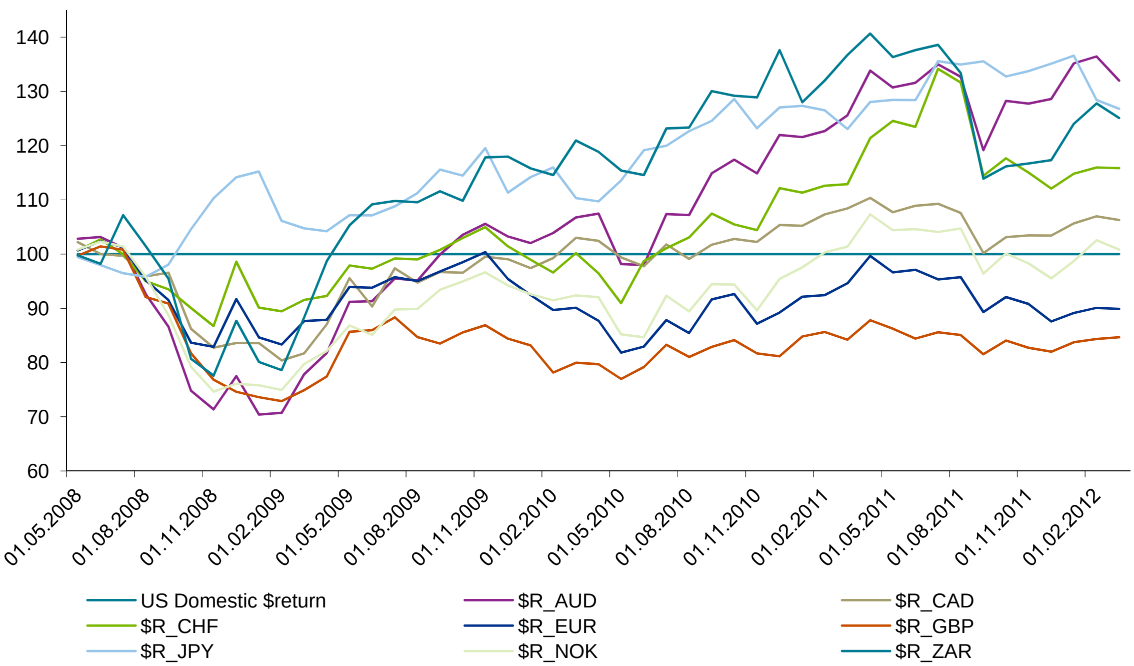
This trend continues up to late 2008 and beginning of 2009, when the performance of the accumulated foreign currency return sharply decline. Most of the currencies peak in the first six months of 2008. The fall of Lehman Brothers in September 2008 marked the start of the worst financial crisis since the Great Depression[15]. This event coincides with a turn in the exchange rate for the US dollar against the analyzed currencies. From September 2008 until the peak in March 2009[16] the US dollar appreciated against all currencies, except the Yen.

[15] http://www.reuters.com/article/2009/02/27/idUS193520+27-Feb-2009+BW20090227

[16] The Swiss Franc peaked three months earlier, in December, 2008.

This might be due to the view of the US dollar as a safe haven currency. In times of financial turmoil, investors liquidate various currency positions, and shift their funds into a [perceived] less risk currency, such as the US dollar. The increased demand for US dollar because of its status as a safe haven currency would help to explain the considerable appreciation of the US dollar in this period.

Graph 2: Currency crash - The US dollar as a safe haven currency



As noted by Xanthopoulos (2011), market corrections may reverse some of the profits from carry trade. Excluding the Yen, the average drop in accumulated profit was 21% from mid 2008 until March 2009. The accumulated return of the Australian dollar, Swiss Franc, Canadian dollar and Euro was close to or entirely eradicated.

It seems that timing is very important, as illustrated by the graph above. An investor undertaking this strategy the summer of 2008 would experience a sharp decline in return. An investor entering the market in March 2009 would however achieve the opposite, namely excess returns throughout the remainder of the period.

In fact, when looking at the period as a whole, all currencies except the Yen have returned excess profit, although not all have recovered completely from the reduction in accumulated profit after the appreciation of the US dollar. Note also that the currencies Australian dollar and Norwegian krone are the currencies with the highest and second highest accumulated return at the end of the period respectively, are at the same time the currencies with the lowest p-values under the empiric testing.

3.4 Strategy 2 (monthly, USD)

The second strategy is what traditionally has been referred to as carry trade. It involves investing in the currency which has the highest nominal interest rate at the beginning of each period, and comparing the return with consistently investing in the low interest rate currency. This implies that if the nominal interest rate of Norwegian krone exceeds that of the US dollar, we invest in the Norwegian krone, and revert back to US dollars at the end of the period. If the interest rate differential stays the same, we would again invest in Norwegian krone the following period. Consequently, if the US interest rate has increased above the Norwegian equivalent, funds are held domestically earning the US domestic rate of return.

Table 4: Results for Strategy 2 (monthly, USD)

Variable	Count	α	StDev	t-statistic	*p*-value α	Skewness	Kurtosis	JB	*p*-value
AUD_P2	219	0,008	0,035	3,49	0,001	-0,42	1,67	22,6	0,001
CAD_P2	219	0,002	0,024	1,35	0,180	-0,23	3,20	2,3	0,100
CHF_P2	219	-0,002	0,033	-0,98	0,327	-0,24	1,79	15,5	0,001
GBP_P2	219	0,002	0,025	0,91	0,366	-0,16	2,34	4,9	0,010
JPY_P2	219	0,002	0,034	0,92	0,357	-0,94	3,65	36,1	0,001
NOK_P2	219	0,005	0,031	2,28	0,024	-0,18	0,61	53,3	0,001
ZAR_P2	219	0,003	0,045	0,84	0,401	-0,24	1,43	24,6	0,001
EUR_P2	159	0,005	0,031	1,83	0,069	-0,15	0,73	34,7	0,001

Table 4 provides an overview of the combined descriptive statistics and results from the empirical testing. A complete overview of the results is available in appendix 6.

As described under the outline of the results for Strategy 1, a standard t-test is applied to test the null hypothesis of $\alpha = 0$ which implies that there are no excess returns from pursuing the high interest currency strategy. Contrary to the results under Strategy 1, the p-value of α indicate that the null hypothesis is rejected for the currencies Australian dollar and Norwegian krone. The Euro is also very close to being rejected at 95% confidence. This can also be illustrated by looking at the confidence intervals for α shown in appendix 6. Only NOK and AUD have a positive α within the 95% confidence interval.

This is a rather different result than reported findings by Olmo and Pilbeam (2011). They analyze four currency pairs; the Swiss Franc, the Yen, the Euro, and the British Pound against US dollars. In their article, they reject the null hypothesis for the Euro and the British Pound.

Two things are worth noting when comparing these results. Firstly, Olmo and Pilbeam (2011) have limited their study to just four currency pairs. In general, longer time series are available for all these currencies, compared to the additional currencies analyzed in this thesis. Their data span from November 1978 until January 2006. This period excludes the recent events outline above, which includes both the sharp appreciation, and consequent depreciation of the US dollar, and the currencies recovery from March 2009 and onwards.

Secondly, Olmo and Pilbeam (2011) find that the data are better behaved than what is suggested based on the results shown in table 4. Specifically, normality of the standard error holds for both the Swiss Franc and the Euro parities. Furthermore, no correlation between the residuals is found in the data.

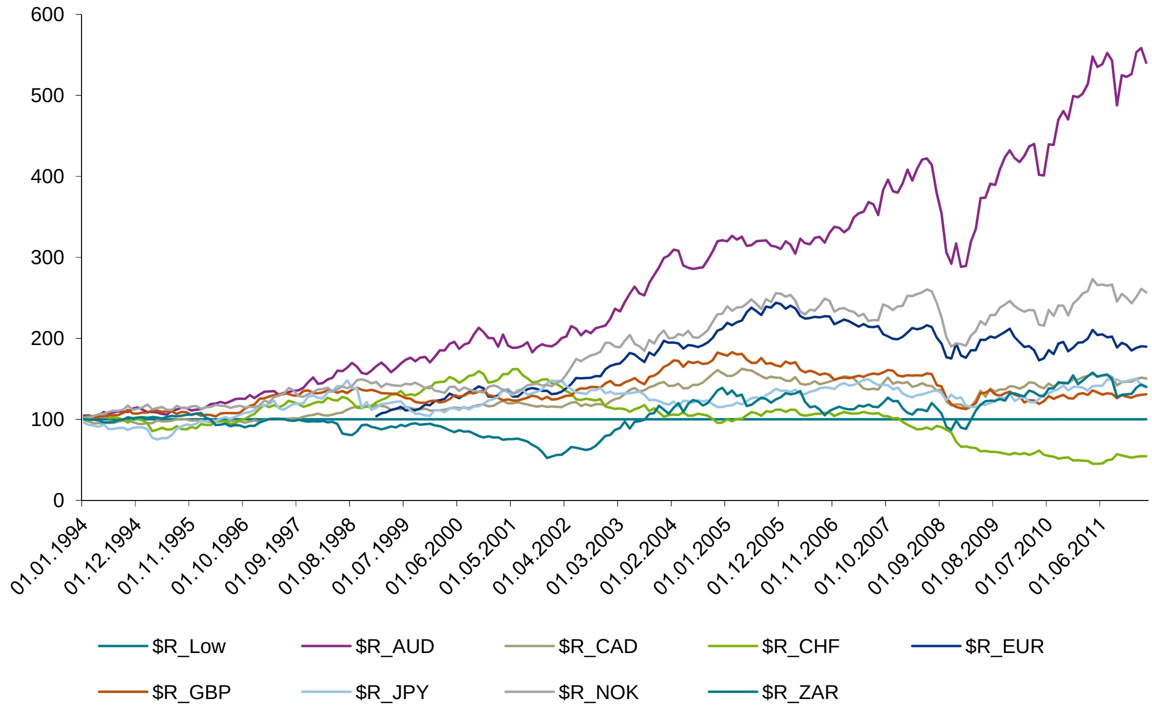
Based on the Jarque-Bera test for normality and corresponding p-value the normal distribution of the error term is clearly rejected for all currencies except the Swiss Franc, which comes close with a very low p-value. These findings are supported by the diagnostic diagrams produced with Minitab, and are presented in appendix 6. It should be pointed out that these violations do not affect the estimated coefficient, but over/under estimate the standard deviations as explained above. A true estimate of the coefficient might lead to the rejection of the null hypothesis of $\alpha = 0$ for additional currency pairs.

3.4.1 Accumulated return Strategy 2

To present this strategy in a visual context, the strategy has been put to use on the collected data, calculating the accumulated return from investing in the high interest rate currency at the beginning of each month. At the end of each month, the position is dissolved and reinvested according to the same rule the following month. The return from consistently choosing to invest in the low interest rate currency is calculated in the same way so we are able to compare the two.

Graph 3 shows the excess return in US dollar from investing in the high interest currency. The low interest return equals 100 to provide a reference point.

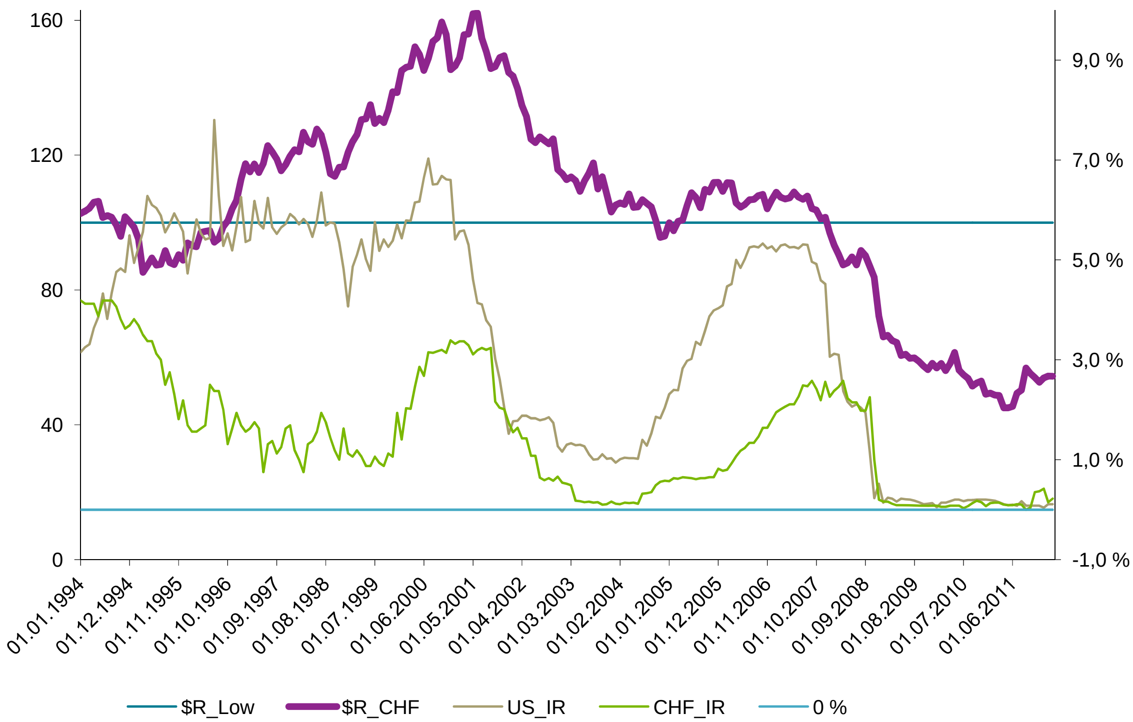
Graph 3: Strategy 2 - Excess return in US Dollar from investing in high interest rate currency



The accumulated returns based on Strategy 2 show similar characteristics as under Strategy 1. Firstly, the α value for the Australian dollar and the Norwegian krone was found to be significantly different from zero. These are also the two currencies with the highest accumulated return at the end of the period. In addition, the null hypothesis came close to being rejected for the Euro which shows the third highest accumulated return. The significant drop is clearly visible also with Strategy 2. The average drop in accumulated profit from this period was 23%.

Compared to the first strategy, the Yen parity now returns positive excess return, while the Swiss Franc at first produce excess return, before underperforming at an increasing rate after 2008. Although most currency pairs have a positive accumulated return at the end of the period when pursuing this strategy, the case of the Swiss Franc show that deciding where to invest only based on the nominal interest rate not always yield positive returns. It should be noted that in the period from 2008 and up to 2012 the interest differential between the Swiss Franc and US dollar was very small, and close to zero. The negative return thus came from unfavourable exchange rate movements, rather than the interest rate differential itself, which according to James et al (2009) demonstrate a further move away from UIP.

Graph 4: Strategy 2 - Accumulated return vs interest rates for the CHF and USD parity



These findings by James et al (2009) might hold in the short run. In the long run however, things tend to average out, as can be shown by looking at the CHF/USD parity. The average excess profit from the Swiss Franc and US dollar parity is only 3% in favour of strategy 2 when the full period is taken into account. It seems therefore, that UIP works better in the long run, at least for the CHF/USD parity.

The main overview graphs (see graph 2 and 4) of strategy 1 and 2 also illustrate this important point. Although each currency pair seemingly returns profit at the end of the period, the *average* profit over the full period is closer to that of the benchmark, the US interest rate in Strategy 1 and investing in the low interest rate currency in the case of Strategy 2.

3.4 Strategy 1&2 with NOK as base currency

In this section the combined results of testing Strategy 1 and 2 with NOK as the base currency is presented. The data have been obtained through Thompson Datastream, which has sourced the data from Norges Bank. The data span from from October 1st 2000 until 1st April 2012.

Table 5: Combined results Strategy 1 & 2 with NOK as base currency

Variable	Count	α	StDev	t-statistic	p-value α	Skewness	Kurtosis	JB	p-value
Strategy 1									
CHF_P1	138	-0,00095	0,028	-0,40	0,688	1,25	5,63	75,7	0,001
EUR_P1	138	-0,00151	0,021	-0,85	0,399	0,68	7,09	106,8	0,001
GBP_P1	138	-0,00294	0,026	-1,35	0,181	0,36	0,87	29,1	0,001
JPY_P1	138	-0,00382	0,042	-1,07	0,287	1,46	5,10	74,4	0,001
US_P1	138	-0,00446	0,034	-1,54	0,126	0,65	1,42	24,1	0,001
Strategy 2									
CHF_P2	138	0,00095	0,028	0,40	0,688	-1,25	5,63	75,7	0,001
EUR_P2	138	0,00163	0,021	0,92	0,361	-0,70	7,12	108,9	0,001
GBP_P2	138	0,00285	0,026	1,31	0,193	-0,32	0,85	28,9	0,001
JPY_P2	138	0,00382	0,042	1,07	0,287	-1,46	5,10	74,4	0,001
US_P2	138	0,00445	0,034	1,53	0,127	-0,63	1,40	23,8	0,001

The results from testing Strategy 1 show that results are very similar to the results of testing Strategy 1 with USD as base currency. The null hypothesis that $\alpha = 0$ cannot be rejected for any of the currency pairs. The Swiss Franc and the Euro present with fairly high p-values, while the US dollar and the British Pound have fairly low p-values. Similarly, under the first test, the NOK/USD parity had the lowest p-value of all currency pairs, with the exception of the Australian dollar (not included with NOK as base currency).

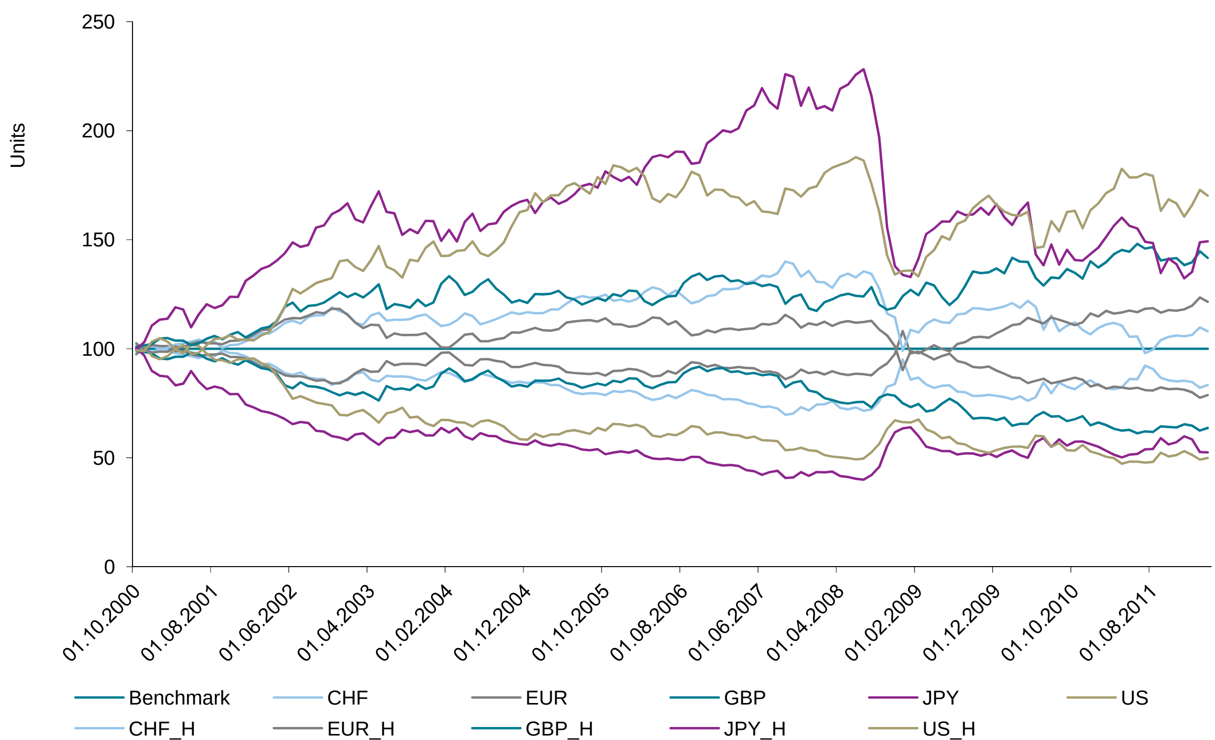
When the JB statistic is applied on these data, the null hypothesis of normality is overwhelmingly rejected. This finding is also supported by diagnostic charts produced with Minitab, which are presented in appendix 7. The error term seems to behave better, in the sense that contrary to previous results, there are no signs of autocorrelation with 5% confidence. Both the Swiss Franc and the British Pound parities come close, but the bars in the diagram stay within the 5% significance limits.

Contrary to the previous results of testing Strategy 2, none of the parities are rejected under the null hypothesis for NOK as base currency, although GBP and USD present with low p-values. This result is especially strange for the NOK/USD parity, which was rejected at the 95% confidence level in the previous section. It should not matter whether the currency pair is in Norwegian krone per US dollar or the other way around. However, the parity does come close to rejection under this test, with a p-value of only 0,126. Violations of the OLS condition might be a contributing factor in getting different results. Other possible explanations might be that the data have different sources and different length of the time series.

3.4.1 Accumulated return Strategy 1&2 with NOK as base currency

The calculated accumulated returns for both strategies are presented in graph six below. The returns to each currency pair have the same colour for both Strategy 1 and Strategy 2.

Graph 5: Excess return Strategy 1 & 2 combined with NOK as base currency

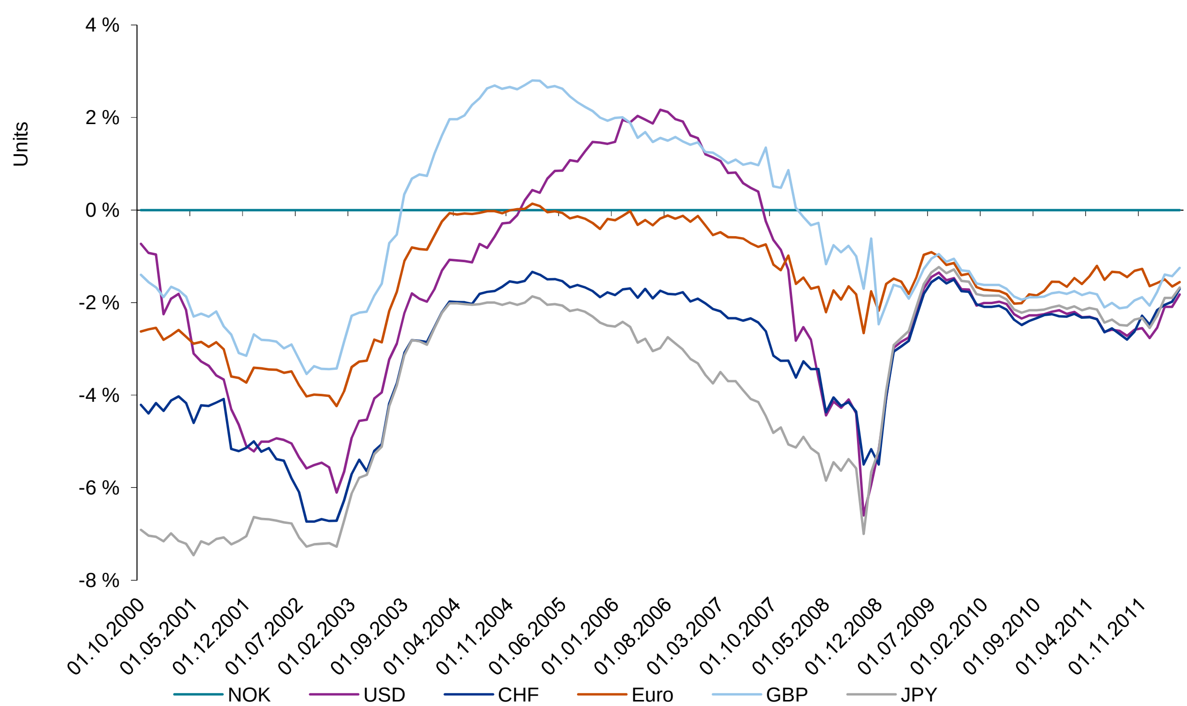


When comparing the two strategies with NOK as base currency we find that the α values are very similar and close to identical for some of the currency pairs. The only difference is the sign of the coefficient value, i.e. negative values for Strategy 1 and positive values for Strategy 2. The reason for this lies in the interest differential between NOK and the analyzed currencies. Only the British Pound and US dollar interest rates have exceeded their Norwegian equivalent since January 1st 2000. The British Pound interest rate stayed above the Norwegian interest rate between September 2003 and January 2008, while the US interest rate only exceeded the Norwegian Interest rate in the short period between January 2005 and August 2007.

This does not affect Strategy 1, which at the beginning of each period always invest in foreign currency to compare with the Norwegian return. For Strategy 2 however, this implies that for the most part, the high interest currency return will equal the Norwegian interest rate, only interrupted for a short period with GBP and USD. Thus for this special case, the two returns will more or less be complete opposites, as is clear when looking at graph seven. The only difference seems to be that Strategy 2 is more volatile.

The development of the respective currencies interest rates are shown in excess of the Norwegian interest rate below.

Graph 6: Interst rate differential from NOK



When the interest rate differential is positive, the foreign interest rate exceeds the Norwegian rate.

3.5 Strategy 1&2 with long time series

Olmo and Pilbeam (2011) analyze longer time series, but for fewer currency pairs than what have formed the basis for this thesis. One of the reasons for this is the challenge of obtaining long data series. For currencies such as the Swiss Franc, the British Pound and the Japanese Yen, this is not a problem, and so are the three currencies which are analyzed in this section. The data are annual data, and span back to 1976 with the US dollar as the base currency. Combined descriptive statistics and results are shown in the table below.

Table 6: Results Strategy 1 & 2: Long annual time series

Variable	Count	α	StDev	t-statistic	p-value α	Skewness	Kurtosis	JB	p-value
Strategy 1									
CHF_LP1	36	0,02	0,1452	0,95	0,348	-0,10	-1,12	25,5	0,001
GBP_LP1	36	0,02	0,1432	0,86	0,397	-0,13	-0,05	14,1	0,001
JPY_LP1	36	0,01	0,1455	0,50	0,622	-0,18	-1,03	24,6	0,001
Strategy 2									
CHF_LP2	36	0,03	0,1446	1,10	0,279	-0,27	-0,99	24,3	0,001
GBP_LP2	36	0,03	0,1405	1,46	0,153	-0,01	-0,14	14,8	0,001
JPY_LP2	36	0,03	0,1434	1,14	0,261	-0,26	-0,95	23,8	0,001

The test results for Strategy 1 show that the null hypothesis is not rejected for any of the three currencies. At a 95% confidence level, the α coefficient is not significantly different from zero, implying that no excess return should be possible in the long run. This is the same test result as with strategy 1 with both the Norwegian krone and US dollar as base currency. Thus, according to the model, market efficiency should prevail also in the long run.

It should be pointed out, that again, the JB statistic indicates that the error variable is not normally distributed. As noted earlier, this is a violation of the OLS methodology and may affect the standard deviations, and therefore consequently the p-value. The diagnostic diagrams from Minitab support the case of non-normality, and show signs of autocorrelation at least for the British Pound. See appendix 8 for details.

3.5.1 Accumulated return long annual time series

The accumulated return for each currency is calculated and presented below. At first, the accumulated returns go through a period of boom and bust before continuing on a horizontal trend. In recent times, the Swiss Franc and the British Pound seem to outperform the Yen and domestic US interest rate.

Graph 7: Accumulated return Strategy 1 long annual time series

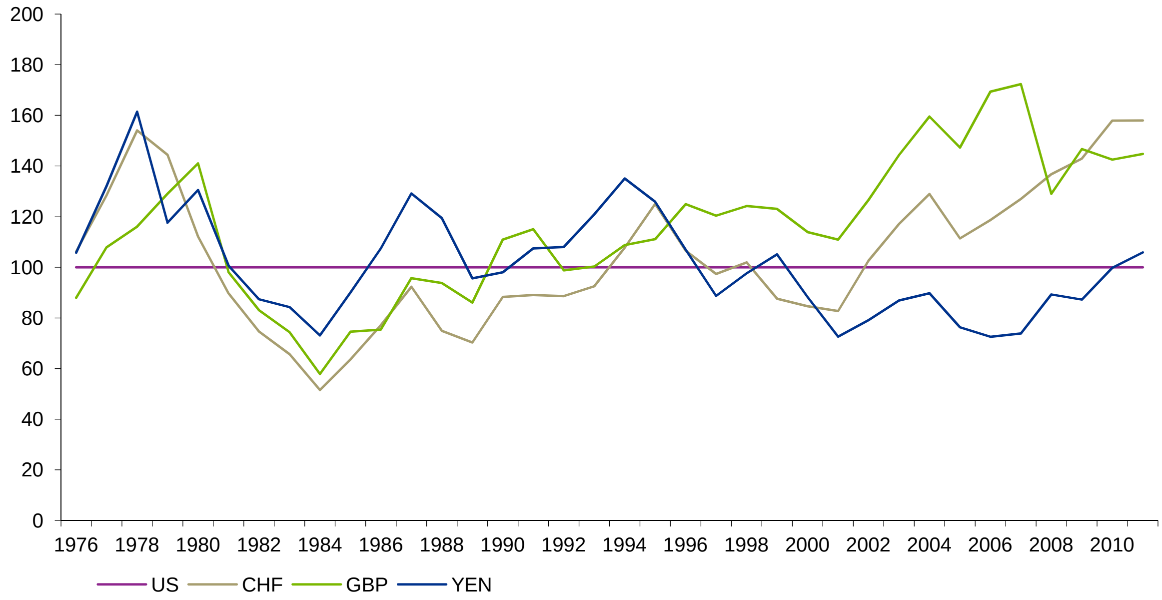
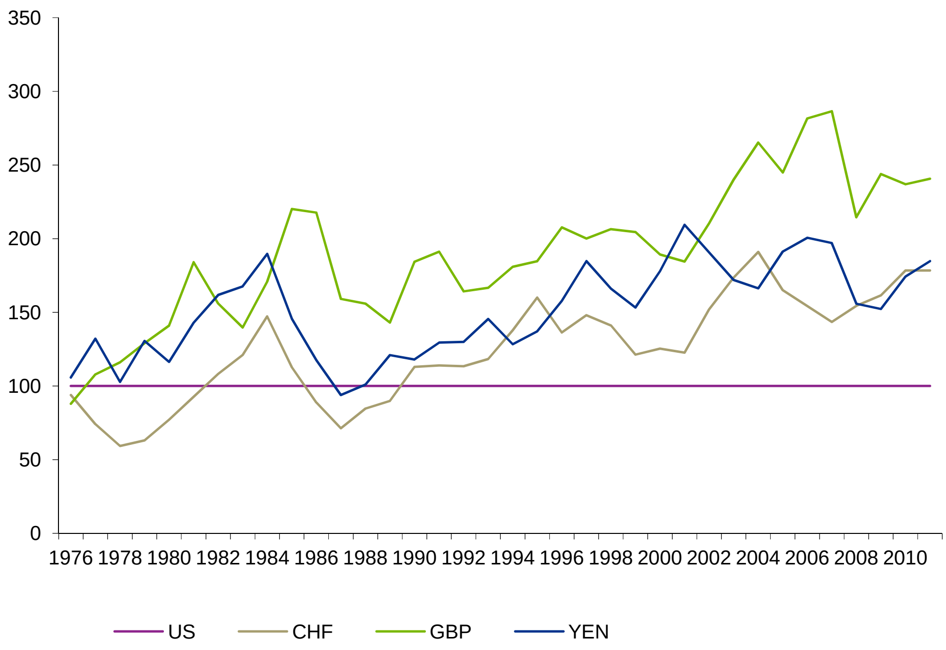


Table 6 shows that we can draw the same conclusions when analyzing the results from Strategy 2 as we did with Strategy 1. The null hypothesis is not rejected for any of the currencies. The ∝-coefficient is not significantly different from zero, and no excess return opportunities should be present. The results differ from Strategy 1 only in the sense that the reported p-values are lower. In the case of the British Pound, it is fairly close to rejection with a value of 0.153.

Normally this p-value is well within the range of acceptance at 95% confidence, but the JB statistic and the corresponding diagnostic charts from Minitab show that the data violates the OLS requirements, and any conclusions should therefore be drawn with care. Both non-normality and autocorrelation in the error terms seems to be present.

The results from strategy 2 also differ from the reported finding of Olmo and Pilbeam (2011), which find that the null hypothesis does not hold for the Euro[17] or the British Pound. As noted above, they have data which do not show signs of either non-normality or correlation of the error terms, and are therefore able to draw more definitive conclusions from their tests.

Graph 8: Accumulated return Strategy 2 long annual time series



The accumulated return of the British Pound has the lowest p-value, and consequently the highest calculated accumulated return. This is also one of two parities for which Olmo and Pilbeam (2011) reject the null hypothesis that no excess return is possible to obtain.

[17] Olmo and Pilbeam (2011) use DM (Deutsche Mark) prior to the introduction of the Euro as an approximation and to obtain equal length on the time series.

3.6 The effect of transaction costs

Where Olmo and Pilbeam (2011) do not take transaction costs into account, James et al (2009) include both the cost of changing positions in the market and rolling contracts. Despite these cost, James et al (2009) show that carry returns significant excess return.

James et al (2009) assume a bid-offer trading cost of 0.06%[18]. This transaction cost is fairly low, and test calculations show that it has little to no effect on the data used in this analysis. It should however be noted, that James et al (2009) use quarterly data as opposed to monthly in this paper. It is possible that the transaction costs would increase, as you change position more frequently and therefore could have a significant impact on the conclusions drawn in the above analysis, at least for the analyzed parities with reported low, but significant p-values.

[18] Position changes and the rolling of contracts have different calculated cost costs, but are both based on the bid-offer cost of 0.06%. See article for details.

Conclusion

This thesis has had two main objectives, namely to test whether recent data show signs of reverting back to the UIP condition in addition to test the efficient market hypothesis through profit based excess return strategies.

In testing the first objective I took the conventional approach to testing UIP, based on the work of Fama (1984) and Bansal and Dalquist (2000). This approach constitutes regressing the change in spot prices on the forward premium under the null hypothesis that the coefficient β equals unity. If the slope coefficient is significantly different from unity, UIP does not hold and if the slope coefficient is negative, the forward premium puzzle is implied.

My findings are consistent with existing literature (see amongst others Fama 1984, Bansal and Dalquist 2000 and Al-Zoubi[19] 2011) in the sense that for all currency pairs included in the analysis, the slope coefficient is negative, i.e. the data show signs of a forward premium puzzle. Based on my findings, it seems that the suggested return to UIP by James et al (2009) from carry trade losses is not evident in recent data. However, the corresponding p-value of the slope coefficient shows that the coefficients are insignificantly different from zero. In addition, the data shows signs of violating important conditions of the OLS framework in regression analysis. Thus, the results from the conventional approach are inconclusive.

The second objective of this thesis was to test the efficient market hypothesis based on excess return strategies. A rejection of this hypothesis would also imply that UIP does not hold. The first strategy is a simple test on whether domestic returns equal the returns of investing in the foreign currency and earning the foreign interest rate.

Using data with the US dollar as base currency, I show that there is no excess return for any of the currency pairs. The same result is obtained both with the Norwegian krone as base currency and with longer annual time series. Again the data shows that the conditions of the OLS method are not fully satisfied. Contrary to Olmo and Pilbeam (2011), the data show

[19] Al-Zoubi (2011) article contains a section on the conventional approach, where the slope coefficient is found to be significantly different from unity.

signs of both non-normality and autocorrelation in the error variable which presents difficulty in arriving at a definitive conclusion.

The second strategy involved investing in the currency which had the highest nominal interest rate at the beginning of each period. The results from this test are similar to Strategy 1, with the exception of the Australian dollar and Norwegian krone. Both currencies show excess return within convenient levels with the US dollar as base currency. With Norwegian krone as base currency and with longer time series, no excess return opportunities are identified under strategy 2. These results are contradictive in the sense that the NOK/USD parity should show equal results, regardless of which currency serves as base currency. As suggested under section three, this might be due to different data sources or violations of the OLS conditions.

Furthermore, Olmo and Pilbeam (2011) reject the null hypothesis of no excess returns for the British Pound. My results show a low p-value in the case of longer annual time series, but the null hypothesis is not rejected.

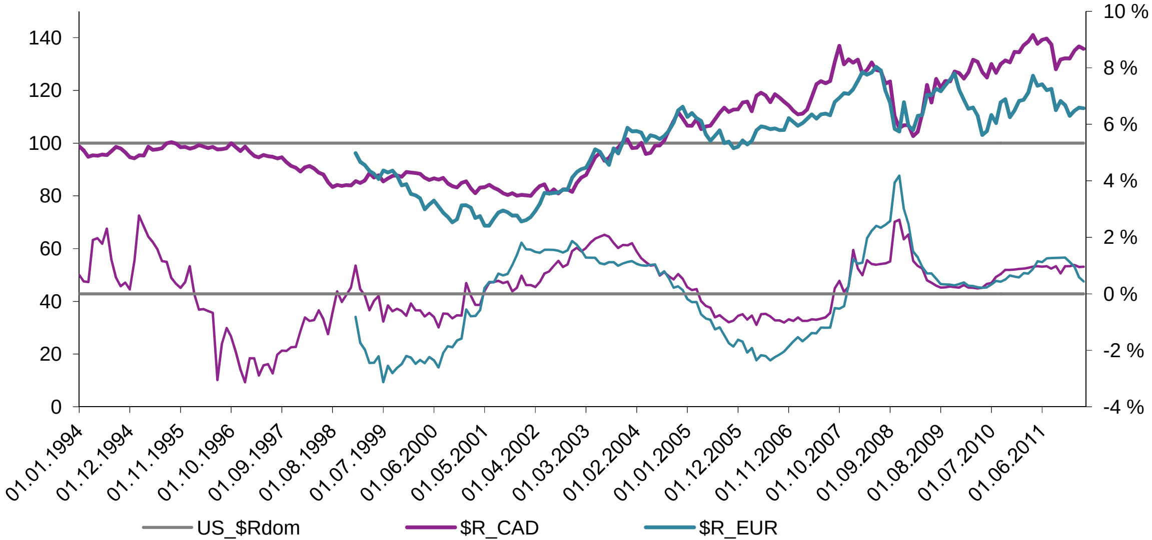
Thus the main conclusions from the tests seems to be contradictive in the sense that UIP and market efficiency, is rejected based on the traditional approach of regressing the change in spot prices against the forward premium. On the other hand, the market efficiency hypothesis seems to hold, at least for the most part with more practical excess return based trading strategies.

It is difficult to draw definitive conclusions due to insignificant coefficients and the fact that the data show characteristics which violate required statistical properties. Nonetheless, it seems that the apparent presence of a forward premium puzzle in the classical approach, not necessarily indicates that the market is inefficient and that excess return possibilities are present.

There have been a growing number of articles in recent years, not only on more sophisticated models to explain the forward premium puzzle, but also on the subject of carry trade and possible excess returns from currency speculation.

When analyzed for the full period, the average return to the Swiss Franc with US dollars as base currency is only 3% in favour of Strategy 2. In the case of Strategy 1, the Canadian dollar returns excess profit just short of 4% while the Euro equals the return from holding capital at the US interest rate when the full period is taken into account. If however an investor would pursue this strategy from mid 2005 and onwards, the return would be 6% and 11% for the Canadian dollar and Euro, respectively. Note that these numbers also include the sharp decline in accumulated profit in late 2008, which is clearly visible in the graph below.

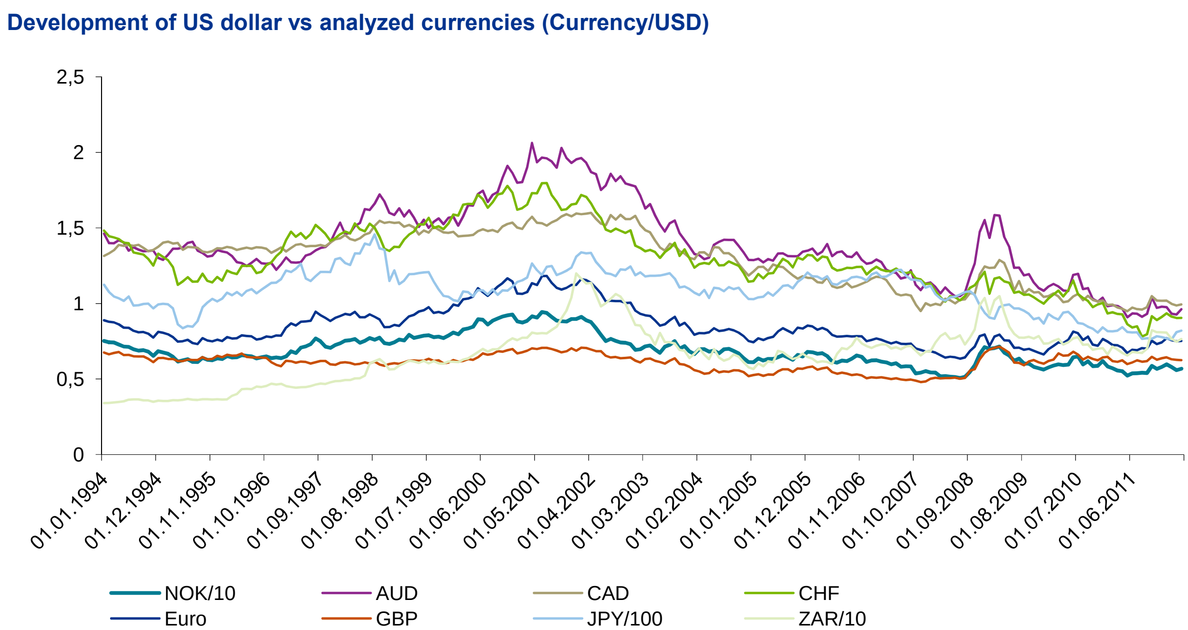
Graph 9 : Strategy 1/USD - Accumulated return for CAD and EUR with interest rate differentials



Timing and different lengths of the investment period could therefore be an interesting area for future research. In addition, more rigorous analysis of the effect of transaction costs, and practical implementation of these strategies could be another avenue for future research.

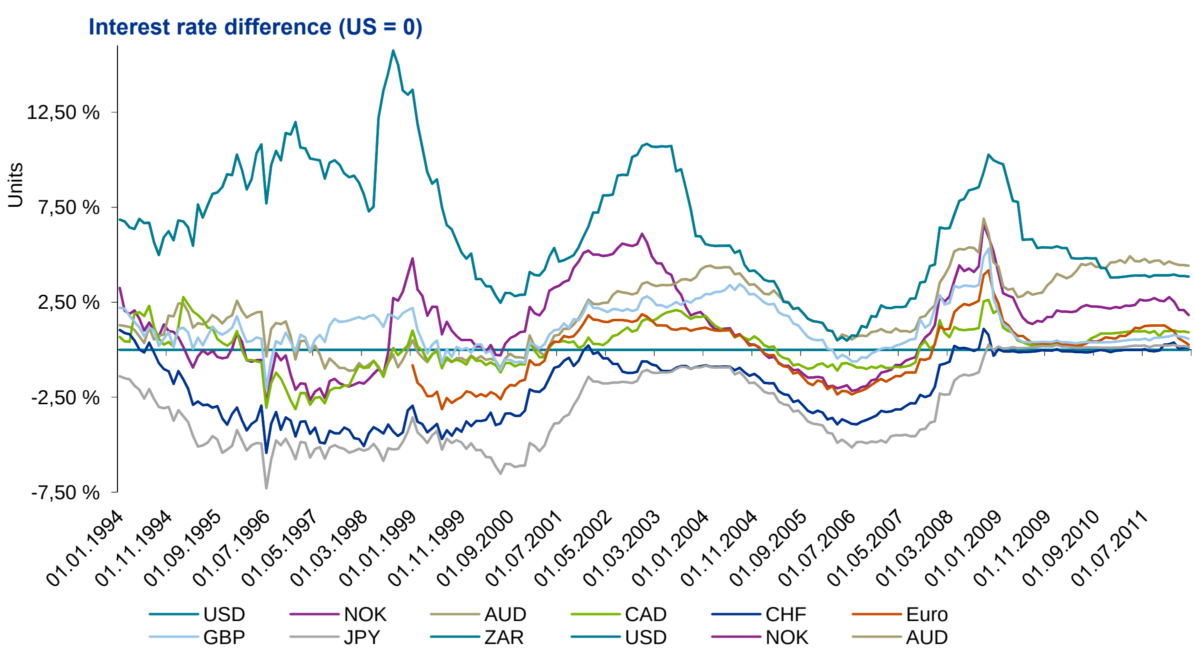
In the case of the forward premium puzzle, Lewis (1995) noted early that one explanation alone might not be enough to explain the puzzle. An increasing number of articles have surfaced in recent years on the behaviour of investors in addition to sophisticated non-linear regression analysis. To my knowledge, no consensus has been reached on the puzzle, and no one has yet followed Lewis' suggestion to combine two or more of the current explanations commonly used to describe and test the puzzle.

Appendix 1 Graph US exchange rate



Note that JPY has been divided by 100 while ZAR and NOK have been divided by 10 to make the graph more presentable.

Appendix 2 Graph Monthly interest rate, differenced against US interest rate



Appendix 3 Data collected from Thompson Datastream

Exchange rates

AUSTRALIAN $ TO US $ (WMR&DS) - Time Series Data
CANADIAN $ TO US $ (WMR) - Time Series Data
EURO TO US $ (WMR&DS) - Time Series Data
JAPANESE YEN TO US $ (WMR) - Time Series Data
NORWEGIAN KRONE TO US $ (WMR) - Time Series Data
SOUTH AFRICA RAND TO US $ (WMR) - Time Series Data
SWISS FRANC TO US $ (WMR) - Time Series Data
US $ TO UK £ (WMR) - Time Series Data

Forward rates

CANADIAN $ TO US $ 1M FWD (WMR) - Time Series Data
EURO TO US $ 1M FWD (WMR) - Time Series Data
JAPANESE YEN TO US $ 1M FWD (WMR) - Time Series Data
NORWEGIAN KRONE TO US $ 1M FWD(WMR) - Time Series Data
SOUTH AFRICA RAND TO US $ 1M FWD(WMR) - Time Series Data
SWISS FRANC TO US $ 1M FWD (WMR) - Time Series Data
UK £ TO US $ 1M FWD (WMR) - Time Series Data
US $ TO AUSTRALIAN $ 1M FWD (WMR) - Time Series Data

Interest rates

AUSTRALIAN $ DEPO 1 MTH (ICAPTR) - Time Series Data
CANADA PRIME CORP PAPER 1M (BOC) - Time Series Data
EURIBOR 1 MONTH - Time Series Data
JAPAN BASIC DISCOUNT & LOAN RATE - Time Series Data
NORWAY DEPOSIT 1 MONTH - Time Series Data
SOUTH AFRICAN INTERBANK CALL - Time Series Data
SWISS INTERBANK 1M (ZRCSNB) - Time Series Data
UK BOE LIBIDLIBOR 1 MONTH - Time Series Data
US FED FUNDS EFF RATE (D) - Time Series Data

Norway time series (Norwegian NOK as base currency)

NORWEGIAN KRONE TO 100 JAPANESE YEN - Time Series Data
NORWEGIAN KRONE TO EURO - Time Series Data
NORWEGIAN KRONE TO SWISS FRANC - Time Series Data
NORWEGIAN KRONE TO UK £ - Time Series Data
NORWEGIAN KRONE TO US $ - Time Series Data

Annual time series (USD as base currency)

JAPANESE YEN TO US $ NOON NY - Time Series Data
SWISS FRANC TO US $ (SW) - Time Series Data
UK £ TO US $ (WMR) - Time Series Data
JAPAN BASIC DISCOUNT & LOAN RATE - Time Series Data
SWISS LIQFINANCING RATE (SNB) - Time Series Data
UK INTERBANK 1 YEAR - Time Series Data
US FED FUNDS EFF RATE (D) - Time Series Data

Appendix 2 Regression results Forward Premium Puzzle

Regression Analysis: AUD_st+1 - st versus AUD_ft -st

The regression equation is
AUD_st+1 - st = 0,00225 - 2,18 AUD_ft -st

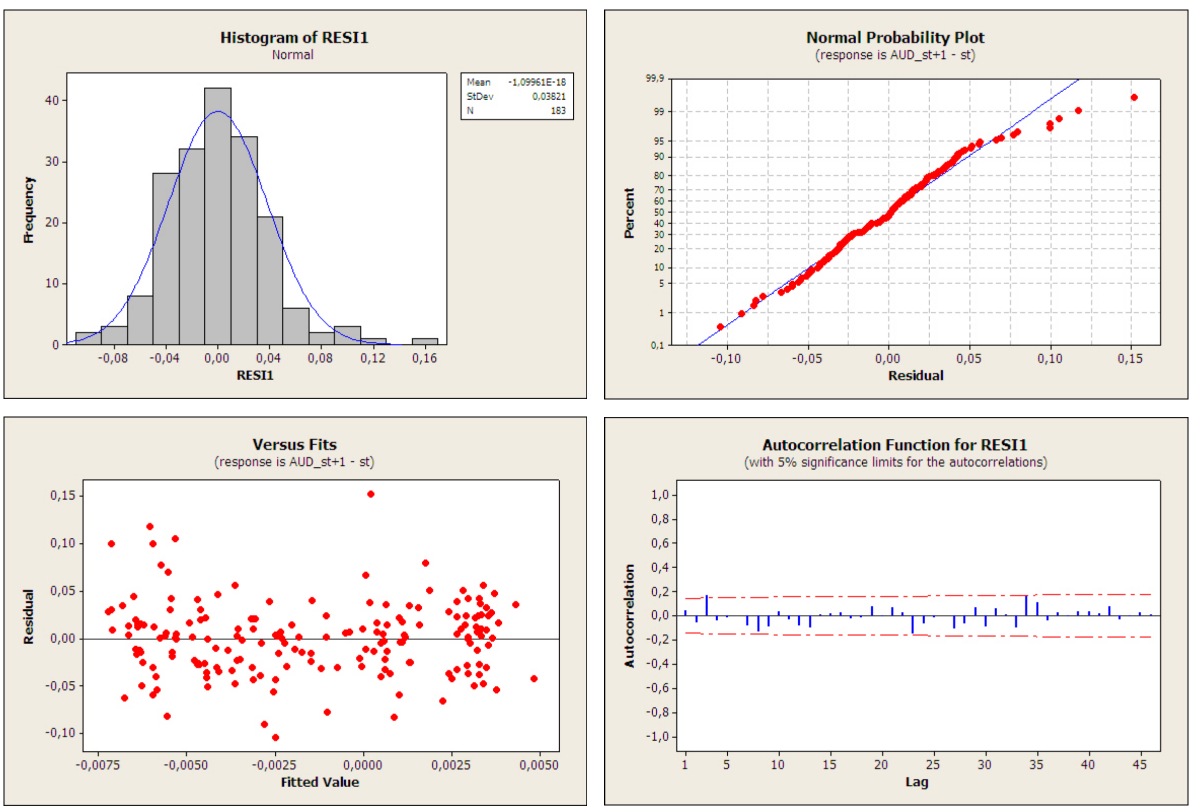
Predictor	Coef	SE Coef	T	P
Constant	0,002251	0,004102	0,55	0,584
AUD_ft -st	-2,177	1,734	-1,26	0,211

S = 0,0383194   R-Sq = 0,9%   R-Sq(adj) = 0,3%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0,002315	0,002315	1,58	0,211
Residual Error	181	0,265776	0,001468		
Total	182	0,268091			

Durbin-Watson statistic = 1,90914



Regression Analysis: CAD_st+1 - st versus CAD_ft -st

The regression equation is
CAD_st+1 - st = - 0,00189 - 1,76 CAD_ft -st

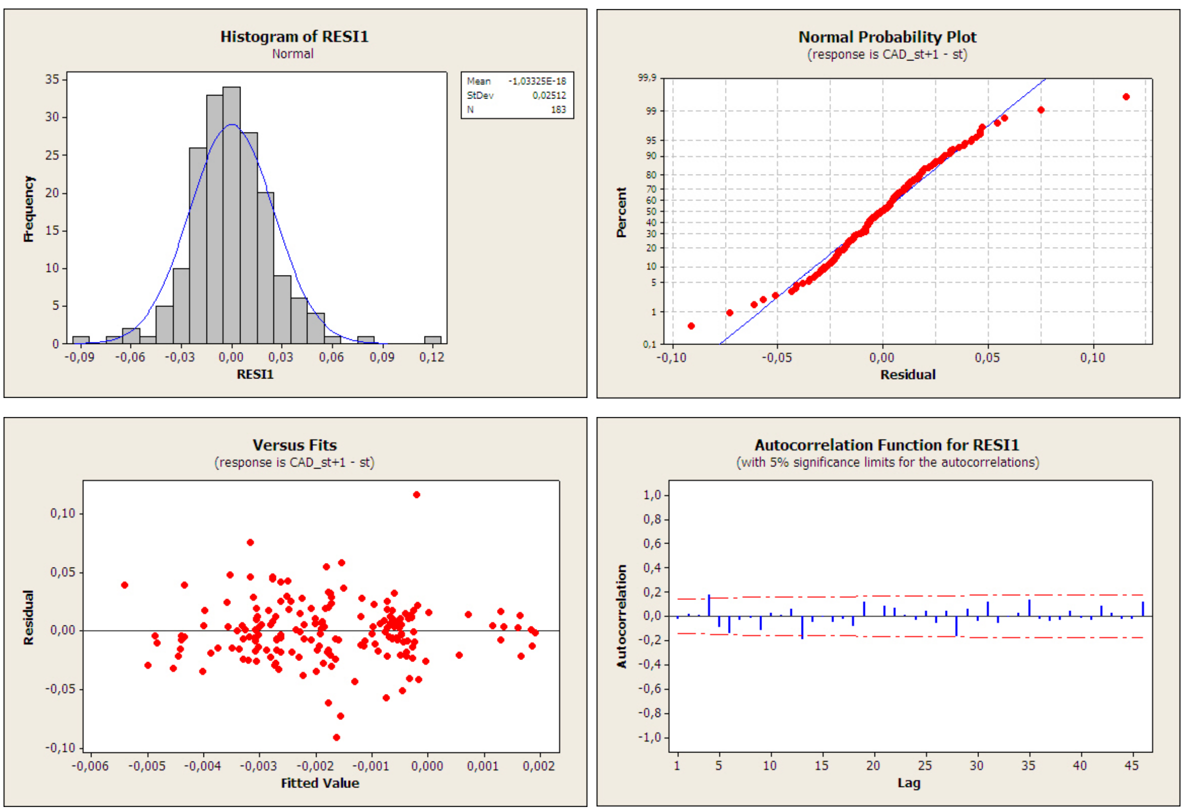
Predictor	Coef	SE Coef	T	P
Constant	-0,001887	0,001868	-1,01	0,314
CAD_ft -st	-1,756	2,161	-0,81	0,418

S = 0,0251871   R-Sq = 0,4%   R-Sq(adj) = 0,0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0,0004189	0,0004189	0,66	0,418
Residual Error	181	0,1148248	0,0006344		
Total	182	0,1152437			

Durbin-Watson statistic = 2,04506



Regression Analysis: CHF_st+1 - st versus CHF_ft -st

The regression equation is
CHF_st+1 - st = - 0,00674 - 2,59 CHF_ft -st

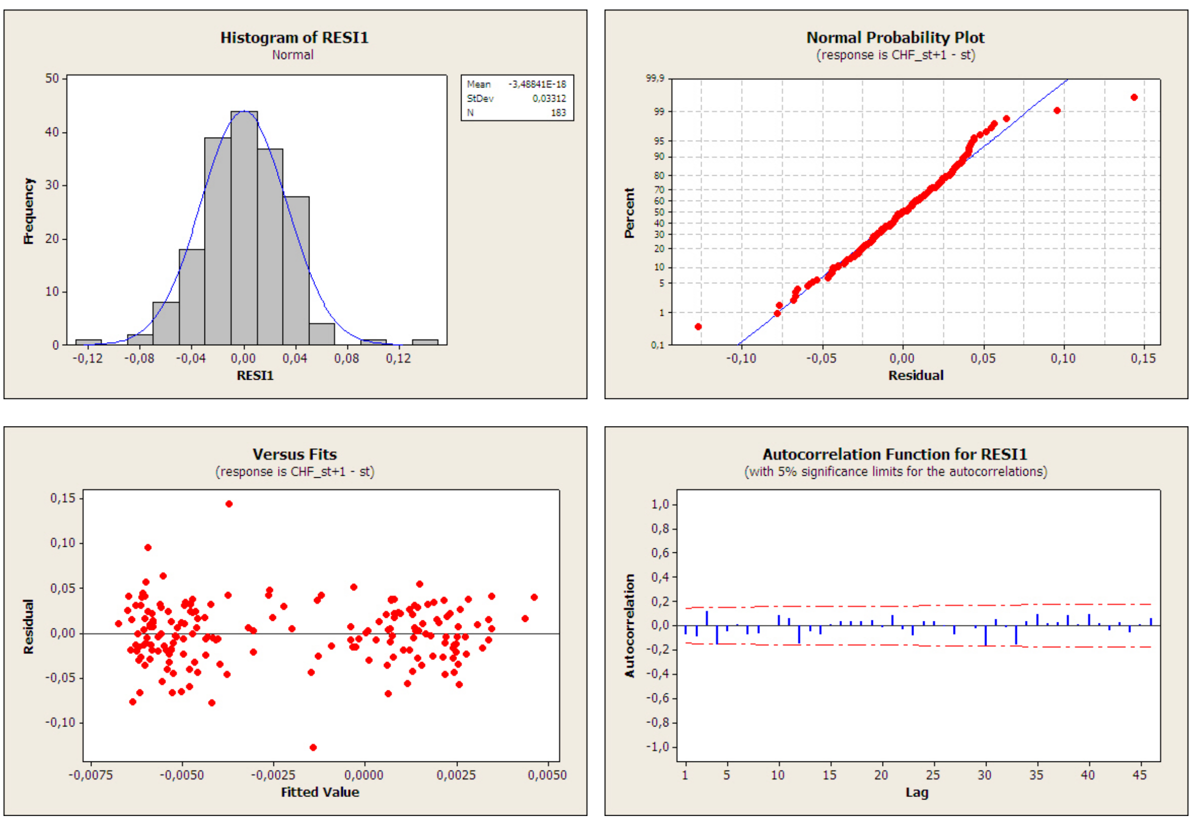
Predictor	Coef	SE Coef	T	P
Constant	-0,006737	0,004067	-1,66	0,099
CHF_ft -st	-2,595	1,837	-1,41	0,159

S = 0,0332071   R-Sq = 1,1%   R-Sq(adj) = 0,5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0,002201	0,002201	2,00	0,159
Residual Error	181	0,199591	0,001103		
Total	182	0,201792			

Durbin-Watson statistic = 2,13719



Regression Analysis: EUR_st+1 - st versus EUR_ft -st

```
The regression equation is
EUR_st+1 - st = - 0,00136 - 2,45 EUR_ft -st


Predictor         Coef   SE Coef      T      P
Constant     -0,001362  0,002521  -0,54  0,590
EUR_ft -st      -2,451     2,062  -1,19  0,236


S = 0,0311939   R-Sq = 0,9%   R-Sq(adj) = 0,3%


Analysis of Variance

Source           DF         SS         MS     F      P
Regression        1  0,0013747  0,0013747  1,41  0,236
Residual Error  157  0,1527705  0,0009731
Total           158  0,1541452


Durbin-Watson statistic = 1,92916
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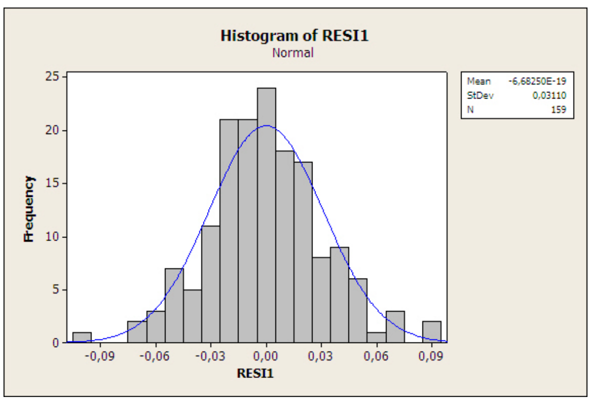
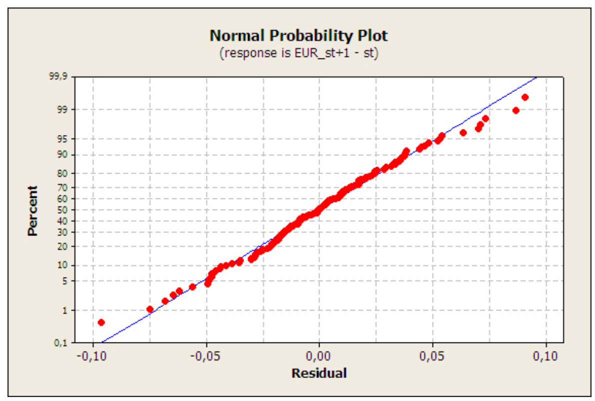
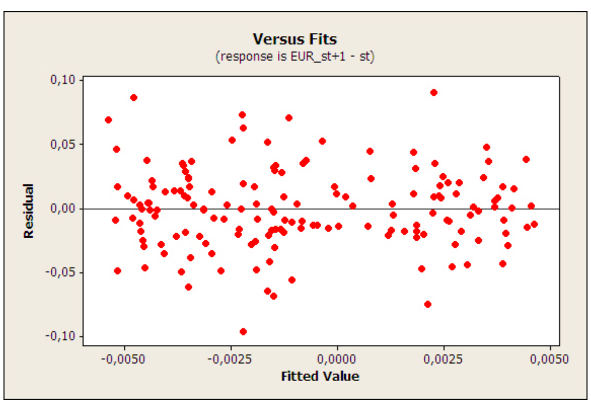
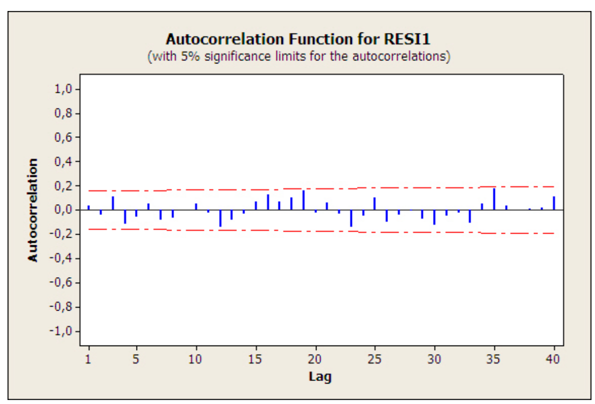








Regression Analysis: GBP_st+1 - st versus GBP_ft -st

The regression equation is
GBP_st+1 - st = 0,00080 - 0,50 GBP_ft -st

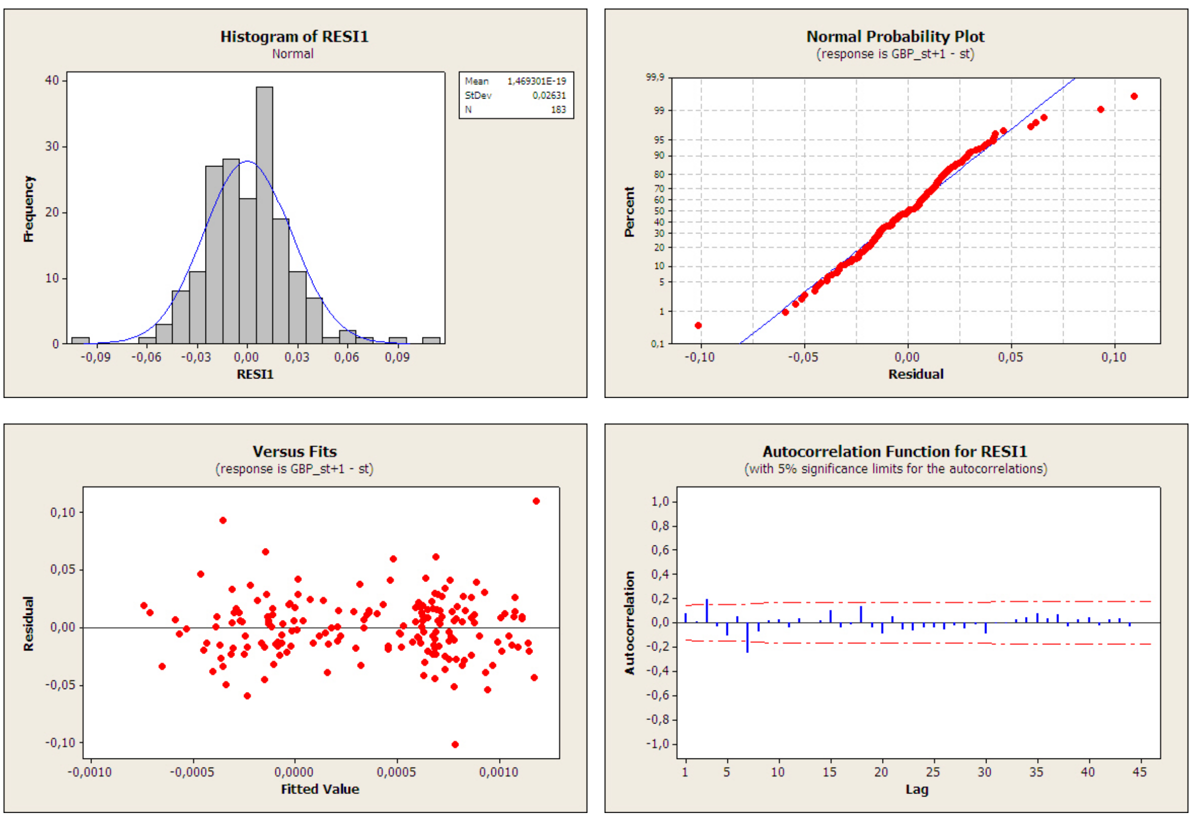
Predictor	Coef	SE Coef	T	P
Constant	0,000797	0,002613	0,31	0,761
GBP_ft -st	-0,499	1,996	-0,25	0,803

S = 0,0263805   R-Sq = 0,0%   R-Sq(adj) = 0,0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0,0000434	0,0000434	0,06	0,803
Residual Error	181	0,1259631	0,0006959		
Total	182	0,1260066			

Durbin-Watson statistic = 1,82546



Regression Analysis: JPY_st+1 - st versus JPY_ft -st

The regression equation is
JPY_st+1 - st = - 0,00441 - 0,95 JPY_ft -st

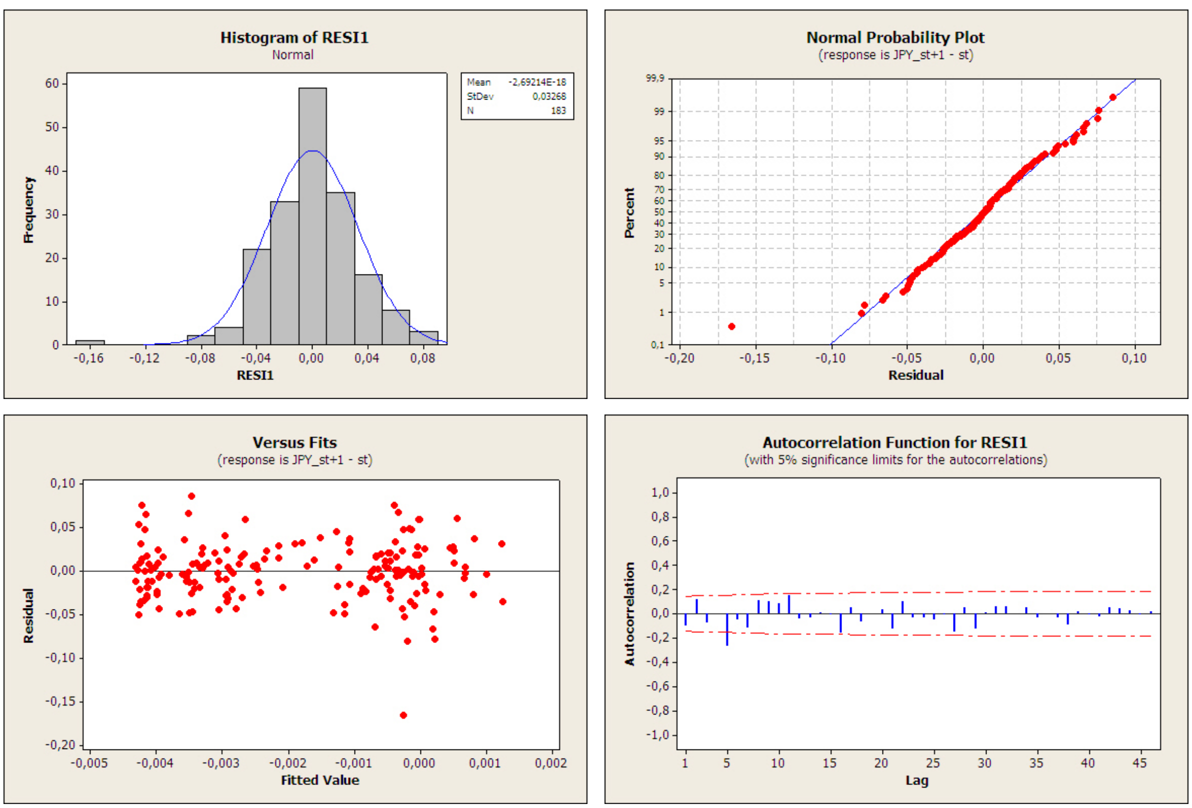
Predictor	Coef	SE Coef	T	P
Constant	-0,004408	0,004338	-1,02	0,311
JPY_ft -st	-0,949	1,360	-0,70	0,486

S = 0,0327663   R-Sq = 0,3%   R-Sq(adj) = 0,0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0,000523	0,000523	0,49	0,486
Residual Error	181	0,194328	0,001074		
Total	182	0,194851			

Durbin-Watson statistic = 2,18772



Regression Analysis: NOK_st+1 - st versus NOK_ft -st

The regression equation is
NOK_st+1 - st = 0,00012 - 0,87 NOK_ft -st

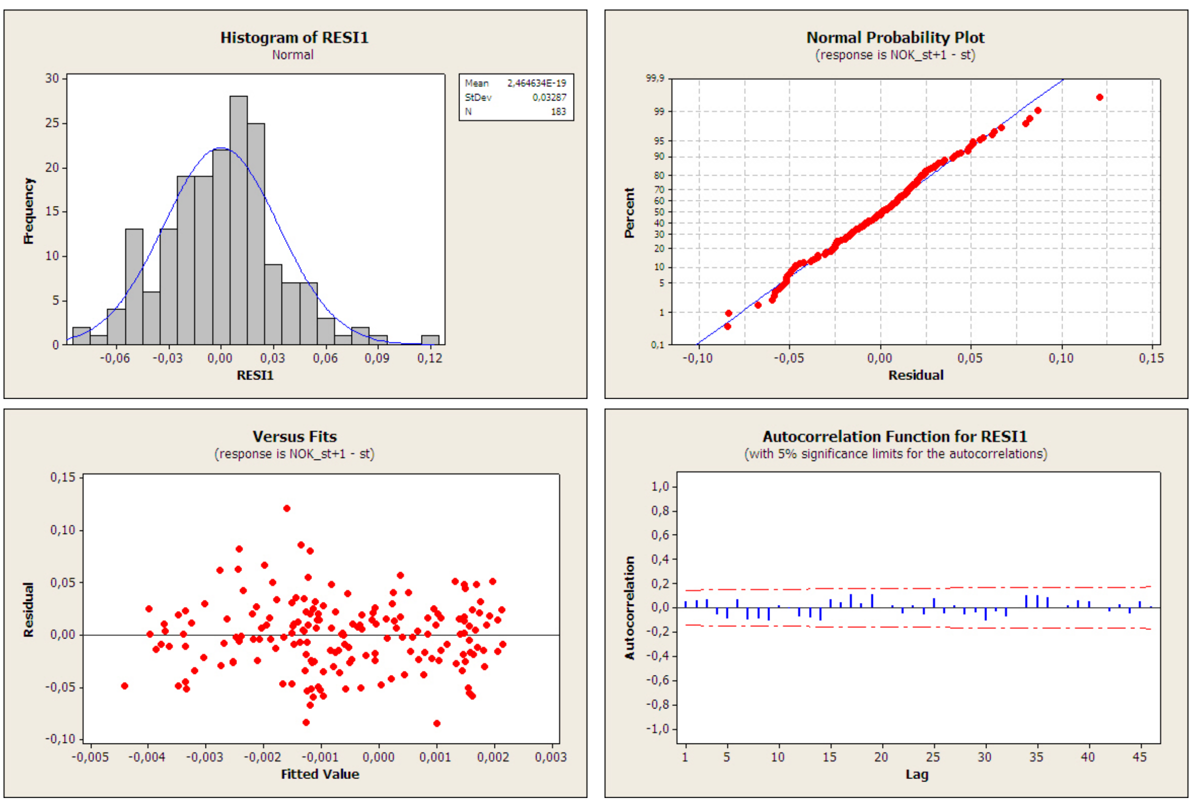
Predictor	Coef	SE Coef	T	P
Constant	0,000122	0,002685	0,05	0,964
NOK_ft -st	-0,870	1,298	-0,67	0,503

S = 0,0329637   R-Sq = 0,2%   R-Sq(adj) = 0,0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0,000489	0,000489	0,45	0,503
Residual Error	181	0,196675	0,001087		
Total	182	0,197164			

Durbin-Watson statistic = 1,89795



Regression Analysis: ZAR_st+1 - st versus ZAR_ft -st

The regression equation is
ZAR_st+1 - st = 0,0122 - 1,53 ZAR_ft -st

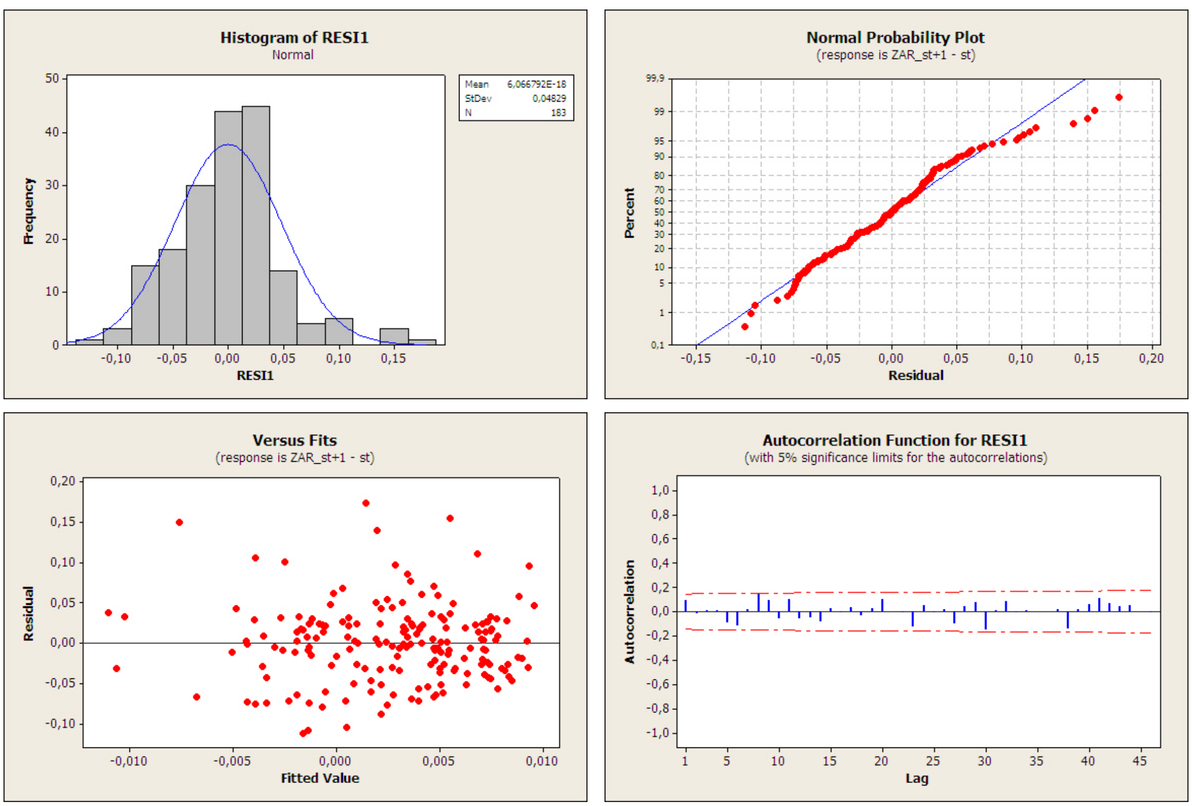
Predictor	Coef	SE Coef	T	P
Constant	0,012214	0,008945	1,37	0,174
ZAR_ft -st	-1,529	1,315	-1,16	0,247

S = 0,0484207   R-Sq = 0,7%   R-Sq(adj) = 0,2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0,003168	0,003168	1,35	0,247
Residual Error	181	0,424366	0,002345		
Total	182	0,427534			

Durbin-Watson statistic = 1,80805



Appendix 5 Profit test Strategy 1 (monthly data, USD as base currency)

Descriptive Statistics: AUD_P1; AUD_P1_RES; CAD_P1; CAD_P1_RES; CHF_P1; ...

Variable	Total Count	Mean	StDev	Skewness	Kurtosis
AUD_P1	219	0,00422	0,03618	-0,21	1,27
AUD_P1_RES	219	0,00000	0,03618	-0,21	1,27
CAD_P1	219	0,00168	0,02360	-0,05	3,11
CAD_P1_RES	219	-0,00000	0,02360	-0,05	3,11
CHF_P1	219	0,00116	0,03348	0,29	1,78
CHF_P1_RES	219	-0,00000	0,03348	0,29	1,78
GBP_P1	219	0,00163	0,02525	-0,15	2,29
GBP_P1_RES	219	0,00000	0,02525	-0,15	2,29
JPY_P1	219	-0,00047	0,03376	0,70	3,42
JPY_P1_RES	219	0,00000	0,03376	0,70	3,42
NOK_P1	219	0,00279	0,03140	-0,09	0,52
NOK_P1_RES	219	0,00000	0,03140	-0,09	0,52
ZAR_P1	219	0,00256	0,04511	-0,24	1,43
ZAR_P1_RES	219	0,00000	0,04511	-0,24	1,43
EUR_P1	159	0,00127	0,03141	0,10	0,60
EUR_P1_RES	159	-0,00000	0,03141	0,10	0,60

One-Sample T: AUD_P1; CAD_P1; CHF_P1; GBP_P1; JPY_P1; NOK_P1; ZAR_P1; EUR_P1

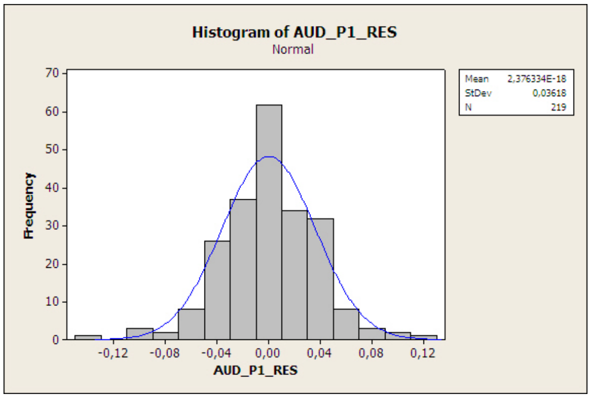
Test of mu = 0 vs not = 0

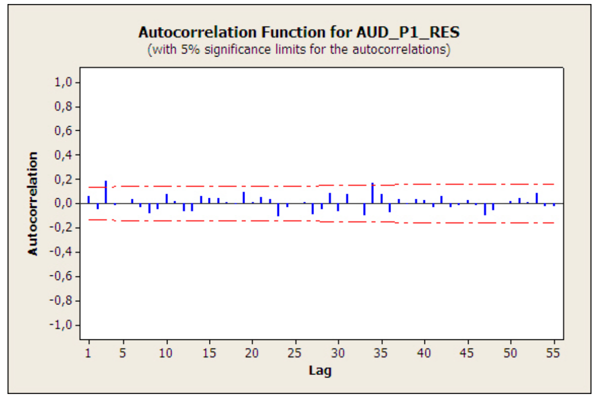
Variable	N	Mean	StDev	95% CI	T	P
AUD_P1	219	0,00422	0,03618	(-0,00059; 0,00904)	1,73	0,085
CAD_P1	219	0,00168	0,02360	(-0,00147; 0,00482)	1,05	0,295
CHF_P1	219	0,00116	0,03348	(-0,00330; 0,00562)	0,51	0,607
GBP_P1	219	0,00163	0,02525	(-0,00174; 0,00499)	0,95	0,341
JPY_P1	219	-0,00047	0,03376	(-0,00497; 0,00403)	-0,21	0,837
NOK_P1	219	0,00279	0,03140	(-0,00139; 0,00698)	1,32	0,189
ZAR_P1	219	0,00256	0,04511	(-0,00344; 0,00857)	0,84	0,401
EUR_P1	159	0,00127	0,03141	(-0,00365; 0,00619)	0,51	0,610

Jarque-Bera Statistic

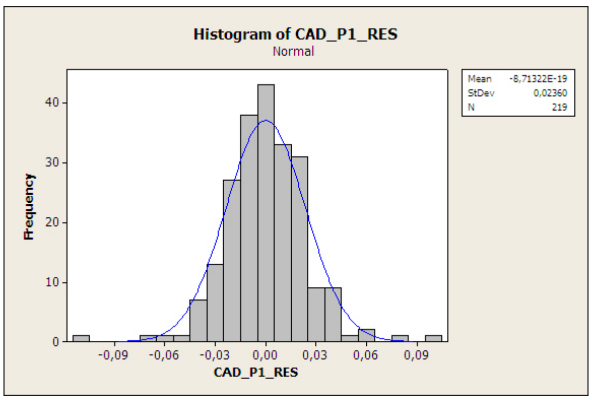
$$JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right)$$

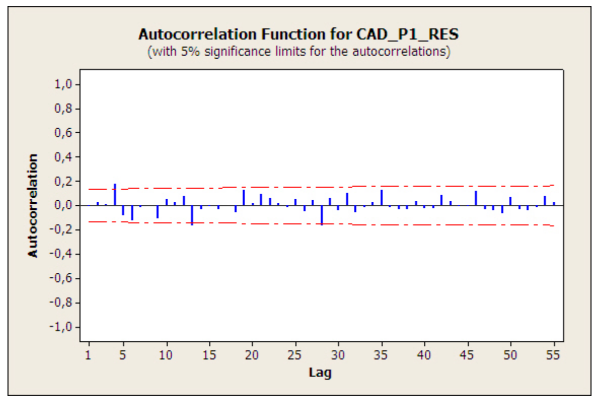
AUD_P1



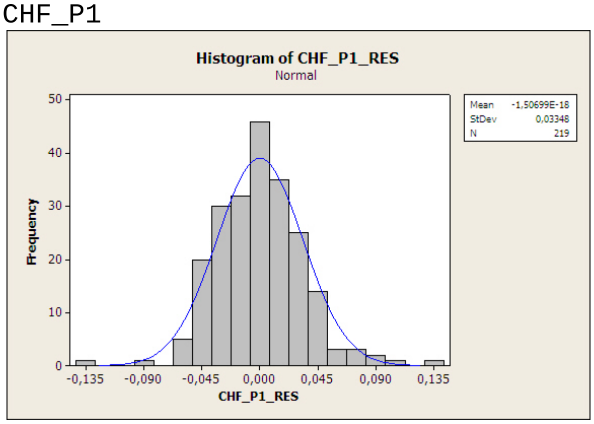


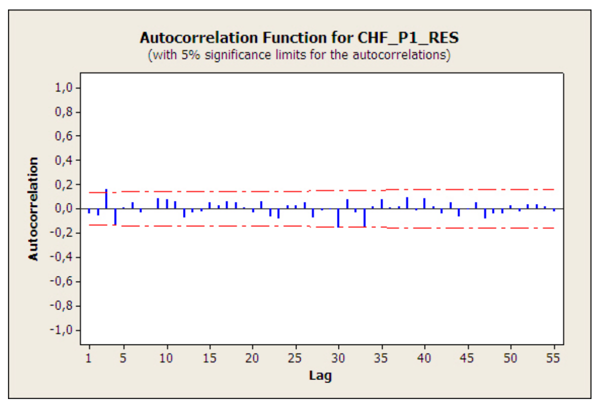
CAD_P1



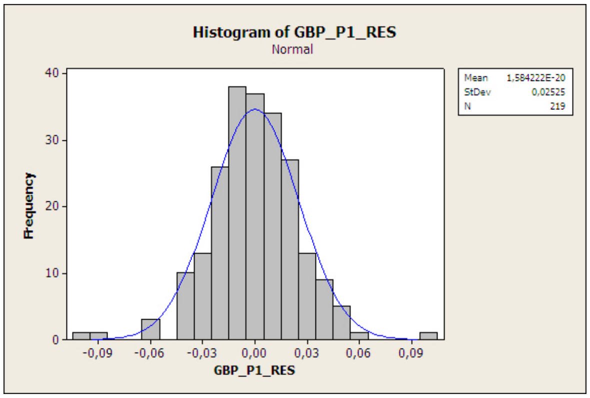


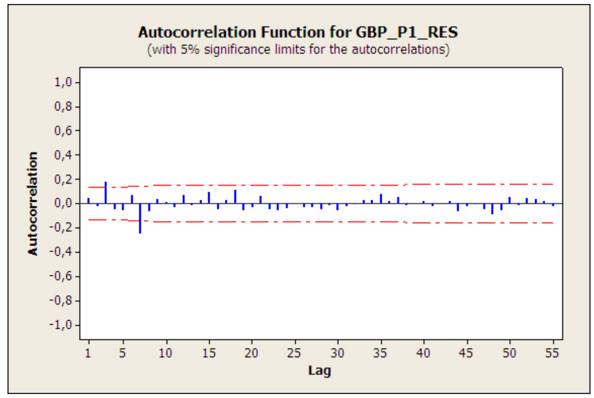
CHF_P1



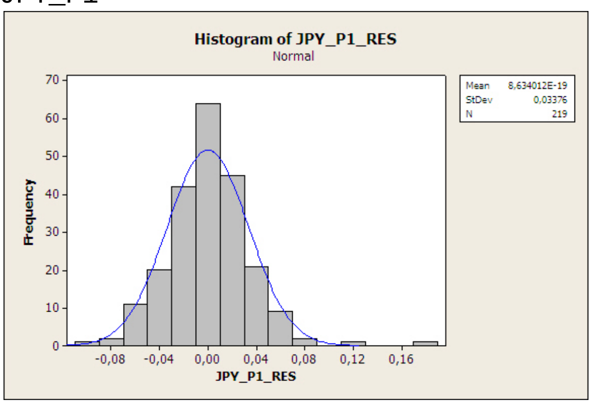


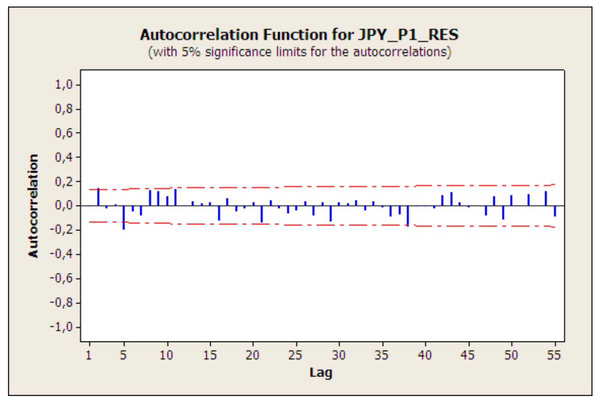
GBP_P1



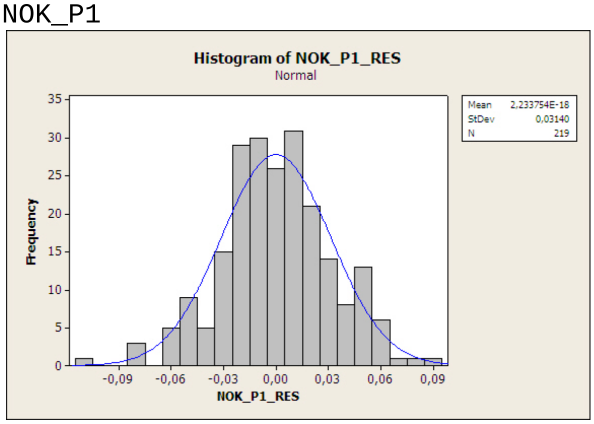


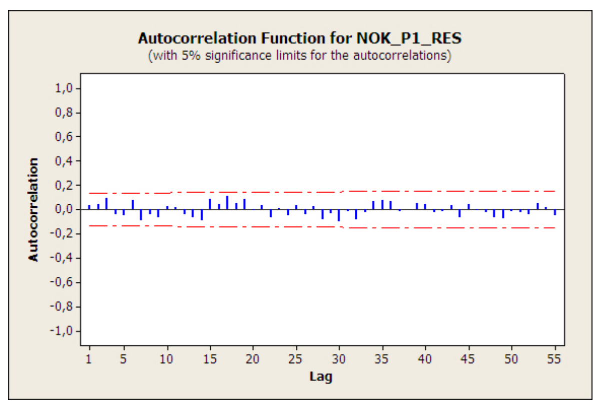
JPY_P1



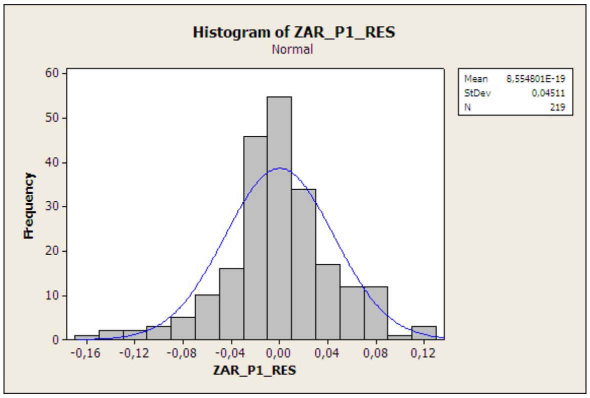


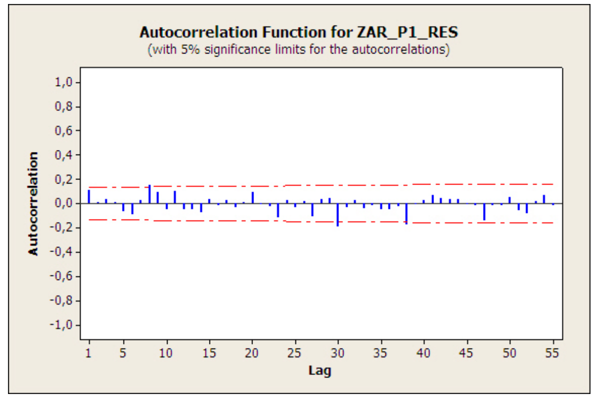
NOK_P1



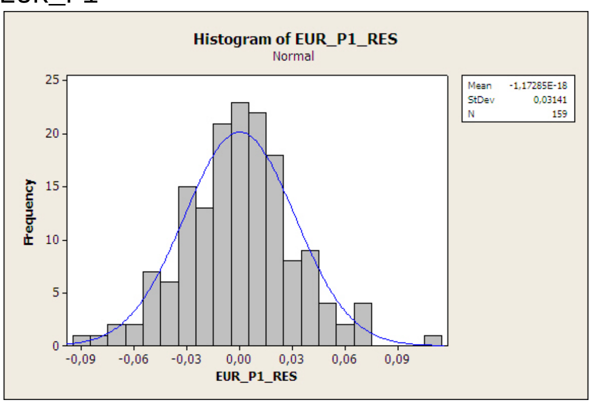


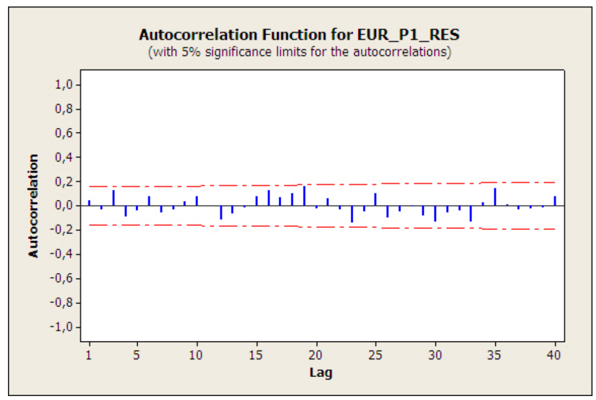
ZAR_P1


Histogram of ZAR_P1_RES
Normal
Mean 8,554801E-19
StDev 0,04511
N 219
Frequency
ZAR_P1_RES


Autocorrelation Function for ZAR_P1_RES
(with 5% significance limits for the autocorrelations)
Autocorrelation
Lag

EUR_P1


Histogram of EUR_P1_RES
Normal
Mean -1,17285E-18
StDev 0,03141
N 159
Frequency
EUR_P1_RES


Autocorrelation Function for EUR_P1_RES
(with 5% significance limits for the autocorrelations)
Autocorrelation
Lag

Appendix 6 Profit test Strategy 2 (monthly data, USD as base currency)

Descriptive Statistics: AUD_P2; AUD_P2_RES; CAD_P2; CAD_P2_RES; CHF_P2; ...

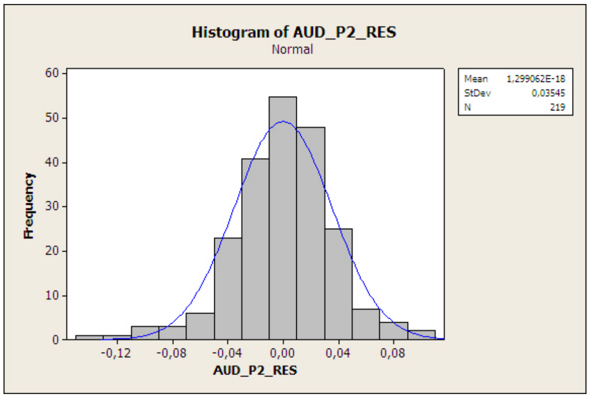
Variable	Total Count	Mean	StDev	Skewness	Kurtosis
AUD_P2	219	0,00836	0,03545	-0,42	1,67
AUD_P2_RES	219	0,00000	0,03545	-0,42	1,67
CAD_P2	219	0,00214	0,02357	-0,23	3,20
CAD_P2_RES	219	-0,00000	0,02357	-0,23	3,20
CHF_P2	219	-0,00222	0,03338	-0,24	1,79
CHF_P2_RES	219	0,00000	0,03338	-0,24	1,79
GBP_P2	219	0,00154	0,02519	-0,16	2,34
GBP_P2_RES	219	-0,00000	0,02519	-0,16	2,34
JPY_P2	219	0,00210	0,03370	-0,94	3,65
JPY_P2_RES	219	-0,00000	0,03370	-0,94	3,65
NOK_P2	219	0,00480	0,03116	-0,18	0,61
NOK_P2_RES	219	0,00000	0,03116	-0,18	0,61
ZAR_P2	219	0,00256	0,04511	-0,24	1,43
ZAR_P2_RES	219	0,00000	0,04511	-0,24	1,43
EUR_P2	159	0,00452	0,03110	-0,15	0,73
EUR_P2_RES	159	0,00000	0,03110	-0,15	0,73

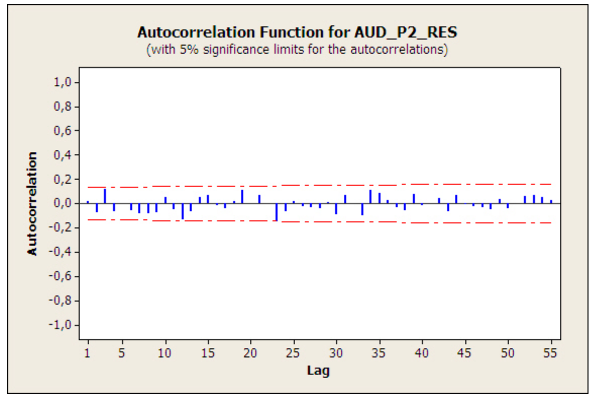
One-Sample T: AUD_P2; CAD_P2; CHF_P2; GBP_P2; JPY_P2; NOK_P2; ZAR_P2

Test of mu = 0 vs not = 0

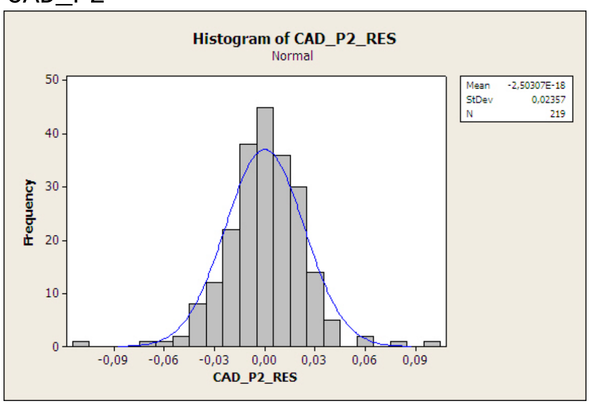
Variable	N	Mean	StDev	95% CI	T	P
AUD_P2	219	0,00836	0,03545	(0,00364; 0,01308)	3,49	0,001
CAD_P2	219	0,00214	0,02357	(-0,00100; 0,00528)	1,35	0,180
CHF_P2	219	-0,00222	0,03338	(-0,00666; 0,00223)	-0,98	0,327
GBP_P2	219	0,00154	0,02519	(-0,00181; 0,00490)	0,91	0,366
JPY_P2	219	0,00210	0,03370	(-0,00239; 0,00659)	0,92	0,357
NOK_P2	219	0,00480	0,03116	(0,00065; 0,00895)	2,28	0,024
ZAR_P2	219	0,00256	0,04511	(-0,00344; 0,00857)	0,84	0,401
EUR_P2	159	0,00452	0,03110	(-0,00035; 0,00939)	1,83	0,069

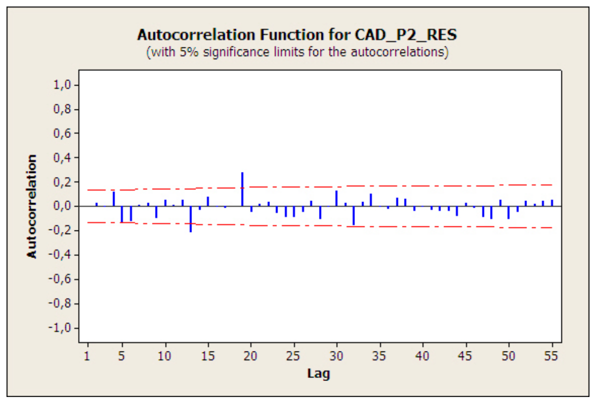
AUD_P2



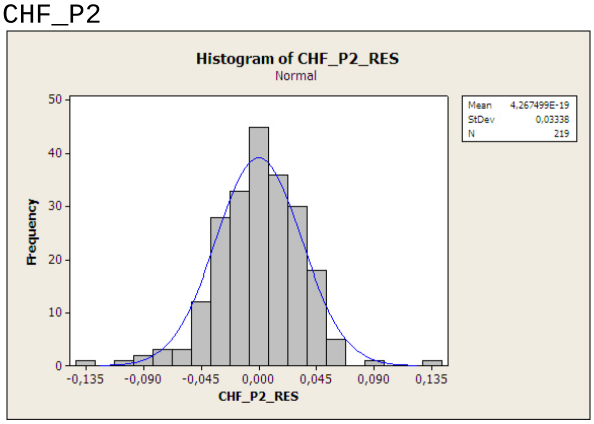


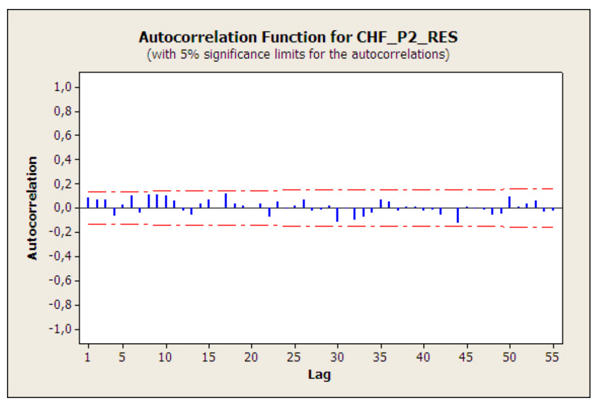
CAD_P2



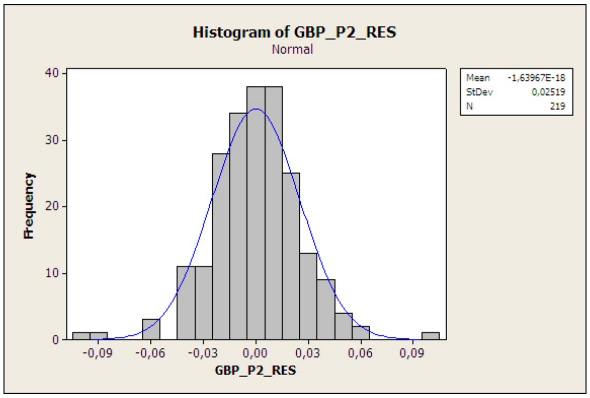


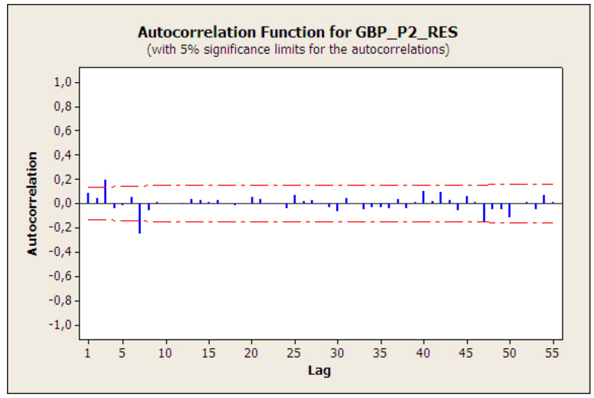
CHF_P2



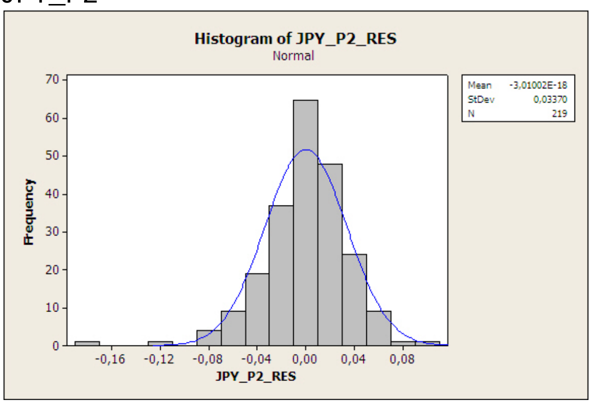


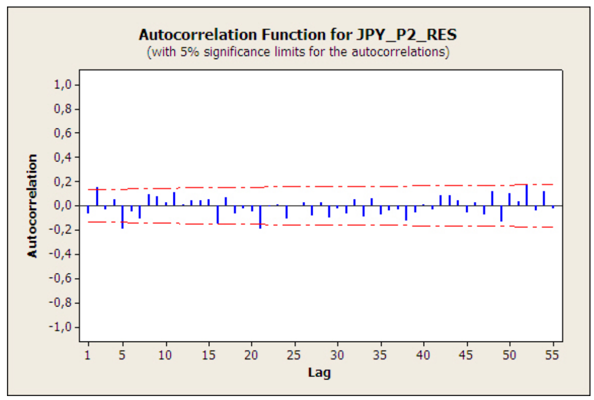
GBP_P2



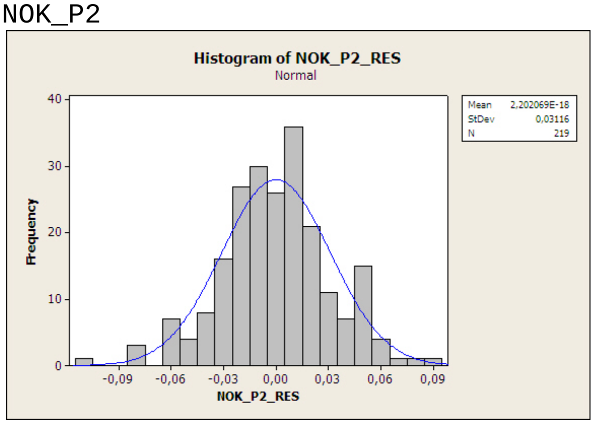


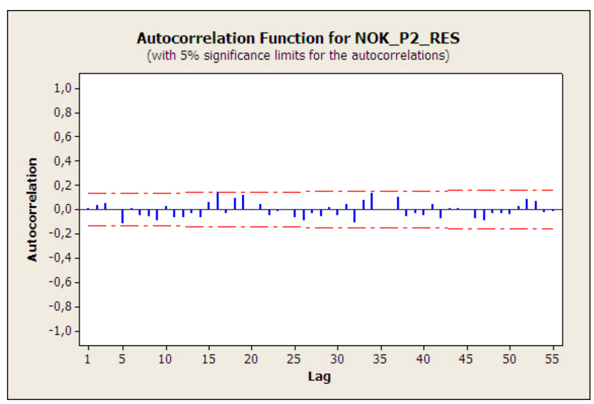
JPY_P2



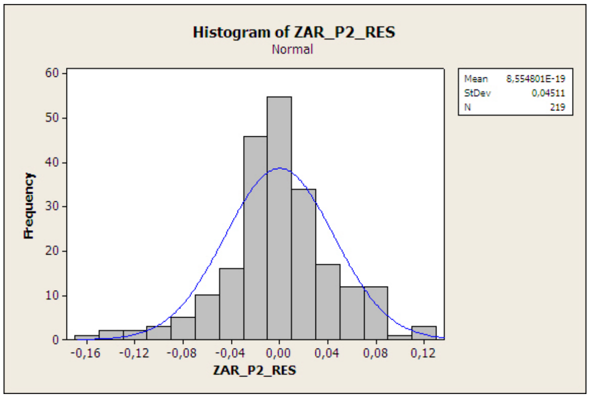


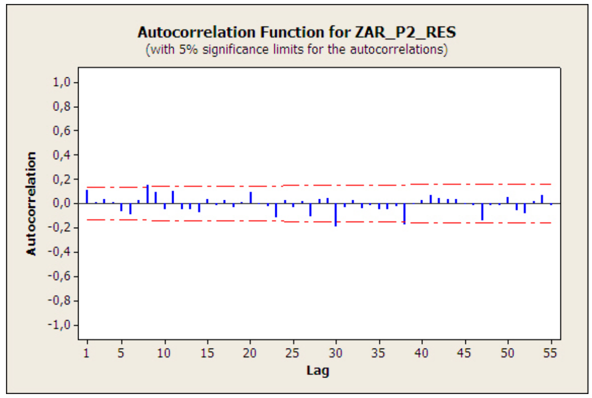
NOK_P2



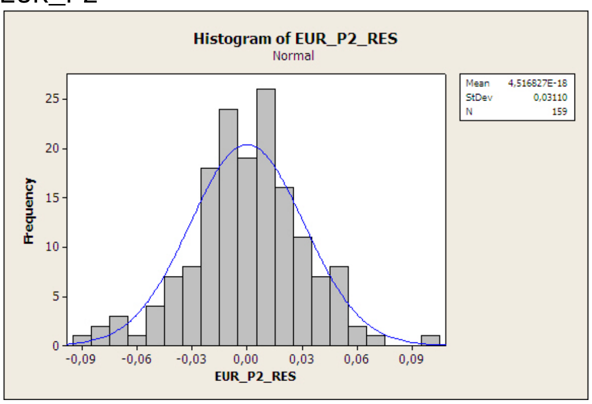


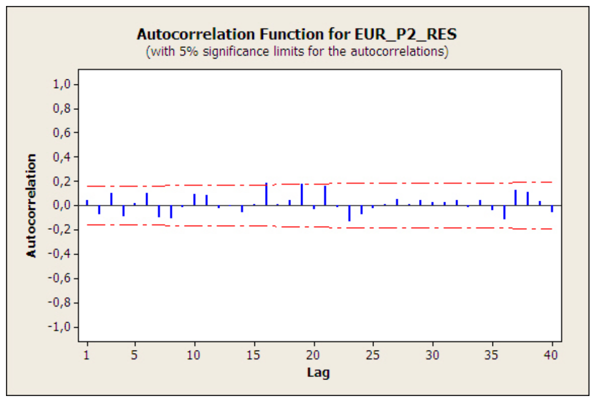
ZAR_P2


Histogram of ZAR_P2_RES
Normal
Mean 8,554801E-19
StDev 0,04511
N 219
Frequency
0 10 20 30 40 50 60
-0,16 -0,12 -0,08 -0,04 0,00 0,04 0,08 0,12
ZAR_P2_RES


Autocorrelation Function for ZAR_P2_RES
(with 5% significance limits for the autocorrelations)
Autocorrelation
1,0 0,8 0,6 0,4 0,2 0,0 -0,2 -0,4 -0,6 -0,8 -1,0
1 5 10 15 20 25 30 35 40 45 50 55
Lag

EUR_P2


Histogram of EUR_P2_RES
Normal
Mean 4,516827E-18
StDev 0,03110
N 159
Frequency
0 5 10 15 20 25
-0,09 -0,06 -0,03 0,00 0,03 0,06 0,09
EUR_P2_RES


Autocorrelation Function for EUR_P2_RES
(with 5% significance limits for the autocorrelations)
Autocorrelation
1,0 0,8 0,6 0,4 0,2 0,0 -0,2 -0,4 -0,6 -0,8 -1,0
1 5 10 15 20 25 30 35 40
Lag

Appendix 7 Profit test strategy 1& 2 (monthly data, NOK)

Descriptive Statistics: CHF_P1; CHF_P1_RES; EUR_P1; EUR_P1_RES; GBP_P1; ...

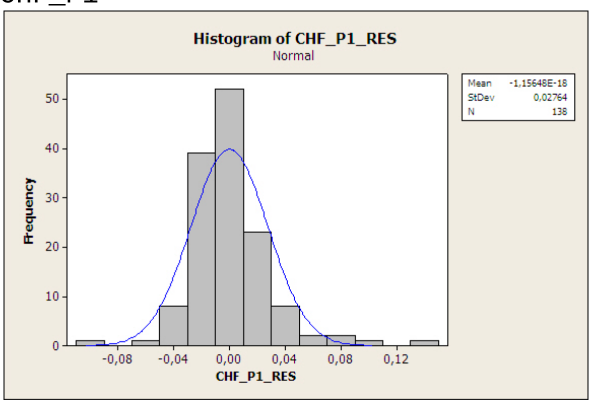
Variable	Total Count	Mean	StDev	Skewness	Kurtosis
CHF_P1	138	-0,00095	0,02764	1,25	5,63
CHF_P1_RES	138	-0,00000	0,02764	1,25	5,63
EUR_P1	138	-0,00151	0,02098	0,68	7,09
EUR_P1_RES	138	-0,00000	0,02098	0,68	7,09
GBP_P1	138	-0,00294	0,02563	0,36	0,87
GBP_P1_RES	138	0,00000	0,02563	0,36	0,87
JPY_P1	138	-0,00382	0,04197	1,46	5,10
JPY_P1_RES	138	-0,00000	0,04197	1,46	5,10
US_P1	138	-0,00446	0,03403	0,65	1,42
US_P1_RES	138	-0,00000	0,03403	0,65	1,42

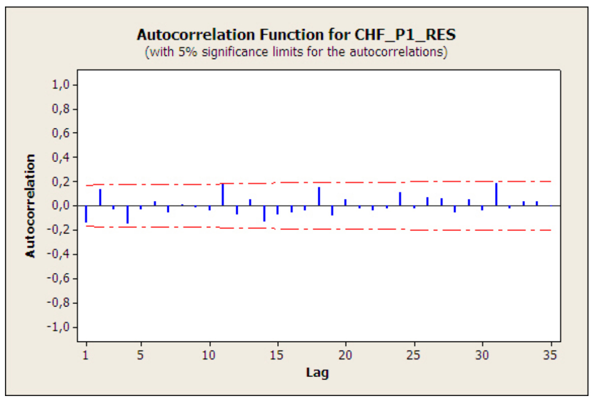
One-Sample T: CHF_P1; EUR_P1; GBP_P1; JPY_P1; US_P1

Test of mu = 0 vs not = 0

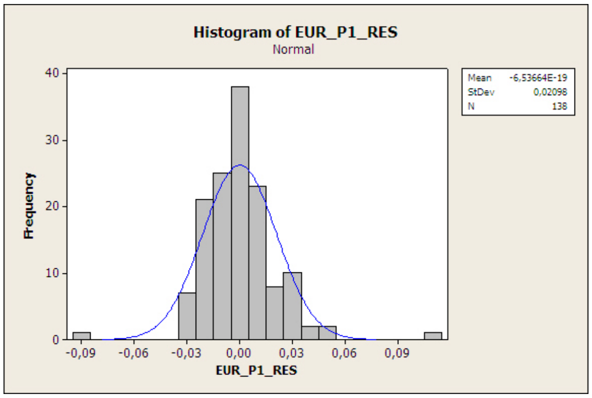
Variable	N	Mean	StDev	95% CI	T	P
CHF_P1	138	-0,00095	0,02764	(-0,00560; 0,00371)	-0,40	0,688
EUR_P1	138	-0,00151	0,02098	(-0,00504; 0,00202)	-0,85	0,399
GBP_P1	138	-0,00294	0,02563	(-0,00725; 0,00138)	-1,35	0,181
JPY_P1	138	-0,00382	0,04197	(-0,01089; 0,00325)	-1,07	0,287
US_P1	138	-0,00446	0,03403	(-0,01019; 0,00127)	-1,54	0,126

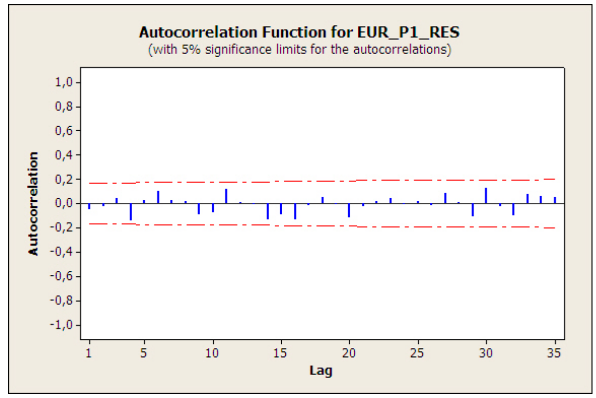
CHF_P1



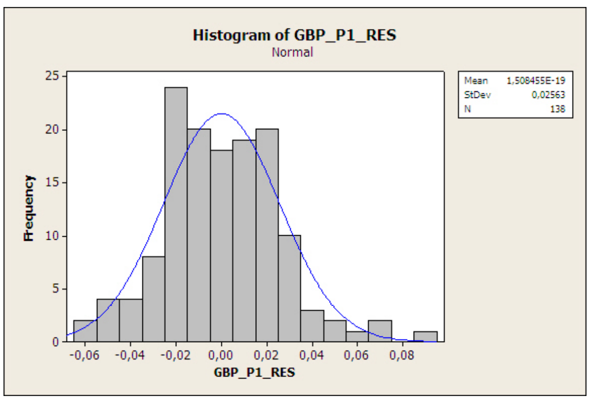


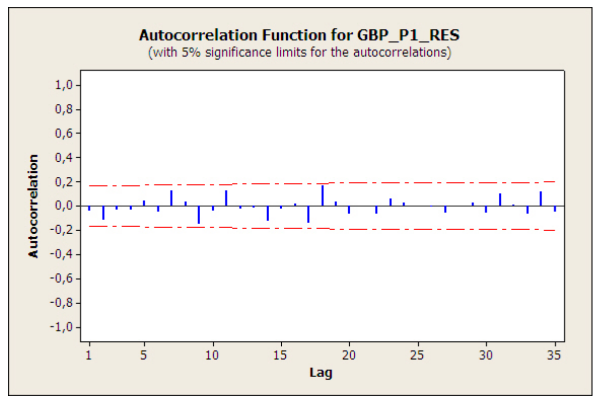
EUR_P1



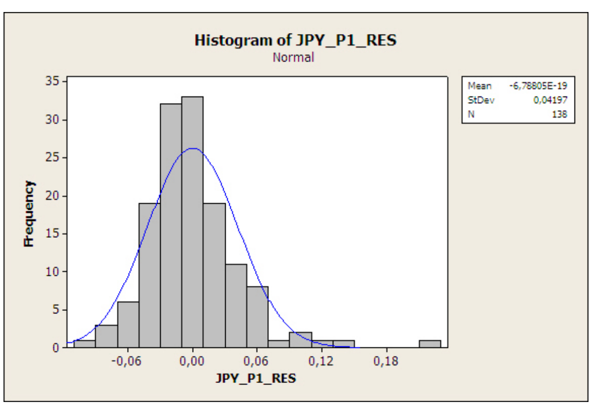


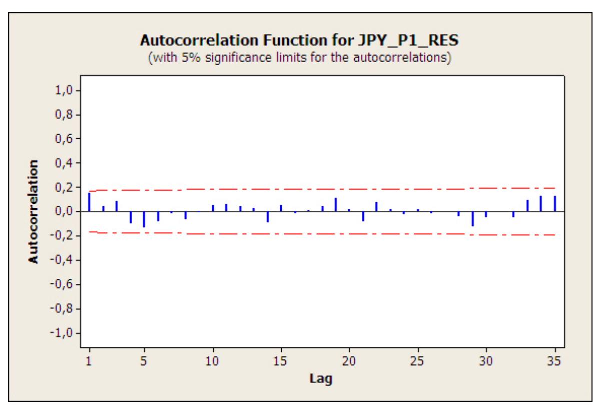
GBP_P1



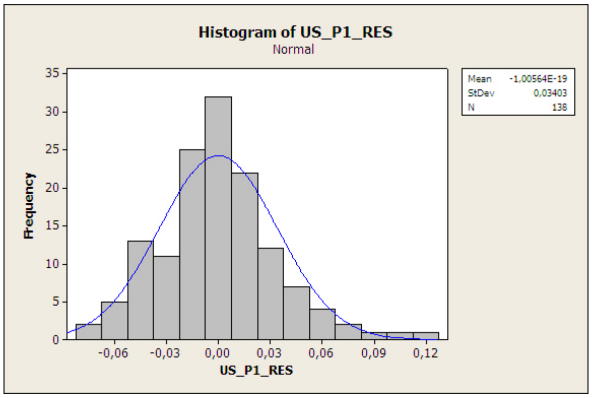


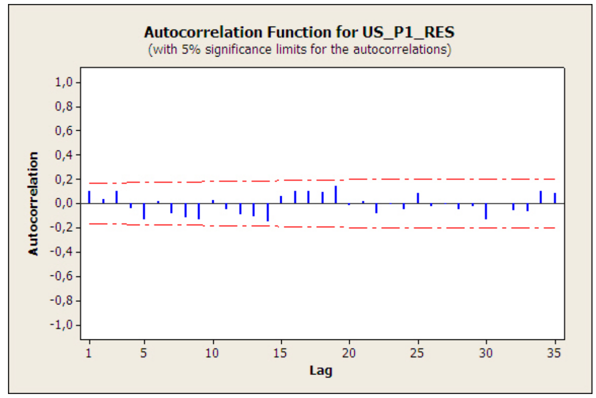
JPY_P1





US_P1



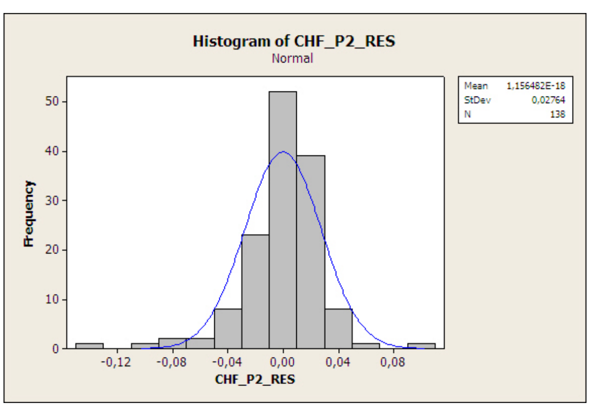


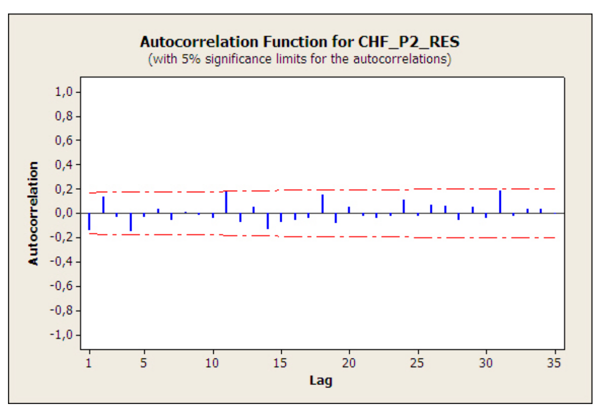
Descriptive Statistics: CHF_P2; CHF_P2_RES; EUR_P2; EUR_P2_RES; GBP_P2; ...

Variable	Total Count	Mean	StDev	Skewness	Kurtosis
CHF_P2	138	0,00095	0,02764	-1,25	5,63
CHF_P2_RES	138	0,00000	0,02764	-1,25	5,63
EUR_P2	138	0,00163	0,02097	-0,70	7,12
EUR_P2_RES	138	-0,00000	0,02097	-0,70	7,12
GBP_P2	138	0,00285	0,02564	-0,32	0,85
GBP_P2_RES	138	-0,00000	0,02564	-0,32	0,85
JPY_P2	138	0,00382	0,04197	-1,46	5,10
JPY_P2_RES	138	0,00000	0,04197	-1,46	5,10
US_P2	138	0,00445	0,03404	-0,63	1,40
US_P2_RES	138	-0,00000	0,03404	-0,63	1,40

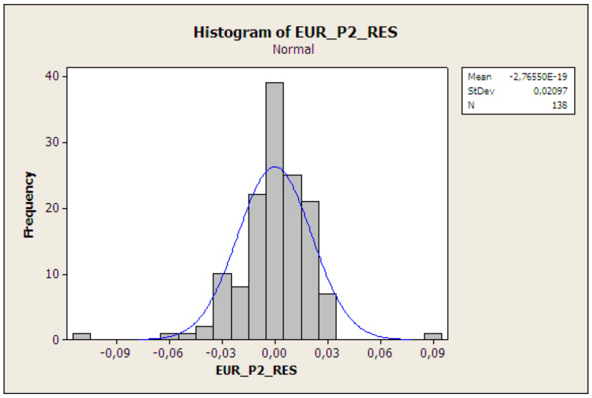
Variable	N	Mean	StDev	95% CI	T	P
CHF_P2	138	0,00095	0,02764	(-0,00371; 0,00560)	0,40	0,688
EUR_P2	138	0,00163	0,02097	(-0,00190; 0,00517)	0,92	0,361
GBP_P2	138	0,00285	0,02564	(-0,00146; 0,00717)	1,31	0,193
JPY_P2	138	0,00382	0,04197	(-0,00325; 0,01089)	1,07	0,287
US_P2	138	0,00445	0,03404	(-0,00128; 0,01017)	1,53	0,127

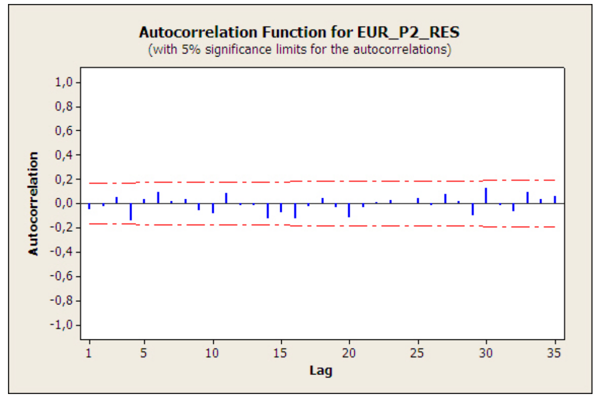
CHF_P2



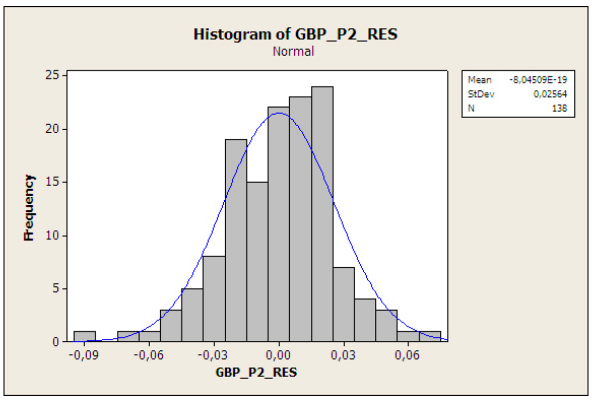


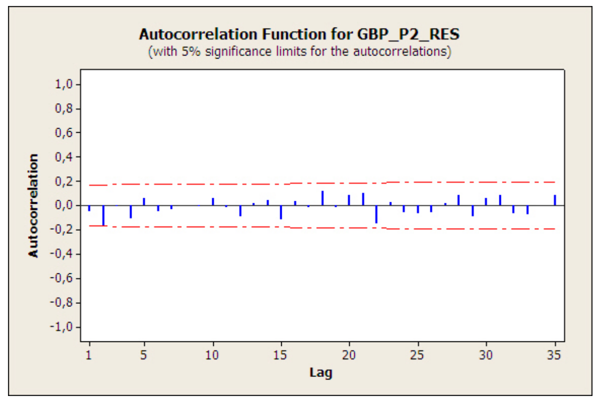
EUR_P2



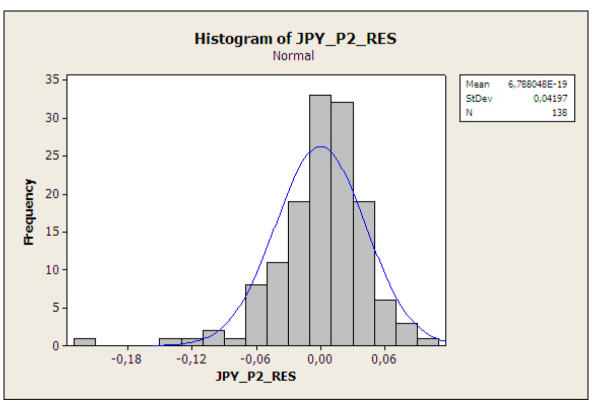


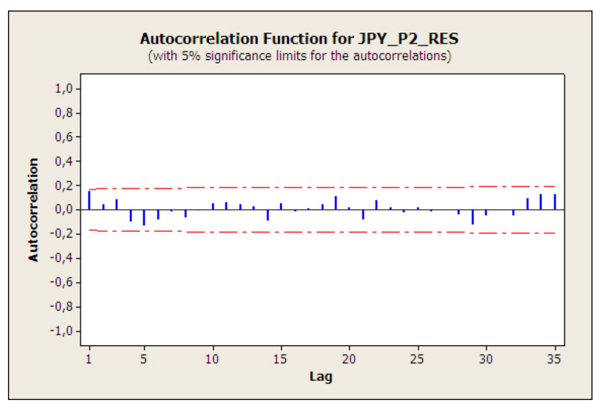
GBP_P2



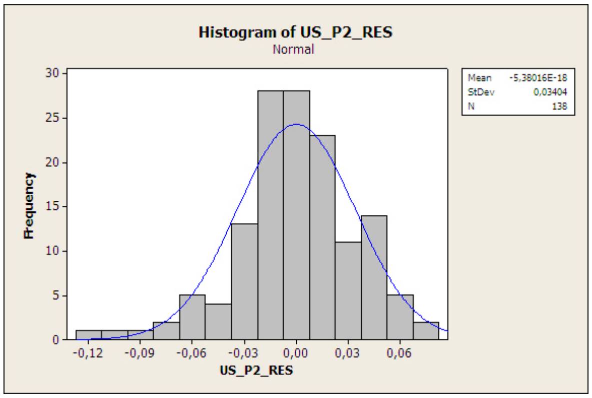


JPY_P2

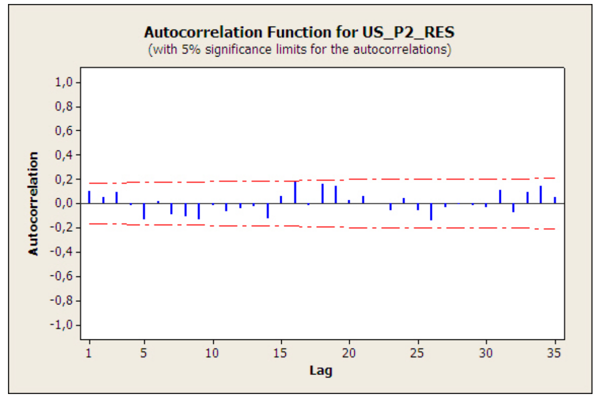




US_P2



Histogram of US_P2_RES
Normal
Mean -5,38016E-18
StDev 0,03404
N 138
Frequency
30
25
20
15
10
5
0
-0,12
-0,09
-0,06
-0,03
0,00
0,03
0,06
US_P2_RES



Autocorrelation Function for US_P2_RES
(with 5% significance limits for the autocorrelations)
Autocorrelation
1,0
0,8
0,6
0,4
0,2
0,0
-0,2
-0,4
-0,6
-0,8
-1,0
1
5
10
15
20
25
30
35
Lag

Appendix 8 Long annual time series (monthly data, USD)

Descriptive Statistics: CHF_LP1; CHF_LP1_RES; GBP_LP1; GBP_LP1_RES; ...

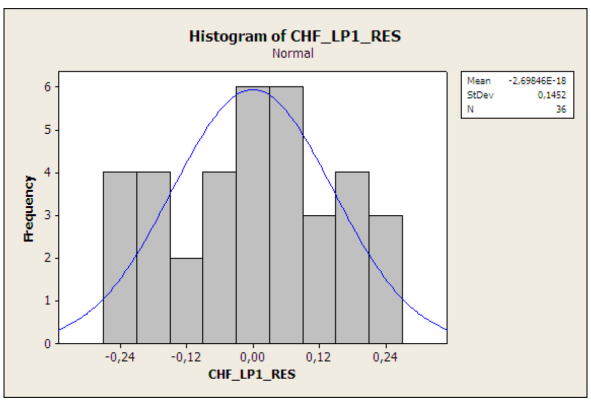
Variable	Total Count	Mean	StDev	Skewness	Kurtosis
CHF_LP1	36	0,0230	0,1452	-0,10	-1,12
CHF_LP1_RES	36	-0,0000	0,1452	-0,10	-1,12
GBP_LP1	36	0,0205	0,1432	-0,13	-0,05
GBP_LP1_RES	36	0,0000	0,1432	-0,13	-0,05
JPY_LP1	36	0,0121	0,1455	-0,18	-1,03
JPY_LP1_RES	36	-0,0000	0,1455	-0,18	-1,03

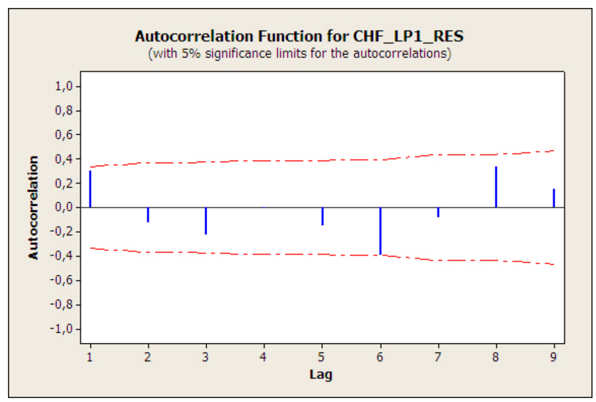
One-Sample T: CHF_LP1; GBP_LP1; JPY_LP1

Test of mu = 0 vs not = 0

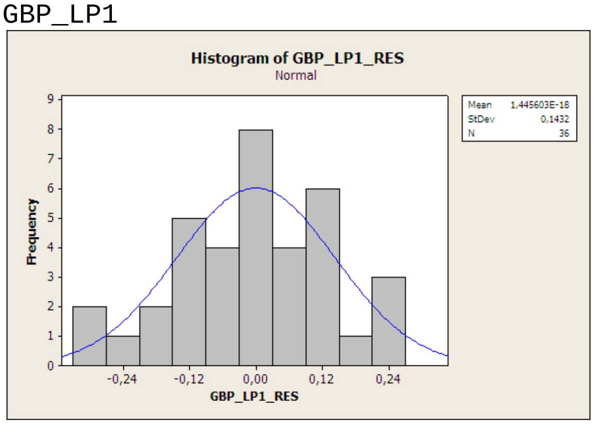
Variable	N	Mean	StDev	95% CI	T	P
CHF_LP1	36	0,0230	0,1452	(-0,0261; 0,0722)	0,95	0,348
GBP_LP1	36	0,0205	0,1432	(-0,0280; 0,0689)	0,86	0,397
JPY_LP1	36	0,0121	0,1455	(-0,0372; 0,0613)	0,50	0,622

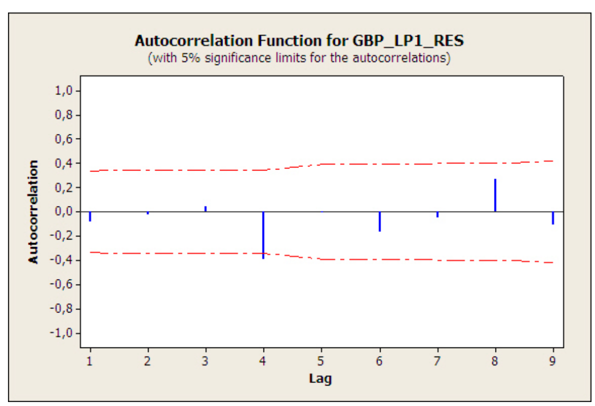
CHF_LP1



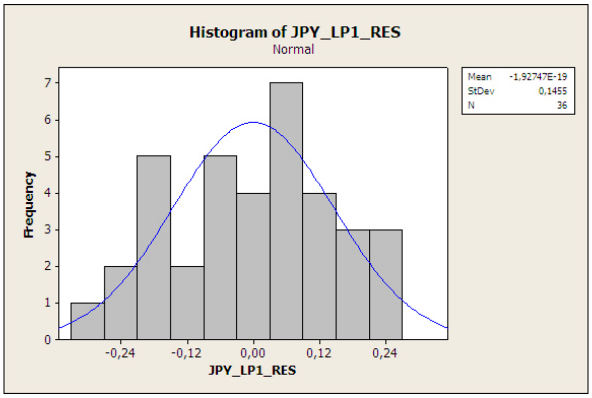


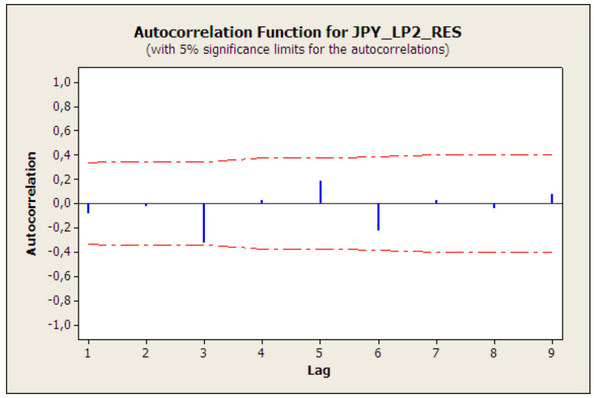
GBP_LP1





JPY_LP1





Descriptive Statistics: CHF_LP2; CHF_LP2_RES; GBP_LP2; GBP_LP2_RES; ...

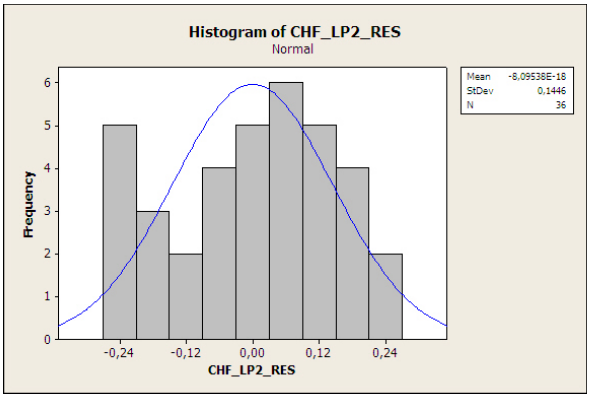
Variable	Total Count	Mean	StDev	Skewness	Kurtosis
CHF_LP2	36	0,0265	0,1446	-0,27	-0,99
CHF_LP2_RES	36	-0,0000	0,1446	-0,27	-0,99
GBP_LP2	36	0,0342	0,1405	-0,01	-0,14
GBP_LP2_RES	36	-0,0000	0,1405	-0,01	-0,14
JPY_LP2	36	0,0273	0,1434	-0,26	-0,95
JPY_LP2_RES	36	0,0000	0,1434	-0,26	-0,95

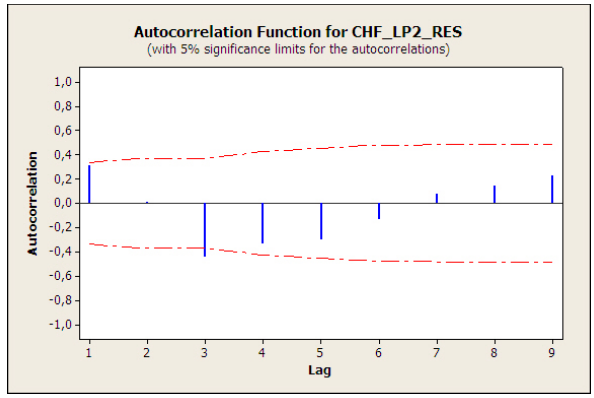
One-Sample T: CHF_LP2; GBP_LP2; JPY_LP2

Test of mu = 0 vs not = 0

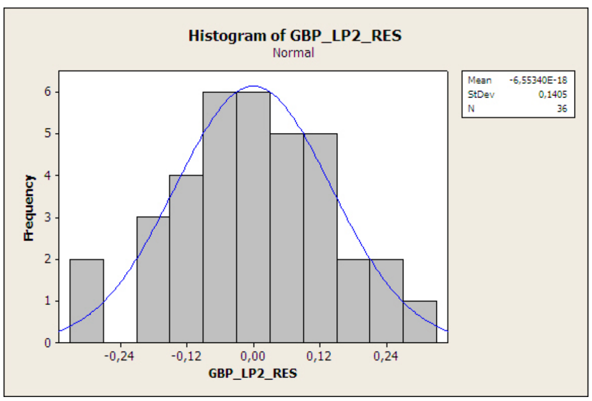
Variable	N	Mean	StDev	95% CI	T	P
CHF_LP2	36	0,0265	0,1446	(-0,0224; 0,0754)	1,10	0,279
GBP_LP2	36	0,0342	0,1405	(-0,0133; 0,0817)	1,46	0,153
JPY_LP2	36	0,0273	0,1434	(-0,0212; 0,0758)	1,14	0,261

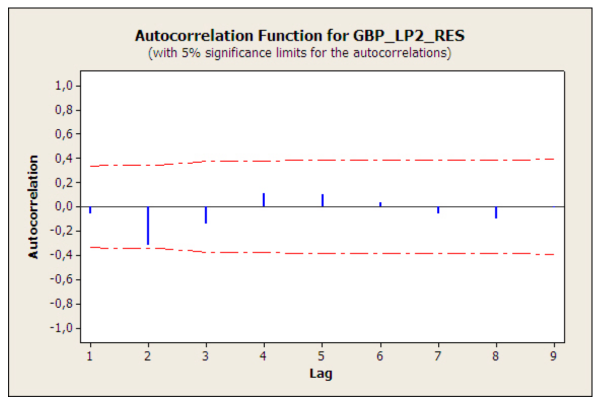
CHF_LP2



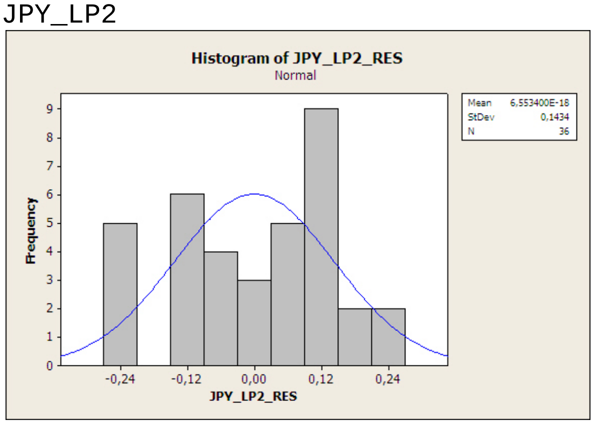


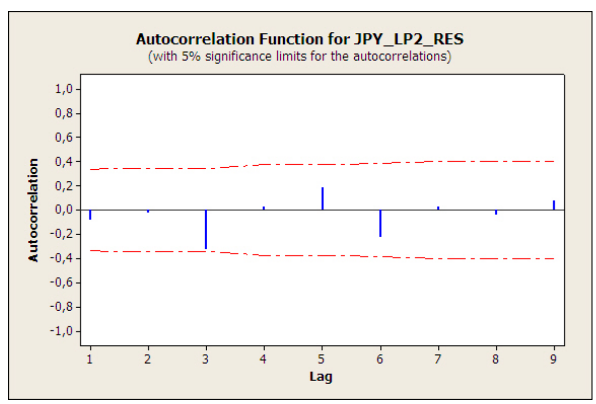
GBP_LP2





JPY_LP2





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