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The Carry Trade

From 1990 to 2020

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Abstract

This thesis examines the carry trade movements from 1990 to 2020. The purpose is to evaluate how an actively managed carry trade has behaved during different market conditions.
There are two carry portfolios constructed, the first one is an American carry and the second one makes an active decision every month to invest in the largest interest rate differentials.
The carry trades are based on nine currencies AUD, CHF, EUR, GBP, JPY, NOK, SEK, USD, and ZAR. The result finds evidence for violation of UIP and that the premium puzzle seems to be in line with findings of previous studies during some periods.
During recent years, the study finds that the carry trades are less profitable, although the portfolio Best Carry of All is a viable complement to an investor's portfolio, due to stable performance even during distressed market conditions.

Key Words*: Carry Trade, UIP, CIP, FX-Markets, Premium Puzzle, American Carry trade, Chief dealer back trade*

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Abbreviations

AQR	AQR Capital Management LLC
CIP	Covered Interest Parity
FX	Foreign Exchange
LIBOR	London Interbank Offered Rate
MOM2_VME_FX	Momentum portfolio in FX market
MOM2US	Momentum for US equities
MOM2_VME_EQ	Momentum for Equities
TED	Difference between future U.S. treasury and Eurodollar on a three month contract
UIP	Uncovered Interest Parity
VIX	Market volatility index
AUD	Australian Dollar
CHF	Swiss Franc
EUR	Euro
GBP	Pound Sterling
JPY	Japanese Yen
NOK	Norwegian Krona
SEK	Swedish Krona
USD	US Dollar
ZAR	South African Rand

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1. Introduction

1.1 Background

The level of activity in foreign exchange markets has increased in line with the rise of electronic trading networks. So has the development of specialized investors and hedge funds geared towards foreign exchange (FX) trading done as well (King et al 2011). As the interest and activity in the FX market has increased, the development of trading strategies that rely on short-term anomalies has increased. The number of available FX products suggests that the FX market is heavily used by investors and fund managers (Deutsche Bank, 2007; Pojarliev and Levich, 2010).

Two prominent strategies have evolved to trade in the FX market, the carry trade and the momentum strategy (Gynthelberg and Schrimpf, 2011). The increase in volume on the FX market seems to mostly consist of trading from momentum and carry strategies (Sanders, 2010). When investing in a high-interest rate currency with funding from a low-interest rate currency a carry trade has been executed. The currency that the loan is taken in is called the *funding currency* and the currency in which the funds are invested is called the *target currency*.
Some historically attractive funding currencies are the USD, Japanese Yen, and Swiss Franc. Traditionally common target currencies are the Australian Dollar, Brazilian Real, and the South African Rand. Carry trades are based on the market failure of Uncovered Interest Parity, UIP, which has become commonly known as *the forward premium puzzle* (Gynthelberg and Schrimpf, 2011).

Uncovered Interest Parity, UIP, states that it should not be possible to make profits from a carry trade (Danso, 2014). UIP and forward premium puzzle are described in greater detail in the theory section of this thesis on pages 7-10. The carry trade has become so popular that premade benchmarks and structured products referring to these benchmarks have been created. There are very large positions in the foreign exchange rate market that are based on investor speculations. These carry trades could amplify movements in the exchange rates and increase the speed of those movements. Such amplifications could happen in the foreign exchange market when many investors begin to unwind their positions at the same time. This is made possible due to the upward and downward price pressure that carry trades place on target and funding currencies. A momentum strategy assumes that past winners will continue to be winners for a while and that losers will be losers for a little while. A winning currency is one that has appreciated during the recent past and a loser is a currency that has depreciated during the same period (Gynthelberg and Schrimpf, 2011).

Carry trades and momentum strategies consistently produce profits and are used by fund managers to create an edge in their portfolios. When the time a position is held increases, so does the risk of the carry trade because it ignores the fundamental components that drive the movements of a currency. (Gynthelberg and Schrimpf, 2011).

1.2 Problem description research question

Today there is a large focus placed on equities by investors. The use of other assets when creating investment portfolios could greatly improve the diversification and return of said portfolios. An asset that is often overlooked by private investors and yet accessible to them are currencies. Investing in currencies is often done with a carry trade. The problem with the previous research is that the time horizon often is shorter than 20 years. The second problem is that most of the research is quite rigid in the construction of the carry trades. The structure sometimes allows for an investment even when the interest rate differential is negative. To combat those problems this thesis has created a portfolio that is restructured once every month, that cannot invest if there is a negative interest rate differential.

Are carry trades profitable investments and how do they fare during different market conditions? To answer whether carry trades are profitable and could bring value to an investor’s portfolio the evaluations are made over both long and short time periods. The period is divided into shorter periods that include booms and recessions to evaluate the performance during different market conditions.

1.3 Purpose

The purpose of this study is to see if there is a track record during the past 30 years that can motivate the use of carry trades as an investment strategy. Carry trades generally create small steady profits and suffer from large potential losses. The purpose in this thesis is to examine the carry trade during the last 30 years and evaluate how it has performed during different periods within that horizon. The most recent 30 years contains periods with both high and low-interest rates, booms as well as distressed market conditions.

In this report a carry trade portfolio is created, executed, and evaluated in comparison to equity investments and momentum strategies over the past 30 years. The study divides the 30-year period into shorter periods, which are characterized by crisis and non-crisis periods. Those periods, crisis and non-crisis, are of most interest to investigate more closely during different market conditions to see if there are any differences in performance between asset types and strategies. With the low-interest rates the economy currently is facing, it will be interesting to see how the performance of FX investments has changed. Especially for the carry trade since it speculates on exchange rates based on the interest rate differences between currencies.

The thesis aims to contribute to the body of knowledge in this subject area by presenting the results of more recent data. In addition, it aims to increase the flexibility of the carry trade portfolio by evaluating several possible funding currencies every month. Which makes it possible to identify larger interest rate differentials and not only perform an American carry trade. The time series is to be considered as long, as needed to give good insight into changes over time. With these adjustments and updated time series the thesis hopefully provides value and inspiration for future research within the subject.

1.4 Delimitations

The constructed carry trade is a one month carry trade. The momentum strategy is also carried out monthly to be consistent across portfolios. Nine currencies are used in this thesis, *AUD, CHF, EUR, GBP, JPY, NOK, SEK, USD and ZAR* to construct carry trades. The reason why the study focuses on those currencies is that those currencies are among the most traded ones and include some of the historically common funding and target currencies.
The Swedish Krona, *SEK* is added to this thesis since Sweden is a strong exporting economy in Europe with a floating exchange rate. The reason for including the Norwegian Krona is because Norway is a strong economy built on the country’s oil assets located within Europe. The South African Rand is also added, with the addition of this currency a small part of Africa

is included, as well as a historically common target currency. The goal has been to have a global currency portfolio but, due to insufficient data about BRL, South America is not included. Standard & Poors 500 is used as a representative portfolio for equities since it includes the 500 largest companies on the most liquid stock market. For equities, a momentum strategy is also included for comparison to include an equally frequently readjusted equity portfolio as well. This thesis does not take transaction costs into consideration to simplify calculations.

2. Literature review

Carry trades are widely researched and many studies have been conducted. Among them are the studies conducted by Froot & Thaler (1990) and Sarnos (2005) that concluded that the Uncovered Interest Parity, UIP, fails in the medium and short timeframe. In the thesis section *3. Theoretical Framework* a detailed explanation of Uncovered Interest Parity can be found on pages 7-10. Fama (1984) concluded from his time-series studies that UIP did not only fail but also that above average interest rate currencies appreciated against below average interest rate currencies. Those movements make the carry trade even more profitable as a carry trade goes long in high interest rate currencies and short in low-interest rate currencies. The same movements have been identified by Hodrick (1987). Such movements would further increase the profitability of the carry trade since there will be a profitable exchange rate movement and the payoff then does not only consist of the interest rate differentials. This was later confirmed by another study conducted by Engle (1996) that in a wide-ranging survey found that UIP is a negative predictor of exchange rate movements. Meaning that in line with the research conducted by Fama (1984) and Hodrick (1987) Engle (1996) found that low-interest rate currencies depreciated against high-interest rate currencies and that is what is known as the forward premium puzzle.

Gyntelberg and Schrimpf (2011) did a study where they investigated how widely practiced short-term multicurrency strategies performed over periods of market turmoil. They also tried to identify the downside risks in the different strategies. The study concludes that there is substantial tail risk in the performance of the strategies. During distress periods the performance of the different strategies is not uniform. Having tail risk means that the probability that returns deviate more than three standard deviations from the mean is greater compared to what is expected in a normal distribution. In other words, Gyntelberg and Schrimpf (2011) found that the investments conducted in the study where exposed to greater downside risks compared to a normal distribution. The distress period showed that even though FX investments face downside risks the equity market features an even greater downside risk. Comparing the different FX strategies presented by Gyntelberg and Schrimpf (2011) the result presents that the momentum strategy seemed to face fewer losses during a crisis period, while equity investments suffered the largest losses. The carry trade in their study outperformed both equities and the momentum strategy during the financial crisis of 2008.

Another study that focuses on the period of the financial crisis in 2008 is Danso (2014). He compares the performance of a carry trade to the return in a hedged FX strategy over periods of the financial crisis and non-crisis period. The study finds that the average return of the strategies was not profitable. However, the test in the thesis generated high standard deviations which suggests that it might not be completely accurate. The data suggests that there is a significant difference between crisis and non-crisis periods at the five percent significance level (Danso, 2014). During the financial crisis of 2008, the Deutsche Bank G10 currency future harvest index (*DBCFH*) lost a major size of fits value, -30.9 percent. The carry portfolio for the same period only lost 10.4%. The same carry portfolio managed to generate a mean annualized return of 4.82% over the entire period of interest (Burnside et al. 2011).

Sanders and Chang (2010) tried to explain how foreign exchange trade strategies, such as the carry trade and momentum strategy, can be used to explain the expected movements of Uncovered Interest Parity. More specifically due to short-run carry trades and momentum strategies earning profits on small deviations of UIP. In time as the volume of these trades increase the pressure from them should lead to reversions in the exchange rates. These reversions should also get increasingly stronger as the deviations in Uncovered Interest Parity grow larger. The results in Sanders and Changs (2010) report found evidence for traditional UIP being falsely specified. The findings suggested that the expectation in the exchange rate and interest rate is governed by something called the cross-country beta. Using cross-country betas generates an adequate model in normal times when no extreme events take place. They believe that the model might not be false but rather instead could be mis specified due to a shift in the behavior of investors (Sanders and Chang, 2010).

There is another research paper written by Brunnermeier, Nagel and Pedersen (2008) that found that carry trades such as previously described deliver returns that are negatively correlated to changes in VIX (a market volatility index). Their presented belief is that currency crashes are linked to the sudden unwinding of many carry trades. VIX and TED spread are found to be positively correlated to stock market crashes. Further, the study finds that a high VIX is predictive of higher returns for carry trades. When Brunnermeier, Nagel and Pedersen (2008) control for the predictive power of VIX some of the UIP violation can be explained.

Strategies that combine carry trades, value investments and momentum have managed to generate non-normal returns. (A value investment strategy is based on purchasing power parity and is also widely used). Research on these types of portfolios has been conducted by Burnside, Eichenbaum and Rebelo (2011). They found that the implemented strategies produced good Sharpe ratios. The US equity market only manages to generate a Sharpe ratio that is less than half of that from a carry trade during the same period. The study concludes that Sharpe ratios for the carry trades fall somewhere between 0.5 and 1.0 compared to the equity market which generates ratios close to 0.3 (Burnside, Eichenbaum and Rebelo 2011).

Several research papers have tried to explain these premiums that make large profits possible and determine if these returns are a free lunch or pricing for carrying higher risks. One paper written by Burnside et al. (2011) tries to use explanations based on classical theory. Classical theory entails concepts such as value, market risk premium, Peso problem and tail risks. A Peso problem is that the sample does not contain the occurrence of rare events such as a large disaster that would decrease the profitability significantly. Burnside et al. (2011) find the Peso problem to be a valid explanation for the excess returns in carry trades.

Menkhoff et al. (2012) try to explain the excess returns in the carry trade by using global FX volatility innovations as a proxy for systematic risk. They manage to show that the excess returns can be explained as compensation for bearing risks. Returns in the carry trade are lower during periods with a high amount of volatility innovations. Significant negative movements are found in low-interest rate currencies in relation to Volatility innovations. Menkhoff et al. (2012) work their results in to the asset pricing model in order to state that the excess carry returns can be explained by time-varying risk.

Burnside, Rebelo and Eichenbaum (2008) investigate the effect on the excess returns in carry trades when the carry trade is diversified by using several different currencies. Burnside et al. (2006) find that the Sharpe ratio is typically 0.5 times greater for a diversified portfolio than a non-diversified portfolio. The Sharpe ratios generated in their paper are significantly different from zero. More importantly is that Burnside et al. (2006) finds that it is not suitable to interpret the carry trade payoffs as compensation for risk. This is because the payoffs in their study are found the be significantly uncorrelated with common risk factors.

Burnside, Rebelo and Eichenbaum (2008) argue that the high Sharpe ratios for a carry in the Hong-Kong Dollar might be due to a Peso problem. That specific Peso problem related to the Hong-Kong Dollar carry would be the high political risks associated with China, that during their study did not materialize. High Sharpe ratios were also found for their equally weighted carry portfolio. There is no apparent Peso-problem that could explain the excess return in the equally weighted portfolio. Burnside, Rebelo and Eichenbaum (2008) express it as follows; *"picking up pennies in front of an unknown truck that has never been seen"*.

3. Theoretical framework

To understand how and why carry trades work, it is necessary to go into further detail of what a carry trade is and how it works. Investing in a high-interest rate currency with funding from a low-interest rate currency is called carry trade. The currency in which the loan is taken is called the funding currency and the currency in which the funds are invested in is called the target currency. The spread between the funding currency and the target currency will be the interest rate differential and it is viewed as a gain. This gain is affected by the movements in the spot rate, hence if the target currency does not depreciate against the funding currency the carry trade will have a payoff equal to the interest rate differential. If that were to happen uncovered interest parity would be violated. UIP, short for Uncovered Interest Parity states that low-yield currencies will appreciate against high-yield currencies at a rate so that the expected returns are equal across currencies if denoted in the same currency (Gyntelberg and Schrimpf 2011). Interest rate parity expressed as a formula where $R_{\$}$ is the interest rate in USD and $R_{€}$ is the Euro interest rate, $E_{€/\$}$ is the exchange rate, denoted as the number of Euro per USD. $E^{e}_{€/\$}$ is the expected Euro/USD exchange rate.

$$R_{\$} + \frac{E^{e}_{€/\$} - E_{€/\$}}{E_{€/\$}} = R_{€} \tag{1}$$

If covered interest rate parity, CIP, holds it can be expressed as follows, where F_t is the forward rate (forward rate means that two parties have agreed upon a price for a future transaction, in this case, an exchange rate), S_t is the spot rate (current exchange rate), $e^{i_t^*}$ is the continuously compounded foreign interest rate and e^{i_t} is the continuously compounded domestic interest rate:

$$\frac{S_t e^{i_t^*}}{F_t} - e^{i_t} = 0 \tag{2}$$

It can be rewritten as follows where $f_t = \mathrm{LN}(F_t)$ and $s_t = \mathrm{LN}(S_t)$

$$f_t - s_t = i_t^* - i_t \tag{3}$$

The difference in interest rates is equal to the forward premium. The parity can be achieved with no risk since the future price can be locked in by the forward rate, hence the name covered interest parity. If the forward rate is not used, the uncovered interest parity is acquired and it is equal to:

$$E_t\left[\frac{S_t e^{i_t^*}}{S_{t+1}}\right] - e^{i_t} = 0 \tag{4}$$

Rewritten as

$$E_t(S_{t+1} - S_t) = i_t^* - i_t \tag{5}$$

Such a position is exposed to risks in the spot rate changes and is not covered by a forward rate. When uncovered and covered interest parity are combined, a predictor for future spot rate can be derived given that UIP and CIP holds (Krugman, Obstfeld and Melitz 2018).

$$E_t(S_{t+1}) = f_t \tag{6}$$

To conclude whether there is a violation of UIP, a regression with a joint null hypothesis of $\beta_0 = 0$ and $\beta_1 = 1$ could be conducted. This hypothesis would then be tested with the below regression model.

$$\Delta s_{t+1} = \beta_0 + \beta_1(i_t - i_t^*) + \varepsilon \tag{7}$$

Alternatively, it can be evaluated by observing if the payoff from the carry trade is greater than 0 (Tanamee, 2014). The carry trade can formally be expressed in two parts, the interest rate differential, and the spot rate change, these two components can then be used to construct the carry trade payoff:

$$i_t^* - i_t - E_t(s_{t+1} - s_t) = payoff \tag{8}$$

This formula can also be reformulated by using Covered Interest Parity, CIP. This can be done by taking the forward rate subtracting the spot rate and the expected spot rate change. This is then equal to the forward subtracted by the expected spot rate next period. Carry trade can then be calculated with CIP as:

$$f_t - s_t - E_t(s_{t+1} - s_t) = f_t - E_t(s_{t+1}) \tag{9}$$

If the payoffs are positive it means that the change in spot rate is not large enough to counteract the interest rate differential (Obstfeld, Marc, 2018).

4. Data & Methodology

4.1 Data

4.1.1 Carry trade

The data is collected from Bloomberg and to avoid inconsistencies all the data has been collected from the same database. In the constructed portfolios the spot rates that have been used are *AUD, CHF, EUR, GBP, JPY, NOK, SEK, USD and ZAR*, all currencies are denoted against the US Dollar. The second parameter collected from Bloomberg is the one-month forward rate for all the above-listed currencies. The collected data stretches from 1990-01-31 to 2020-02-28. There are several ways to get the interest rate differential, for example, treasury-bills can be used to get the interest for respective countries, and then the interest rate differential would be computed as, the difference of foreign and domestic rate on the treasury-bill. In this study, the interest rate is derived through the difference in log-normal forward rate and log-normal spot rate. This is in line with the concepts previously explained in the theory section.

4.1.2 Comparable portfolios

The data concerning the payoff for momentum strategies on currencies and other assets such as equities are gathered from the investment firm AQR. They have created a publicly available dataset called value and momentum everywhere. The dataset consists of momentum and value portfolios from an array of equities, commodities, indices, and currencies. The momentum portfolios from this dataset have been extracted and incorporated into the data set of this thesis. The currency portfolios cover the currencies for ten different countries; Australia, Germany (spliced with the Euro), Japan, New Zealand, Norway, Sweden, Switzerland, UK, and the US. From January 1979 to July 2011 the portfolio always has a minimum of seven currencies, from 1980 until now all ten currencies are available. Using forwards, MSCI spot prices and Libor rates the returns extracted are denominated in USD (Asness et al. 2013).

When they created their momentum strategy, the goal was to create the simplest measure possible so that it would be consistent over the different asset classes. The used momentum measure is MOM2-12 which is the past 12-month raw cumulative return on the asset. The most recent month is skipped to avoid the one-month reversal in stocks. In trying to keep the strategy as similar as possible they have kept the same measure for currencies although the one-month reversal is not a problem for currencies. Momentum would have been stronger if the most recent month had been included, so the results generated are conservative for a momentum currency portfolio. The momentum portfolios are ranked by high middle and low weights (Asness et al. 2013).

The index Standard & Poor 500 is the largest measure for US large cap and is collected from Bloomberg. Many investment vehicles speculating on US Equities use S&P500 as the basis. It consists of the 500 largest companies and covers about 4 fifths of the available market cap (Bloomberg, 2020).

4.2 Methodology

There are two main methods to approach a thesis, the quantitative method, and the qualitative method. The quantitative method is preferable when working with big data sets, and want to analyze it, this method can save a lot of time and cost and be of great relevance. This thesis is working with time-series data reaching over a 30-year period, which begins in 1990 and ends in 2020 with an all-time high stock market. The stock market recently got hit by the COVID-19 pandemic, which has led to the Corona crisis. In between, there have been large financial crises such as the housing crisis and the .COM bubble. The study contains a very large number of observations and will conduct testing with data analysis; hence this thesis uses a quantitative method.

With all the needed data collected the next step is to process the data. The carry trade is constructed from two main parameters, the spot rate, denoted S in the calculations and the forward rate denoted F. Both the spot rate and the forward rate will always be stated against the US Dollar, if not otherwise specified. The carry trade formula builds on two components, the interest rate differential, and the change in the spot rate.

$$Return\ Carry\ trade = Interest\ rate\ difference - Spot\ rate\ changes \tag{10}$$

The calculations are made on the monthly spot rates for all eight currencies. The spot rate difference can be calculated by taking the spot rate in period t +1 and subtract it with the spot rate in the period t. This gives the numerical change and not a percentages change. Since relative change is preferable at later stages in the calculations the difference in the natural logarithm of each spot rate is used instead. By using the natural logarithm, the relative change is obtained and not the absolute change.

$$LN(s_{t+1}) - LN(s_t) = \frac{s_{t+1} - s_t}{s_t} = Spot\ rate\ Change \tag{11}$$

The second parameter that the model calculates is the interest rate differential. As previously mentioned, the interest rate differential is derived through the spot rate and forward rate.

$$f_t - s_t = i_t^* - i_t \tag{3}$$

The formula, when implemented in the model, is reformulated to the following:

$$LN(F_t) - LN(s_t) = Interest\ rate\ differential \tag{12}$$

At this point, all the needed parameters to construct a carry trade for every exchange rate from 1990-01-31 until 2020-02-28 are created. The difference in interest rates between the currencies will be the starting point.

4.2.1 Portfolios

There are two portfolios being constructed, the first one, *US Carry* always uses USD as the funding currency. The second portfolio, *Best Carry of All*, is a chief dealer back trade that invests in the largest possible interest rate differentials in the data set. The reason behind having an American carry portfolio is that the USD is the most liquid currency and the US being the largest economy. The other carry portfolio, *Best Carry of All*, sources the largest possible carry component each month which hopefully generates the best possible returns with what can be known at point t in time.

The American carry trade portfolio mentioned above works as follows; For every period it ranks the interest rate differentials and chooses to invest in the top three largest differentials given that they are positive values. The payoff is then calculated for every position by taking the differential minus the spot rate change. The portfolio is equally weighted over all three positions.

The portfolio named *Best Carry of All* is a portfolio that uses the largest and smallest deviations to construct its trades. This portfolio uses the two smallest interest rate differentials each month as funding currencies and the two largest differentials as target currencies. The differential between funding and target currency is acquired by taking the differential of target currency and subtracting the differential from the funding currency (their respective differentials compared to USD). The interest differential (for the cross rate) is subtracted with the change in the respective cross rate to generate the payoff for each month. Using this method, it is possible to get the largest initial payoff opportunity available in our dataset each month. The two investment returns are equally weighted in the portfolio return calculation.

To evaluate and set the portfolios into perspective another FX investment strategy that has not been executed by this study has been included. That will be the momentum strategies for the FX market, for construction of them see the data section. To compare how the FX market fares compared to the stock market also the S&P500 is included. To see if an active strategy, that is measured in the FX market as well, might be better applied on equities the momentum trades on equities from "value and momentum everywhere" are also included.

Two more portfolios are included, E*xchange rate returns US carry* and *Exchange rate return Best Carry of All*. These two portfolios present the exchange rate movements in their respective carry trade. This means that the interest rate differential is not included in the reported return for these portfolios.

4.2.2 Tests

To test if there is a significant difference in mean returns between the portfolios a *one-tailed two-sample Welch t-test assuming unequal variances* is performed. Such a test is referred to as a heteroskedastic test.

$$t_{df} = \frac{\bar{x} - \bar{y} - \Delta_0}{\sqrt{\frac{S_1^2}{m} + \frac{S_2^2}{n}}} \tag{13}$$

$$df = \frac{\left(\frac{S_1^2}{m} + \frac{s_2^2}{n}\right)}{\frac{\left(\frac{S_1^2}{m}\right)^2}{m-1} + \frac{\left(\frac{S_2^2}{n}\right)^2}{n-1}}$$

The *Welch t-test: two-sample assuming unequal variances* reports a p-value for a one-tailed test. If the p-value is less than alpha 0.05 it means that it can be concluded that the mean of variable 1 is greater than that of variable 2.

To test if one variance is greater than the other, a *one-tailed F-test* is used. The F-test computes the p-value for a two-tailed test. Since a one-tailed test is needed the generated p-value is divided by 2 to get the appropriate p-value. If the reported p-value value is less than 0.05 it means that variable 1 at a five percent significance level has a higher variance than variable 2.

$$F_{(df_1, df_2)} = \frac{S_1^2}{S_2^2} \qquad df_1 = n_1 - 1 \qquad df_2 = n_2 - 1 \tag{14}$$

Sharpe ratios will be used to evaluate how the return and volatility in the investments are linked together. The Sharpe ratio describes the connection between volatility and returns in a way that it shows the effect of adding more volatility on the return. This is a common measure to compare investments (Jaggia and Kelly, 2016).

$$\frac{Return - Riskfree\ rate}{Standard\ deviation} = Sharpe\ ratio \tag{15}$$

5. Results

The results are divided into four different time intervals, 1990-2020, 1999-2004, 2006-2012 and 2013-2020. The aim with the separation is to look at different market conditions and time horizons. 1990-2020 presents the results for the entire data set. During the period 1999-2004, as well as 2006-2012, the aim has been to observe what happened to the carry trade during financial distress periods such as the bursting of the .COM bubble and the financial crisis of 2008. From 2013 to 2020 the goal has been to observe the carry trade during the latest boom up until Covid-19. *(Note: All returns in this section are monthly returns if not otherwise stated.)*

5.1 1990-2020

The below diagram shows the mean returns and the standard deviation between 1990 and 2020. Note that the portfolio with the highest mean return is the *S&P500*, with a monthly mean return of 0.84 percent and a yearly return of 11.68 percent. On the other end of the spectrum, the lowest mean return is 0.08 percent, which can be found in the portfolio *MOM2_VME_FX*.
When looking at the carry portfolios note that they have lower standard deviation as well as lower returns compared to equity investments, like the *S&P500*, *MOM2_VME_EQI* and *MOM2US*. The carry trade yields a monthly mean return of 0.10 percent for *US Carry* and 0.40 percent for *Best Carry of All* with a yearly mean return of 5.23 percent.
Although the *S&P500* has the highest mean return it has the second largest standard deviation, which indicates that it is one of the riskier investments. The highest standard deviation is 0.043 and belongs to *MOM2_VME_EQ*, closely followed by the *S&P500* with a standard deviation of 0.042. The lowest standard deviation 0.022 belongs to *MOM2_VME_FX*. Comparing *US Carry* with the portfolio *Best Carry of All* shows that the *Best Carry of All* has a slightly lower standard deviation, 0.25 compared to 0.28.

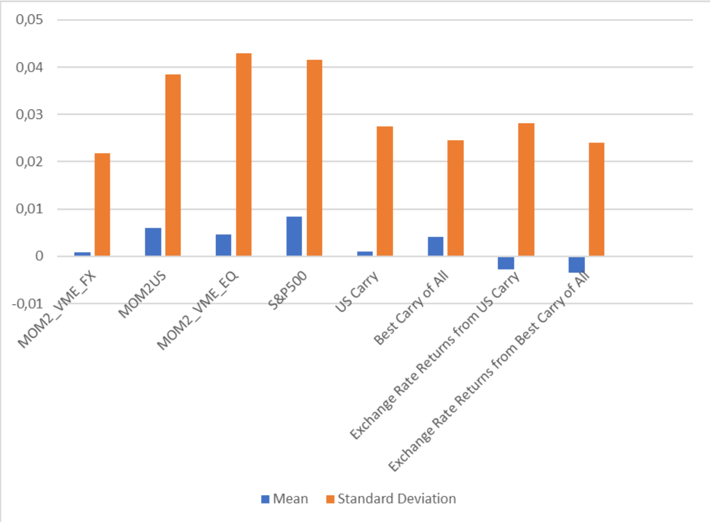

Figure 1. Mean Returns & Standard Deviation 1990-2020

The accumulated returns are presented in the below graph for all portfolios from 1990 to 2020. As pictured in the graph the *S&P500* has had a higher return compared to all other investments with an accumulated return of 16.98 times the initial investment over the 30-year period. As mentioned above, the *S&P500* has the second highest standard deviation, which could be part of the explanation for the huge losses that occur. The second highest accumulated return is generated by *MOM2US*, followed by the portfolio *Best Carry of All*.

The graph shows that the *Best Carry of All* generates the highest return until the end of 1994. After 1994 the *Best Carry of All* has a constant but small and steady growth up to 2020.

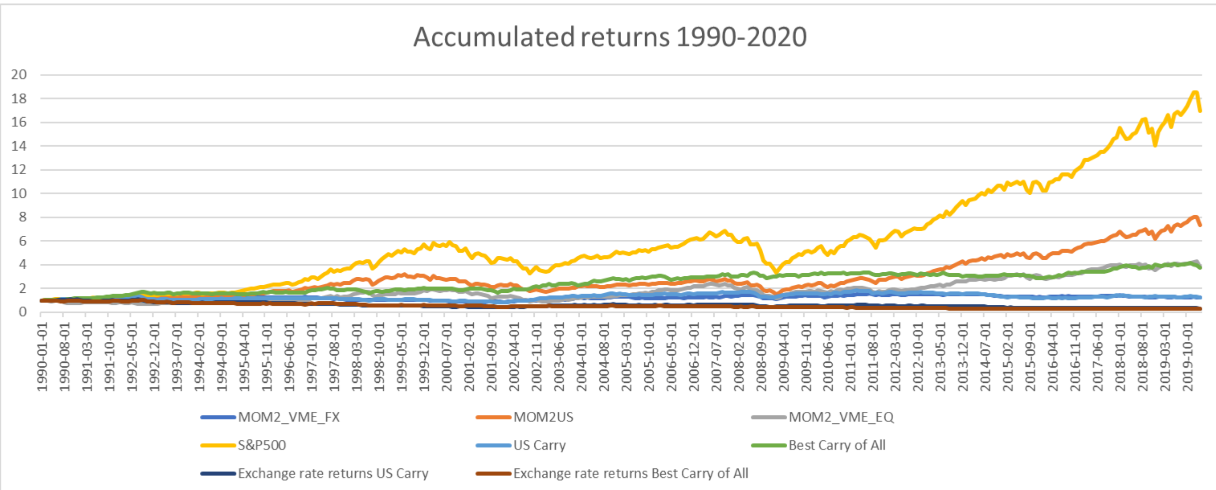

Figure 2 Accumulated Returns 1990-2020

The mean returns are tested with the *Welch´s t-test*, which assumes unequal variances. In the below table the one tailed p-values from *Welch's t-test* are reported. If the p-value is less than 0.05, it means that the portfolio in the column has a higher mean return than the portfolio in the row at the 5% significance level. The below table shows that the *Best Carry of All* has a significantly higher return than the *MOM2_VME_FX* at a five percent significance level and at ten percent significance level a higher mean return than the *US Carry*. With 95 percent confidence, the *S&P500* has generated a higher mean return than all the foreign exchange rate portfolios. Further, the tests show that *MOM2_VME_FX* did not significantly outperform the *MOM2US*, *MOM2_VME_EQ*, *S&P500*, *US Carry* or the *Best Carry of All*, although it generated higher returns than the exchange rate movements from the carry trades.

Differences in mean return 1990-2020 **t-Test: Two-Sample Assuming Unequal Variances**	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
MOM2_VME_FX		0,0048	0,0483	0,0012	0,4628	0,0301	0,9725	0,9929
MOM2US	0,9952		0,7469	0,2206	0,9795	0,8	0,9998	1
MOM2_VME_EQ	0,9517	0,2531		0,1137	0,9094	0,5787	0,9967	0,9989
S&P500	0,9988	0,7794	0,8863		0,9975	0,9552	1	1
US Carry	0,5372	0,0205	0,0906	0,0025		0,0565	0,9656	0,9884
Best Carry of All	0,9699	0,2	0,4213	0,0448	0,9435		0,9997	1
Exchange Rate Returns from US Carry	0,0275	0,0002	0,0033	0	0,0344	0,0003		0,6209
Exchange Rate Returns from Best Carry of All	0,0071	0	0,0011	0	0,0116	0	0,3791	

Table 1 Differences in mean return, Welch t-test, 1990-2020

Table 2 below displays the one tailed p-value from a F-test. The tests alternative hypothesis is that the quote from the test, $F_{(df1,df2)} = \frac{S_1^2}{S_2^2}$, is greater than one. The column is equal to variable 1 in the equation and the row is equal to variable 2. If the below reported p-value value is less than 0.05 it means that the column at the five percent significance level has a higher variance than the row. The equity portfolios all have significantly higher variances than all FX portfolios even at the one percent level. *US Carry* has a significantly greater variance than the *Best Carry of All* with a reported p-value of 0.0142.

Variance tests 1990-2020 **P value of one tailed variance test**	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
MOM2_VME_FX		0	0	0	0	0,013	0	0,0282
MOM2US	1		0,018	0,0693	1	1	1	1
MOM2_VME_EQ	1	0,982		0,731	1	1	1	1
S&P500	1	0,9307	0,269		1	1	1	1
US Carry	1	0	0	0		0,9858	0,326	0,994
Best Carry of All	0,987	0	0	0	0,0142		0,0041	0,6255
Exchange Rate Returns from US Carry	1	0	0	0	0,674	0,9959		0,9985
Exchange Rate Returns from Best Carry of All	0,9718	0	0	0	0,006	0,3745	0,0015	

Table 2 Variance tests, F-test, 1990-2020

5.2 1999-2004

The figure shows the mean returns and the standard deviations for the period 1999 to 2004. The portfolio with the highest mean return is *Best Carry of All*, with a mean return of 0.66 percent, which is higher than during the period 1990-2020. The *US Carry* portfolio has also generated a higher mean return for this period, compared to the entire period 1990-2020. Interesting to see is that the mean returns are higher for *US Carry*, *best Carry of All* and *MOM2_VME_FX* during these market conditions, while almost all other portfolios decrease in profitability. See section 6.Analysis for further discussion.

S&P500 has a mean return of 0.2 percent for the period compared to 0.8 percent between 1990-2020. The variance for the *Best Carry of All* has increased, while the *US Carry* trade has decreased in variance compared to the period 1990-2020.

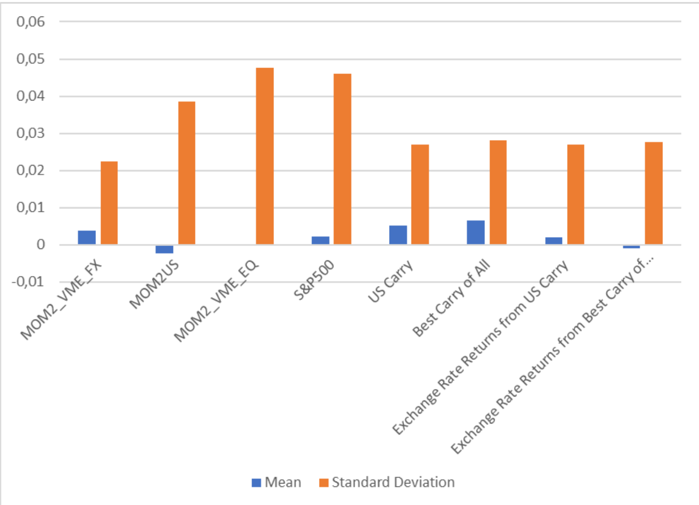

Figure 3 Mean Return & Standard Deviation 1999-2004

Most investments start of with stable growth in this period and generate positive returns until the crisis in March 2000. From the crash, it can be observed that there is a clear downward sloping pattern for all portfolios. The *Best Carry of All* and *US Carry* regain their losses faster and continue to be profitable throughout the entire period. The equity investments do not manage to recuperate from the crash during this shorter time frame.

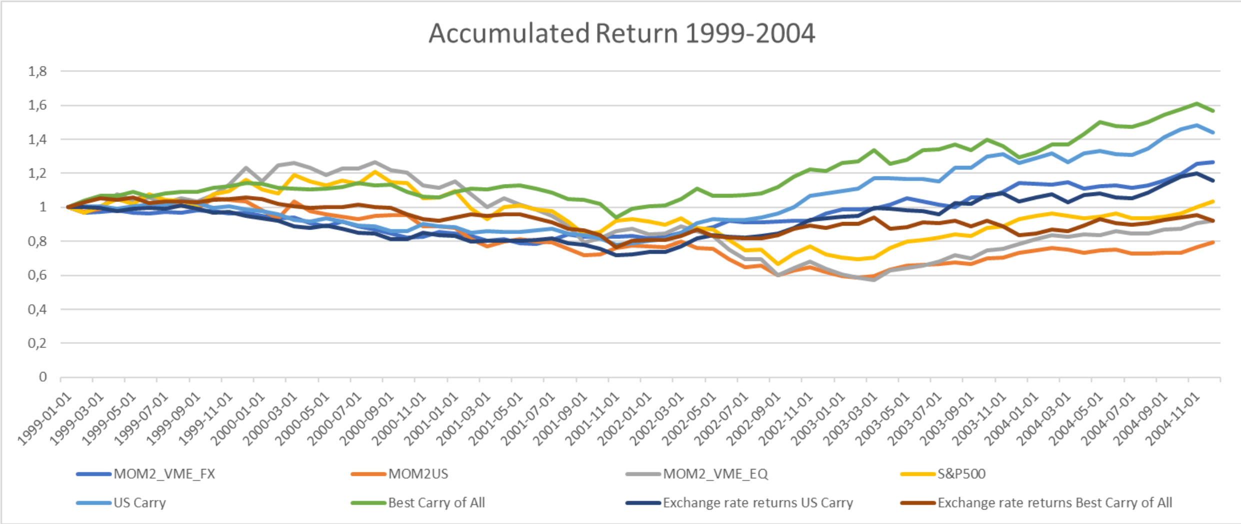

Figure 4 Accumulated Return 1999-2004

The *Welch t-test* for this period shows that the carry portfolios do not have significantly better mean returns than any other portfolio at the five percent significance level. Very interesting is that none of the portfolios has a mean return greater than any other portfolio with 95 percent confidence. The variance in *Best Carry of All* is only significantly greater than for *MOM2_VME_FX*. Equity investments (*MOM2US*, *MOM2_VME_EQ* and *S&P500*) all have significantly greater variances than the different FX portfolios.

Differences in mean return 1999-2004 **t-Test: Two-Sample Assuming Unequal Variances**	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
MOM2_VME_FX		0,9054	0,7349	0,6035	0,3709	0,2442	0,6624	0,863
MOM2US	0,0946		0,3284	0,2654	0,0926	0,0567	0,2194	0,3993
MOM2_VME_EQ	0,2651	0,6716		0,4015	0,2244	0,161	0,3898	0,5653
S&P500	0,3965	0,7346	0,5985		0,32	0,2389	0,5091	0,6828
US Carry	0,6291	0,9074	0,7756	0,68		0,3661	0,754	0,9038
Best Carry of All	0,7558	0,9433	0,839	0,7611	0,6339		0,8449	0,9465
Exchange Rate Returns from US Carry	0,3376	0,7806	0,6102	0,4909	0,246	0,1551		0,7359
Exchange Rate Returns from Best Carry of All	0,137	0,6007	0,4347	0,3172	0,0962	0,0535	0,2641	

Table 3 Differences in mean return, Welch t-test, 1999-2004

Variance tests 1999-2004 **P value of one tailed variance test**	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
MOM2_VME_FX		0	0	0	0,0556	0,0267	0,0608	0,0366
MOM2US	1		0,0411	0,0712	0,9985	0,9958	0,9987	0,9972
MOM2_VME_EQ	1	0,9589		0,6079	1	1	1	1
S&P500	1	0,9288	0,3921		1	1	1	1
US Carry	0,9444	0,0015	0	0		0,3661	0,5183	0,4207
Best Carry of All	0,9733	0,0042	0	0	0,6339		0,651	0,5566
Exchange Rate Returns from US Carry	0,9392	0,0013	0	0	0,4817	0,349		0,4029
Exchange Rate Returns from Best Carry of All	0,9634	0,0028	0	0	0,5793	0,4434	0,5971	

Table 4 Variance tests, F-test, 1999-2004

5.3 2006-2012

In the below chart the mean returns and the standard deviation for the portfolios between 2006 and 2012 are presented. The global financial crisis that occurred during this period was at the time the largest financial crisis since the great depression. Even though there was a large crisis, all portfolios except *Exchange Rate Returns from US Carry* and *Exchange Rate Returns from Best Carry of All*, did generate a positive mean return. Comparing the performance of the portfolio *Best Carry of All* with the other turbulent period 1999-2004 it can be observed that the period 2006-2012 has generated a lower mean return and standard deviation. Meanwhile, the *US Carry* experienced opposite movements, this later period generated a higher mean return and larger standard deviation.

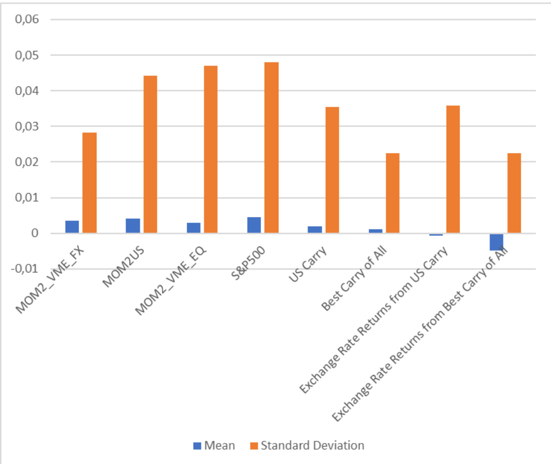

Figure 5 Mean Return & Standard Deviation 2006-2012

This is the only period in the data set were the accumulated return is higher for the *US Carry* than for the *Best Carry of All*. During this crash, the downward movement is not as large in the carry portfolios. In addition to this the *MOM2US* and *S&P500* hold both the highest and lowest portfolio values during this six-year period. The same pattern as in the *.COM* bubble occurs as the carry trades recuperate back to their original level faster than the other investments. *Exchange rate returns from best carry of all* has a clear downward movement suggesting that the patterns discovered by Hodrick are not present during this period. This period has the largest losses in *exchange rate returns from best carry of all.*

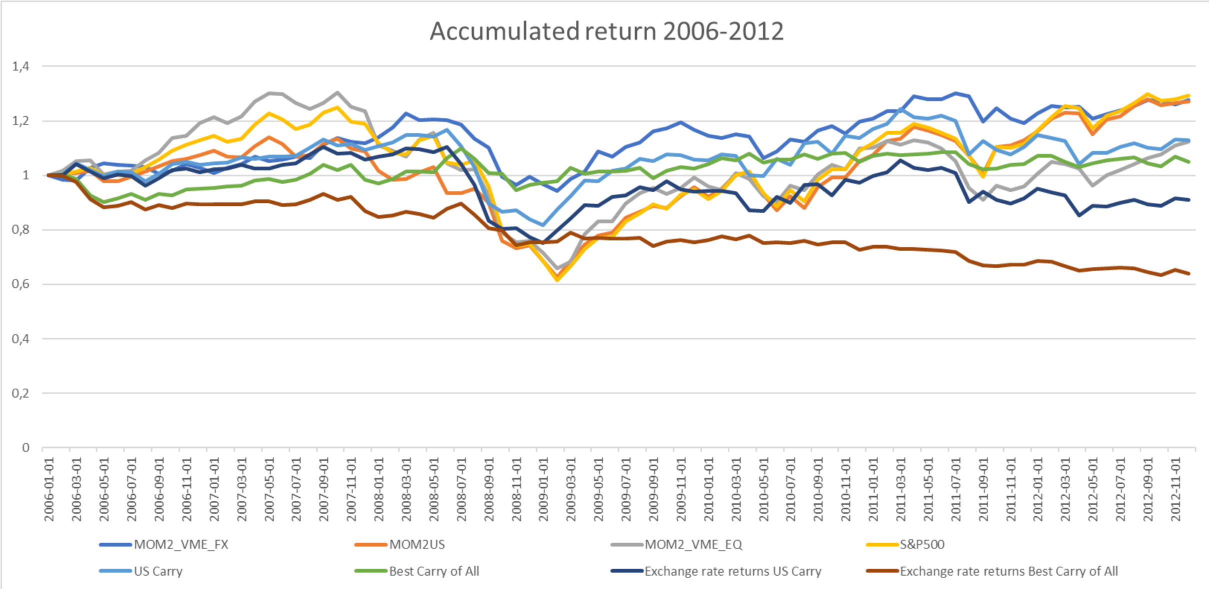

Figure 6 Accumulated Return 2006-2012

Excluding *Exchange Rate Returns from Best Carry of All*, none of the portfolios has a higher mean return compared to any other portfolio with 95 percent confidence. This could be expected from the quite similar movements seen in the above graph.

All portfolios, except *Exchange Rate Returns from Best Carry of All*, have a significantly greater variance than *Best Carry of All* at the five percent significance level. The equity investment portfolios all have significantly greater variances than *US Carry* and *MOM2_VME_FX* .

Differences in mean return 2006-2012 **t-Test: Two-Sample Assuming Unequal Variances**	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
MOM2_VME_FX		0,4626	0,5491	0,4412	0,6381	0,7431	0,8058	0,9842
MOM2US	0,5374		0,5839	0,4751	0,6391	0,7118	0,7777	0,9503
MOM2_VME_EQ	0,4509	0,4161		0,4171	0,5688	0,6335	0,7151	0,9164
S&P500	0,5588	0,5249	0,5829		0,658	0,726	0,7868	0,9475
US Carry	0,3619	0,3609	0,4312	0,342		0,5719	0,679	0,9301
Best Carry of All	0,2569	0,2882	0,3665	0,274	0,4281		0,6457	0,9563
Exchange Rate Returns from US Carry	0,1942	0,2223	0,2849	0,2132	0,321	0,3543		0,8194
Exchange Rate Returns from Best Carry of All	0,0158	0,0497	0,0836	0,0525	0,0699	0,0437	0,1806	

Table 5 Differences in mean return, Welch t-test, 2006-2012

Variance tests 2006-2012 **P value of one tailed variance test**	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
MOM2_VME_FX		0	0	0	0,0217	0,9813	0,0163	0,9827
MOM2US	1		0,2936	0,2355	0,979	1	0,9723	1
MOM2_VME_EQ	1	0,7064		0,4293	0,9949	1	0,9929	1
S&P500	1	0,7645	0,5707		0,9969	1	0,9957	1
US Carry	0,9783	0,021	0,0051	0,0031		1	0,4528	1
Best Carry of All	0,0187	0	0	0	0		0	0,513
Exchange Rate Returns from US Carry	0,9837	0,0277	0,0071	0,0043	0,5472	1		1
Exchange Rate Returns from Best Carry of All	0,0173	0	0	0	0	0,487	0	

Table 6 Variance tests, F-test, 2006-2012

5.4 2013-2020

The period of 2013 to 2020 is for the major part characterized by a boom that at the beginning of 2020 had led to an all-time high stock market. The last two-three months of this period also captures the early stages of the Corona crisis the world economy is currently facing. In this period the portfolios *MOM2US* and *S&P500* are extremely similar in their characteristics. Performing a carry trade during this boom, regardless of it being an American carry trade or chief dealer back trading portfolio, has performed a lot worse looking at mean returns than it did compared to the entire period 1990-2020. Compared to the period 1990-2020 the variances are lower in this period for the carry trades. All equity portfolios generated higher mean returns and lower standard deviations during this boom than for the entire data set in this thesis.

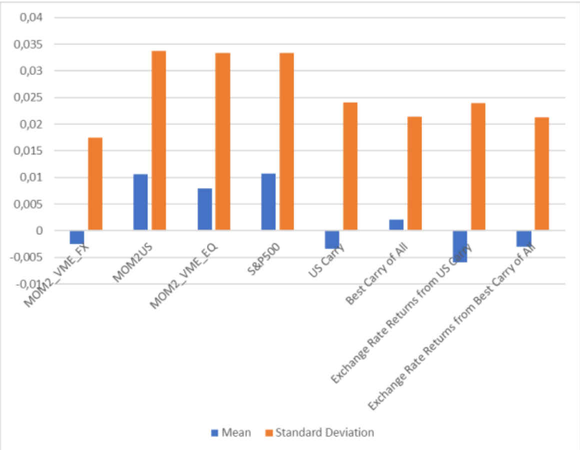

Figure 7 Mean Return & Standard Deviation 2013-2020

As could be expected during an economic boom the stock market generated positive accumulated returns. Only one FX portfolio did not lose money at the end of this seven-year period and it was the *Best Carry of All*. What is eye-catching during this period is the very similar movements in *S&P500* and *MOM2US.*

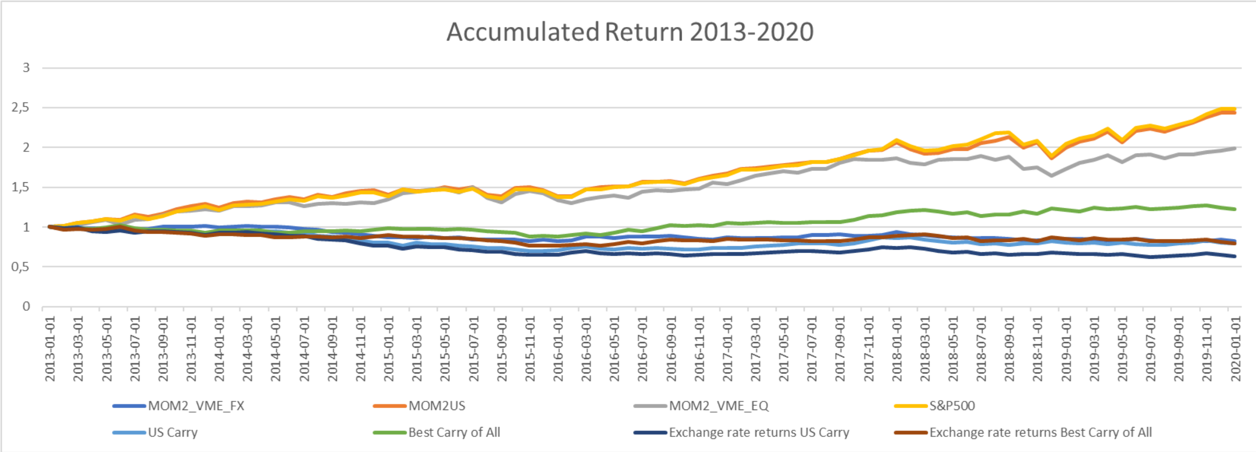

Figure 8 Accumulated Return 2013-2020

What could be said for the carry trades is that during this period they do not have significantly higher mean returns than any of the equity investments. Interesting is that during this period the chief dealer back trading portfolio, *Best carry of All*, has managed to perform significantly higher returns than the American carry trade, at the ten percent level.

Looking at the variances the equity investments have larger variances than the *Best Carry of All* even at a one percent significance level and the *US Carry* at the five percent level.

Differences in mean return 2013-2020								
t-Test: Two-Sample Assuming Unequal Variances	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
MOM2_VME_FX		0,0003	0,0026	0,0007	0,6097	0,0661	0,8659	0,5764
MOM2US	0,9997		0,7717	0,4845	0,9989	0,9746	0,9999	0,999
MOM2_VME_EQ	0,9974	0,2283		0,2854	0,9939	0,9122	0,999	0,9942
S&P500	0,9993	0,5155	0,7146		0,9991	0,9782	0,9999	0,9992
US Carry	0,3903	0,0011	0,0061	0,0009		0,0607	0,7656	0,4633
Best Carry of All	0,9339	0,0254	0,0878	0,0218	0,9393		0,9894	0,9396
Exchange Rate Returns from US Carry	0,1341	0,0001	0,001	0,0001	0,2344	0,0106		0,1954
Exchange Rate Returns from Best Carry of All	0,4236	0,001	0,0058	0,0008	0,5367	0,0604	0,8046	

Table 7 Differences in mean return, Welch t-test, 2013-2020

Variance tests 2013-2020								
P value of one tailed variance test	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
MOM2_VME_FX		0	0,1054	0	0,0018	0,03	0,0021	0,0333
MOM2US	1		0,5527	0,5535	0,9991	1	0,9992	1
MOM2_VME_EQ	1	0,4473		0,5008	0,9986	1	0,9987	1
S&P500	1	0,4465	0,4992		0,9985	1	0,9987	1
US Carry	0,9982	0,0009	0,0014	0,0015		0,851	0,5164	0,8616
Best Carry of All	0,97	0	0	0	0,149		0,1587	0,5187
Exchange Rate Returns from US Carry	0,9979	0,0008	0,0013	0,0013	0,4836	0,8413		0,8524
Exchange Rate Returns from Best Carry of All	0,9667	0	0	0	0,1384	0,4813	0,1476	

Table 8 Variance tests, F-test, 2013-2020

5.5 Sharpe ratios

The Sharpe ratio is calculated by taking the mean return of the investment, subtracting the risk-free rate, and then dividing the difference by the standard deviation. The below Sharpe ratios are calculated with a 10-year US Treasury-bill as the risk-free rate since all portfolios begin and end with USD. Over the entire 30-year period all the portfolios had positive ratios which means that the added risk is validated. Although all portfolios had positive Sharpe ratios this was not the case for the exchange rate returns that generated negative Sharpe ratios. *S&P500* had the highest Sharpe ratio for the whole period but not for all periods. The carry trade seems to be the second-best investment according to the Sharpe ratios for the whole period and had its highest Sharpe during the beginning of the data set, 0.216. The American carry trade did show a similar pattern as the chief dealer back trading portfolio and did also perform its highest Sharpe ratio during the period of 1990-2004. This table confirms the relations that could be suspected previously in the result sections. There is a difference between the portfolios and their respective Sharpe ratios during different market conditions.

Yearly Sharpe ratios	**1990-2020**	**1999-2004**	**2006-2012**	**2013-2020**
MOM2_VME_FX	0,068	0,343	0,416	-0,471
MOM2US	0,473	-0,215	0,259	0,968
MOM2_VME_EQ	0,315	0,023	0,184	0,885
S&P500	0,638	0,113	0,273	1,054
US Carry	0,084	0,341	0,124	-0,309
Best Carry of All	0,499	0,591	0,116	0,343
Exchange Rate Returns from US Carry	-0,288	0,143	-0,086	-0,626
Exchange Rate Returns from Best Carry of All	-0,629	-0,164	-1,489	-0,426

Table 9 Sharpe ratios

5.6 Distribution of Portfolio Returns

The kurtosis is larger than zero which indicates that the distribution of the monthly returns seems to have fat tails. Especially the *US Carry* suffers from fat tails as it is the portfolio with the highest kurtosis. Having a fat tail problem means that the data has more outliers than what would be expected from a normal distribution. If the portfolio has more outliers than for a normal distribution it means that unusual events are more likely to occur than normally in numbers this would be observations that are more than three standard deviations away from the mean in any direction. When any of the two carry portfolios, *US Carry* and *Best Carry of All*, exerts a negative skewness it is found that the same period has fat tails indicated by the positive kurtosis reported in the descriptive statistic tables in the appendix A.4 on page X and XI.

The skewness reported in the appendix does not exhibit a clear pattern of positive nor negative skewness for all the periods. However, for the whole period, 1990-2020, both carry trades are negatively skewed. The *Best Carry of All* is the most negatively skewed -0.45 out of the two, *US Carry* is generating a skewness of -0.34.

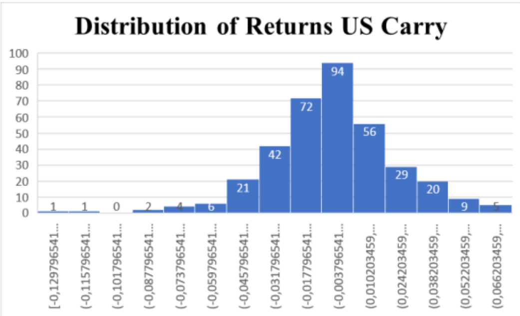

Figure 9 Distribution of Returns US Carry

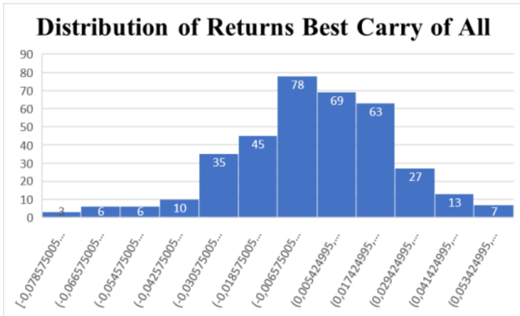

Figure 10 Distribution of Returns Best Carry of All

In the appendix, there is an output from Shapiro-Wilk W test for normality on the portfolios *US Carry* and *Best Carry of All*. The result differs throughout the data set. Both the *US Carry* and the *Best Carry of All* have returns that follow a distribution significantly different from a normal distribution for the period 1990-2020 as well as 2006-2012. For the periods 1999-2004 and 2013-2020 are assumed to be normally distributed since the null hypothesis cannot be rejected.

6. Analysis and Discussion

The constructed portfolios *US Carry* and the *Best Carry of All* generate a mean return that is positive for the entire sample period of 1990-2020. When looking at the exchange rate returns, which is one of the two components in the carry trade, the data shows that the exchange rate returns from both the *US Carry* and the *Best Carry of All* on average where negative from 1990 to 2020.

The concept of Uncovered Interest Parity, which was introduced in the theory section, says that the exchange rate movements should cancel out the interest rate differential that exists between the countries. As such, one would expect that the exchange rate movements would at least generate negative payoffs. That expectation from reading the theory is not what we would expect because when looking at the literature review section a different picture is painted. Instead, the previous studies conducted in the literature review section would suggest that the exchange rate returns ought to be positive. In the theory section, it was presented that the failure of Uncovered Interest Parity, UIP, could be validated by the carry trade generating a positive payoff. The positive excess returns for 1990-2020 confirm that UIP fails both for the portfolios *US Carry* and *Best Carry of All.*

Fama (1984) and Hodrick (1987) both discovered that high-interest rate currencies appreciate against low-interest rate currencies. If the movements that they discovered would be present in this thesis it should be possible to identify it by looking at the respective exchange rate returns. The exchange rate returns are positive when the target currency is worth more in terms of the funding currency. During the total 30-year period in the thesis the exchange rate movements discovered by Hodrick (1987) and Fama (1984) cannot be identified as the exchange rate returns are on average negative for the two carry trades. Finding negative exchange rate returns is contradictory to the research conducted by Engle (1996) as well as his research confirmed the findings of Fama and Hodrick.

When looking at the shorter periods like 1999 to 2004 and 2006 to 2012, the *US Carry* and *Best Carry of All* generated excess returns. The returns where expected to be positive since Froot and Thaler (1990) as well as Sarno (2005) concluded that Uncovered Interest Parity fails in the short and medium timeframe. The violation of UIP can be confirmed by the carry trade generating a profitable payoff. Contradictory to the discoveries that Sarno (2005), Froot and

Thaler (1990) made the *US Carry* did not manage to generate an average positive payoff during the period 2013-2020. That the *US Carry* did not generate a positive mean return suggests that Uncovered Interest Parity holds during this period for the American carry trade. The other carry trade portfolio, *Best Carry of All*, was able to generate a positive mean return during 2013-2020, even though there was large volatility. However, the *Best Carry of All* still generated lower returns for the period 2013-2020 compared to the entire 30-year period included in the data set.

Uncovered Interest Parity is found to only hold during a single period, 2013-2020 for only the American carry trade, *US Carry*. All other periods for both the portfolios, *US Carry* and *Best Carry of All*, confirm that UIP is violated. In the appendix, A.6 test results can be found for a t-test that tests if the mean returns during different periods are significantly greater than zero. Out of the two carry portfolios, *Best carry of All* and *US Carry*, only the *Best Carry of All* is significantly greater than zero for two periods. Those two periods are 1999-2004 and 1990-2020 which means that the *Best Carry of All* significantly violates UIP during those two periods. At the five percent significance level, the *US Carry* cannot reject the null hypothesis of the mean return being equal to zero.

Traditionally carry trades suffer from large crashes at times that wipe out large portions of the previously generated returns. These types of crashes have been identified by previous research and do at times also make themselves present in the dataset of this thesis for the American carry trade. In the *Best Carry of All* these traditional crash patterns are not present to the same extent as in the *US Carry*. Perhaps the *Best Carry of All* reduces the crash risk by following the structure of a chief dealer back trade. It is eye-catching to see that the portfolio, *Best Carry of All*, continuously generates positive mean returns, while the other carry portfolio, *US Carry*, does not provide positive mean returns for all of the periods, 1990-2020, 1999-2004, 2006-2012 and 2013-2020. When taking a closer look at what could have caused this pattern it becomes clear that the variance in the exchange rate returns for the American carry trade is larger than for the chief dealer back trade. The larger variance in exchange rate movements combined with the lower interest rate differentials in the *US Carry* portfolio, makes it more sensitive to larger negative effects from negative exchange movements. As mentioned previously in the analysis the Sharpe ratios are almost always larger for the chief dealer back trading portfolio, *Best Carry of All*, than for the *US Carry*. Except for the period 2006 until 2012 were the *US Carry* had a marginally better Sharpe ratio. This is most likely due to the greater variance in the exchange rate returns in the *US Carry* portfolio being a tad more on the positive side.

After the financial crisis of 2008 in general the interest rates are lower than what they were before the global financial crisis. The profitability in the carry trades, *Best Carry of All* and *US Carry*, has decreased as the interest rate level decreased. For the period after 2013-2020 both the carry trades do not generate nearly as much in returns as they do even during the distressed period of 1999-2004. The reason for the larger returns generated during this distress period, 1999-2004, compared to the large economic boom during the most recent seven years, is due to the interest rates that where higher during the last years of the 20th and early 21st century. The graph in appendix A.8 shows the movements of the interest rate differentials, exchange rate returns, LIBOR and the accumulated return in the chief dealer back trade and American carry trade. In the same graph the above-mentioned pattern of decreased profitability in the carry trades when the interest rates are lower is clear. It is a reasonable pattern as one would assume that if the interest rates are larger, then the potential differences between interest rates in two different countries also be larger. Reverting the argument, the differentials should be smaller when the interest rates are small. In the graph note that the exchange rate return movements do not change a lot from low-interest rate and higher interest rate periods the decreased profitability must be an effect of decreased interest rate differentials.

The generally low interest might explain the poor performance of the portfolios *US Carry* and *Best Carry of All* during the most recent economic boom. Even though the explanation makes sense and such patterns are indicated in the produced graphs the thesis has not performed any appropriate tests to test how significant and if it at all has a significant relationship. Appropriate tests have not been run because for them to make sense and be accurate the data must include the risk-free rate of every country used in the carry portfolios that are being tested. The data set in this thesis does not contain the necessary rates as this thesis acquires the interest rate differentials from taking the log normal forward rate and subtracting the log normal spot rate.

The best risk neutral investment available during the period 1999 to 2004 was the *Best Carry of All* with a yearly Sharpe ratio of 0.59. The portfolio, *Best Carry of All*, generated the highest Sharpe ratio by having a significantly lower variance than the other portfolios during the same period of 1999-2004. When only looking at the implemented FX strategies, carry trade and momentum, the relevant portfolios are, *Best Carry of All*, *US Carry* and *MOM2_VME_FX*. All the three FX portfolios offered better Sharpe ratios for the period of 1999-2004 which means that the FX investments offered a better investment opportunity than equities during this period.

During the period of 2006 to 2012 *MOM2_VME_FX* generated the highest yearly Sharpe ratio of 0.42 due to significantly lower variances than all the other portfolios. At the end of 2012, the accumulated return from investing with this very simple strategy is equal to the accumulated return of S&P500. MOM2_VME_FX managed to do so without having as large fluctuations in portfolio value as S&P500 during the six-year period of 2006 to 2012. Stating that FX investments are better during this crisis as well would be to misguide the reader because the *US Carry* and *Best Carry of All* did not offer better Sharpe ratios nor higher accumulated returns than the *S&P500* and *MOM2US*. That the *S&P500* and *MOM2US* offer better Sharpe ratios is very surprising since the financial crisis of 2008 hit the US stock market very hard during this period, it was at the time the largest financial crisis since the great depression. Due to FX investments offering better and worse investments from 2006 to 2008 it cannot be concluded that FX investments are better than equity investments.

It is not surprising that the best investment opportunities during a large economic boom are equity investments. The *S&P500* is to be considered the best risk neutral investment when accounting for added risk during 2013-2020 as it generated the highest Sharpe ratio of 1.05. Having generated significantly higher mean returns than the FX investments, *US Carry*, *Best Carry of All* and *MOM2_VME_FX*, is the driving factor behind the higher Sharpe ratio for *S&P500*. In the results section, the variance tests show that it also generates higher variance but due to the Sharpe ratios it is possible to know that the return is larger in relation to the risk taken.

If the investment horizon consists of the entire data set from 1990 to 2020 the *S&P500* would have been the best investment opportunity available in the thesis. *S&P500* generated the highest Sharpe ratio and the largest accumulated return. Which portfolio strategy that generates the second-best investment opportunity depends on whether weighing risk to return heavier than the accumulated return or not. The portfolio *MOM2US* managed to generate the second largest accumulated return over the past 30 years. The road to achieving the high accumulated return is very volatile for *MOM2US* which does affect the Sharpe ratio. If one where to look at the Sharpe ratios instead to make the choice of which investment is the second best, they would conclude that *Best Carry of All* is the second-best investment. The *Best Carry of All* has a significantly lower variance than both the *MOM2US* and *S&P500* for the period 1990 to 2020. *S&P500* does on the other hand have significantly greater mean returns than the *Best Carry of All* which is large enough for the Sharpe ratio of the *S&P500* to trump the chief dealer back trade portfolio. Due to the significantly lower variance in the *Best Carry of All* compared to *MOM2US* it has generated a better Sharpe ratio during the 30-year period.

Burnside, Eichenbaum and Rebelo (2011) did in their study generate Sharpe ratios that are inconsistent with the findings of this study. They find that the Sharpe ratios for the carry trades in their paper is somewhere between 0.5-1.0. The Sharpe ratios are in addition to that also higher for carry trades than for equities in their study. For the period 1999 to 2004 the Sharpe ratio of the *Best Carry of All* falls within the interval 0.5-1.0 and looking at 1990-2020 the Sharpe ratio if rounded is 0.5 just on the edge. Their study contains the period of 1976-2010 (Burnside, Eichenbaum and Rebelo 2011) and since the only period in our data set that is included in theirs entirely is 1999-2004, it might explain why the ratios also only match for that given period. Especially since the carry trades decrease in profitability during the latter periods, 2006-2012 and 2013-2020.

In line with Gyntelberg and Schrimpf (2011) the result shows that the carry trades outperformed both equities as well as momentum trades, during the financial crises. Regarding the fat tail risk that occurs in Gyntelberg and Schrimpf (2011) study, this study cannot conclude that there is a substantial tail risk for all periods. Although it can be observed that for the whole period both the carry trades include fat tails, but this is not true for all tested periods. Considering the reported losses for the Deutsche Bank G10 currency index and their carry trade that generated negative returns it might be a bit ambiguous, since the *Best Carry of All* generated positive returns during the same period. A closer look at the structure of the constructed carry portfolio during 2008 crisis shows that the main component of the return in best carry of all is the South African Rand, ZAR, which is not included in the G10 currencies. This might explain why the two portfolios have slightly different outcomes. Since the *Best Carry of All* does not seem to be as affected as the other investments, it could potentially be useful as an investment option, when the market faces larger fluctuations than normal. Although investing in a carry trade might seem to be quite a good investment even during certain crises, it still faces tail risk as well as negative skewness. The constantly low return in carry portfolios together with the negative skewness indicates that carry trade could be characterized as “picking up penny’s in front of a steam roller”.

7. Conclusion

With the constructed carry portfolio, *Best Carry of All,* an investor would have made small and consistent profits over the last 30 years. The original invested capital would have increased with a multiple of four, which is less than the *S&P500* and the *MOM2US*. On the other hand, those equity investments would have been exposed to larger risks.
Taking risks into account, the *Best Carry of All* offered a better investment opportunity compared to all other portfolios, except the *S&P500* from 1990-2020 considering the Sharpe ratios. The American Carry portfolio did not perform as well as the *Best Carry of All* and suffers from severe losses at times, which are not present for the chief dealer back trade portfolio to the same extent. These crashes often occur at the same time as the equity market crashes. The results show that the *Best Cary of All* does not crash severely during turbulent times, as the equity investments and the American Carry trade do. As the portfolio *Best Carry of All* does not crash during turbulent times it could be a good complement to an investor's portfolio, since it manages to provide small and steady returns even during distressed periods. In addition, this thesis observes a clear pattern of positively related movements between the LIBOR rate and excess carry returns.

What could be observed from the results is that the carry trades seem to have been affected by the low-interest rate level. During the last few years carry trades have not been as profitable as before. The reason behind this could be the lower interest rates restricting the possibility to find large interest rate differentials. Even though such a pattern has been observed no suitable tests have been made in this thesis, hence it cannot be concluded that such a relationship exists. Extending this thesis with such a test would maybe help to explain the observed pattern.
As mentioned in the analysis, it would be interesting to make a deeper analysis into what causes the American portfolio to crash and why this trait is not as present in the *Best Carry of All*. Further investigations in respect of this would be of great interest since it could potentially be used to detect and avoid such events. It could also be of interest to look deeper into what types of currencies that are included in the portfolio and how the portfolio characteristics change if the currencies are exchanged. Further research with a larger data set, consisting of more than nine currencies, is encouraged to get a better understanding of the less frequently traded currencies. Furthermore, dividing the data set into even narrower periods could show an even more detailed view of how the carry trades performs during turbulent times.

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Appendix

A.1 to A.3 are the tests conducted to choose which of the portfolios from the AQR data set to include.

A.1 Momentum FX

t-Test: Two-Sample Assuming Equal Variances

	MOM1_VME_FX	*MOM2_VME_FX*
Mean	-0,000668168	0,000567191
Variance	0,000586935	0,000485073
Observations	376	376
Pooled Variance	0,000536004	
Hypothesized Mean Difference	0	
df	750	
t Stat	-0,731623839	
P(T<=t) one-tail	0,232313363	
t Critical one-tail	1,646887846	
P(T<=t) two-tail	0,464626725	
t Critical two-tail	1,963132037	

F-Test Two-Sample for Variances

	MOM1_VME_FX	*MOM2_VME_FX*
Mean	-0,000668168	0,000567191
Variance	0,000586935	0,000485073
Observations	376	376
df	375	375
F	1,209992493	
P(F<=f) one-tail	0,032665141	

F Critical one-tail	1,185417857

t-Test: Two-Sample Assuming Equal Variances

	MOM1_VME_FX	*MOM3_VME_FX*
Mean	-0,000668168	0,001032247
Variance	0,000586935	0,000533536
Observations	376	376
Pooled Variance	0,000560235	
Hypothesized Mean Difference	0	
df	750	
t Stat	-0,985028227	
P(T<=t) one-tail	0,162463931	
t Critical one-tail	1,646887846	
P(T<=t) two-tail	0,324927863	
t Critical two-tail	1,963132037	

F-Test Two-Sample for Variances

	MOM1_VME_FX	*MOM3_VME_FX*
Mean	-0,000668168	0,001032247
Variance	0,000586935	0,000533536
Observations	376	376
df	375	375
F	1,100086101	
P(F<=f) one-tail	0,178054568	
F Critical one-tail	1,185417857	

t-Test: Two-Sample Assuming Equal Variances

	MOM2_VME_FX	*MOM3_VME_FX*

Mean	0,000567191	0,001032247
Variance	0,000485073	0,000533536
Observations	376	376
Pooled Variance	0,000509305	
Hypothesized Mean Difference	0	
df	750	
t Stat	-0,282550535	
P(T<=t) one-tail	0,38879968	
t Critical one-tail	1,646887846	
P(T<=t) two-tail	0,777599361	
t Critical two-tail	1,963132037	

F-Test Two-Sample for Variances

	MOM2_VME_FX	*MOM3_VME_FX*
Mean	0,000567191	0,001032247
Variance	0,000485073	0,000533536
Observations	376	376
df	375	375
F	0,909167708	
P(F<=f) one-tail	0,178465027	
F Critical one-tail	0,84358439	

A.2 Momentum Equity US

t-Test: Two-Sample Assuming Equal Variances

	MOM1US	*MOM2US*
Mean	0,004714873	0,006391541
Variance	0,002732727	0,00146267
Observations	375	375
Pooled Variance	0,002097699	
Hypothesized Mean Difference	0	
df	748	
t Stat	-0,50127531	
P(T<=t) one-tail	0,308162433	
t Critical one-tail	1,646893292	
P(T<=t) two-tail	0,616324866	
t Critical two-tail	1,963140521	

F-Test Two-Sample for Variances

	MOM1US	*MOM2US*
Mean	0,004714873	0,006391541
Variance	0,002732727	0,00146267
Observations	375	375
df	374	374
F	1,868314273	
P(F<=f) one-tail	1,03827E-09	
F Critical one-tail	1,185687957	

t-Test: Two-Sample Assuming Equal Variances

	MOM1US	*MOM3US*

Mean	0,004714873	0,008595349
Variance	0,002732727	0,002184106
Observations	375	375
Pooled Variance	0,002458417	
Hypothesized Mean Difference	0	
df	748	
t Stat	- 1,071662287	
P(T<=t) one-tail	0,142108694	
t Critical one-tail	1,646893292	
P(T<=t) two-tail	0,284217388	
t Critical two-tail	1,963140521	

F-Test Two-Sample for Variances

	MOM1US	*MOM3US*
Mean	0,004714873	0,008595349
Variance	0,002732727	0,002184106
Observations	375	375
df	374	374
F	1,251187903	
P(F<=f) one-tail	0,015263872	
F Critical one-tail	1,185687957	

t-Test: Two-Sample Assuming Equal Variances

	MOM2US	*MOM3US*
Mean	0,006391541	0,008595349
Variance	0,00146267	0,002184106
Observations	375	375
Pooled Variance	0,001823388	
Hypothesized Mean Difference	0	

df	748
	-
t Stat	0,706699568
P(T<=t) one-tail	0,239986638
t Critical one-tail	1,646893292
P(T<=t) two-tail	0,479973277
t Critical two-tail	1,963140521

F-Test Two-Sample for Variances

	MOM2US	*MOM3US*
Mean	0,006391541	0,008595349
Variance	0,00146267	0,002184106
Observations	375	375
df	374	374
F	0,669688136	
P(F<=f) one-tail	5,63478E-05	
F Critical one-tail	0,843392221	

A.3 NON-US Equities

t-Test: Two-Sample Assuming Equal Variances

	MOM1_VME_EQ	*MOM2_VME_EQ*
Mean	0,002075777	0,004609044
Variance	0,002274275	0,001897295
Observations	376	376
Pooled Variance	0,002085785	
Hypothesized Mean Difference	0	
df	750	
t Stat	-0,76054532	
P(T<=t) one-tail	0,223583859	
t Critical one-tail	1,646887846	
P(T<=t) two-tail	0,447167717	
t Critical two-tail	1,963132037	

F-Test Two-Sample for Variances

	MOM1_VME_EQ	*MOM2_VME_EQ*
Mean	0,002075777	0,004609044
Variance	0,002274275	0,001897295
Observations	376	376
df	375	375
F	1,198693664	
P(F<=f) one-tail	0,039851813	
F Critical one-tail	1,185417857	

t-Test: Two-Sample Assuming Equal Variances

	MOM1_VME_EQ	*MOM3_VME_EQ*
Mean	0,002075777	0,006536489
Variance	0,002274275	0,001982734
Observations	376	376
Pooled Variance	0,002128504	
Hypothesized Mean Difference	0	
df	750	
t Stat	-1,325701665	
P(T<=t) one-tail	0,092671088	
t Critical one-tail	1,646887846	

F-Test Two-Sample for Variances

	MOM1_VME_EQ	*MOM3_VME_EQ*
Mean	0,002075777	0,006536489
Variance	0,002274275	0,001982734
Observations	376	376
df	375	375
F	1,147040117	
P(F<=f) one-tail	0,092273948	
F Critical one-tail	1,185417857	

P(T<=t) two-tail	0,185342176	
t Critical two-tail	1,963132037	

t-Test: Two-Sample Assuming Equal Variances

	MOM2_VME_EQ	*MOM3_VME_EQ*

Mean	0,004609044	0,006536489
Variance	0,001897295	0,001982734
Observations	376	376
Pooled Variance	0,001940014	
Hypothesized Mean Difference	0	
df	750	
t Stat	-0,600009931	
P(T<=t) one-tail	0,274340427	
t Critical one-tail	1,646887846	
P(T<=t) two-tail	0,548680853	
t Critical two-tail	1,963132037	

F-Test Two-Sample for Variances

	MOM2_VME_EQ	*MOM3_VME_EQ*
Mean	0,004609044	0,006536489
Variance	0,001897295	0,001982734
Observations	376	376
df	375	375
F	0,956908468	
P(F<=f) one-tail	0,334985794	
F Critical one-tail	0,84358439	

A.4 Summary Statistics

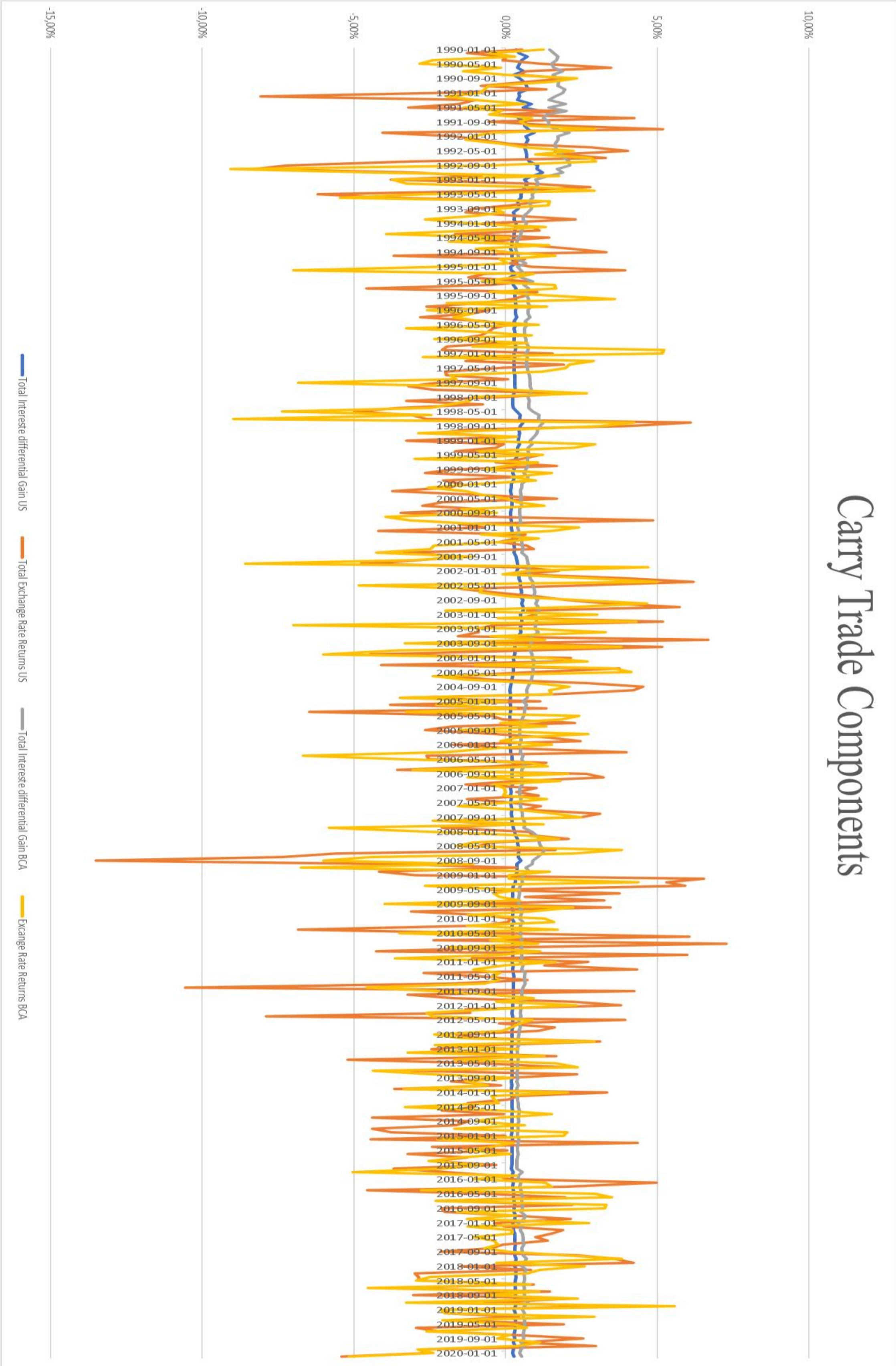
Descriptive Statistics	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
Mean	0,0008022	0,006067052	0,004564234	0,008362065	0,000974409	0,004047659	-0,002797974	-0,0033982
Standard Error	0,001145627	0,002022236	0,0022585	0,002186416	0,001446279	0,001288408	0,00148104	0,00126687
Median	0,000704571	0,009526554	0,009851754	0,012910858	0,000864641	0,005069538	-0,003124416	-0,001753
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Standard Deviation	0,021797043	0,038475669	0,042970885	0,041599403	0,027517326	0,024513629	0,028178715	0,024103838
Sample Variance	0,000475111	0,001480377	0,001846497	0,00173051	0,000757203	0,000600918	0,00079404	0,000580995
Kurtosis	1,391067827	1,534847538	1,229783995	1,328720066	1,83990594	0,738463002	1,611124929	1,063323791
Skewness	-0,215006349	-0,568327568	-0,597072612	-0,663445705	-0,343879682	-0,452145227	-0,33817149	-0,571556645
Range	0,169009079	0,274085626	0,301290182	0,282306698	0,205116325	0,14075577	0,207793967	0,146291282
Minimum	-0,096395023	-0,155150019	-0,151087705	-0,167950619	-0,129796541	-0,078575005	-0,134944267	-0,090507689
Maximum	0,072614055	0,118935607	0,150202477	0,114356079	0,075319784	0,062180766	0,0728497	0,055783593
Sum	0,290396334	2,196272767	1,652252788	3,027067423	0,352735879	1,465252659	-1,0128667	-1,23014858
Count	362	362	362	362	362	362	362	362

Descriptive Statistics	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
Mean	0,003671409	-0,002360463	0,000138686	0,002086802	0,005034972	0,006610975	0,001943105	-0,000929648
Standard Error	0,002631006	0,004549735	0,005600539	0,00542089	0,003182495	0,003314947	0,003165197	0,00325923
Median	0,002787282	-0,000109809	0,003906145	0,006637861	0,001630454	0,007274509	-0,001325518	-0,00053133
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Standard Deviation	0,02232483	0,038605779	0,047522145	0,045997781	0,027004368	0,028128257	0,026857586	0,027655483
Sample Variance	0,000498398	0,001490406	0,002258354	0,002115796	0,000729236	0,000791199	0,00072133	0,000764826
Kurtosis	-0,418138212	0,179385813	0,04774656	-0,354085997	-0,142317116	0,338329901	-0,193731057	0,494353656
Skewness	0,345491714	0,087177778	-0,391914372	-0,171933578	0,441874581	-0,428943408	0,42785966	-0,527585304
Range	0,096651161	0,196090262	0,227593547	0,2065145	0,114073718	0,137151356	0,114271172	0,135484748
Minimum	-0,037713413	-0,08848642	-0,13341498	-0,108685989	-0,043484452	-0,07824538	-0,047477015	-0,085594997
Maximum	0,058937748	0,107603842	0,094178567	0,097828511	0,070589265	0,058905976	0,066794157	0,049889751
Sum	0,264341473	-0,169953345	0,009985421	0,15024971	0,362517982	0,475990164	0,139903548	-0,066934638
Count	72	72	72	72	72	72	72	72

Descriptive Statistics 2013-2020	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
Mean	-0,002429372	0,010587	0,007900284	0,010786	-0,00332351	0,002084627	-0,005978239	-0,00300367
Standard Error	0,00188379	0,0036451	0,003592891	0,003592	0,002590907	0,002313266	0,002579368	0,002301471
Median	-0,004244752	0,0168711	0,012355252	0,016165	-0,00242312	0,002632084	-0,005759892	-0,002579735
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Standard Deviation	0,017469554	0,0338029	0,033319099	0,033312	0,024027079	0,021452345	0,023920075	0,021342963
Sample Variance	0,000305185	0,0011426	0,001110162	0,00111	0,000577301	0,000460203	0,00057217	0,000455522
Kurtosis	0,013347635	1,1429402	1,236867146	1,093935	-0,62290458	-0,050966527	-0,620963399	-0,086146711
Skewness	0,54624267	-0,850739	-0,865856367	-0,69004	0,181462933	0,103137816	0,181375414	0,066328127
Range	0,080893403	0,1752168	0,180556476	0,174644	0,103385359	0,108203457	0,103623618	0,107171942
Minimum	-0,03121556	-0,094977	-0,099513869	-0,09029	-0,0511111	-0,046022691	-0,053923997	-0,051388349
Maximum	0,049677843	0,0802397	0,081042607	0,084355	0,052274259	0,062180766	0,049699621	0,055783593
Sum	-0,208926025	0,9104827	0,679424444	0,92756	-0,28582199	0,179277959	-0,514128546	-0,258315639
Count	86	86	86	86	86	86	86	86

Descriptive Statistics	MOM2_VME_FX	MOM2US	MOM2_VME_EQ	S&P500	US Carry	Best Carry of All	Exchange Rate Returns from US Carry	Exchange Rate Returns from Best Carry of All
Mean	0,003629467	0,004084563	0,00299434	0,004529916	0,001880342	0,001050862	-0,000676632	-0,004899145
Standard Error	0,003085376	0,004829699	0,005127204	0,005228745	0,003857553	0,002450984	0,003908255	0,002442198
Median	0,00495582	0,009526554	0,008194928	0,012701086	0,000684723	0,004125409	0,001676219	-0,001443574
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Standard Deviation	0,028277941	0,044264918	0,046991601	0,04792224	0,03535506	0,022463643	0,035819751	0,022383112
Sample Variance	0,000799642	0,001959383	0,002208211	0,002296541	0,00124998	0,000504615	0,001283055	0,000501004
Kurtosis	1,565932695	1,396143543	1,436196958	1,376871726	2,251511285	0,621269315	2,215600505	0,66953139
Skewness	-0,667683624	-0,669295109	-0,412309475	-0,729172229	-0,824526451	-0,622132871	-0,839613571	-0,726811603
Range	0,169009079	0,252749704	0,298947352	0,27724267	0,205116325	0,112038282	0,207793967	0,111149634
Minimum	-0,096395023	-0,154524593	-0,148744875	-0,167950619	-0,129796541	-0,060716293	-0,134944267	-0,067372999
Maximum	0,072614055	0,098225111	0,150202477	0,109292051	0,075319784	0,051321989	0,0728497	0,043776635
Sum	0,304875246	0,343103292	0,251524547	0,380512973	0,157948768	0,088272427	-0,056837066	-0,411528213
Count	84	84	84	84	84	84	84	84

A.5 Carry Trade Components



A.6 UIP violation significance tests

One-sample t test 2013-2020

```
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
 USCarry |      86   -.0033235    .0025909    .0240271   -.0084749    .0018279
------------------------------------------------------------------------------
    mean = mean(USCarry)                                          t =  -1.2828
Ho: mean = 0                                     degrees of freedom =       85

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 0.1015         Pr(|T| > |t|) = 0.2031          Pr(T > t) = 0.8985

------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
BestCa~l |      86    .0020846    .0023133    .0214523   -.0025148     .006684
------------------------------------------------------------------------------
    mean = mean(BestCarryofAll)                                   t =   0.9012
Ho: mean = 0                                     degrees of freedom =       85

    Ha: mean < 0                 Ha: mean != 0                 Ha: mean > 0
 Pr(T < t) = 0.8150         Pr(|T| > |t|) = 0.3700          Pr(T > t) = 0.1850
```

One-sample t test 2006-2012

```
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
 USCarry |      84    .0018803    .0038576    .0353551   -.0057922    .0095529
------------------------------------------------------------------------------
    mean = mean(USCarry)                                          t =   0.4874
Ho: mean = 0                                     degrees of freedom =       83
```

Ha: mean < 0 Ha: mean != 0 Ha: mean > 0

Pr(T < t) = 0.6864 Pr(|T| > |t|) = 0.6272 Pr(T > t) = 0.3136

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
BestCa~l	84	.0010509	.002451	.0224636	-.003824	.0059258

mean = mean(BestCarryofAll) t = 0.4288

Ho: mean = 0 degrees of freedom = 83

Ha: mean < 0 Ha: mean != 0 Ha: mean > 0

Pr(T < t) = 0.6654 Pr(|T| > |t|) = 0.6692 Pr(T > t) = 0.3346

One-sample t test 1999-2004

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
USCarry	72	.005035	.0031825	.0270044	-.0013107	.0113807

mean = mean(USCarry) t = 1.5821

Ho: mean = 0 degrees of freedom = 71

Ha: mean < 0 Ha: mean != 0 Ha: mean > 0

Pr(T < t) = 0.9410 Pr(|T| > |t|) = 0.1181 Pr(T > t) = 0.0590

Variable	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
BestCa~l	72	.006611	.0033149	.0281283	1.16e-06	.0132208

mean = mean(BestCarryofAll) t = 1.9943

Ho: mean = 0 degrees of freedom = 71

Ha: mean < 0 Ha: mean != 0 Ha: mean > 0

Pr(T < t) = 0.9750 Pr(|T| > |t|) = 0.0500 Pr(T > t) = 0.0250

One-sample t test 1990-2020

```
------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
 USCarry |     362    .0009744    .0014463    .0275173   -.0018698    .0038186
------------------------------------------------------------------------------
    mean = mean(USCarry)                                  t =   0.6737
Ho: mean = 0                                 degrees of freedom =      361

    Ha: mean < 0               Ha: mean != 0               Ha: mean > 0
 Pr(T < t) = 0.7495         Pr(|T| > |t|) = 0.5009          Pr(T > t) = 0.2505

------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
BestCa~l |     362    .0040477    .0012884    .0245136    .0015139    .0065814
------------------------------------------------------------------------------
    mean = mean(BestCarryofAll)                           t =   3.1416
Ho: mean = 0                                 degrees of freedom =      361

    Ha: mean < 0               Ha: mean != 0               Ha: mean > 0
 Pr(T < t) = 0.9991         Pr(|T| > |t|) = 0.0018          Pr(T > t) = 0.0009
```

A.7 Normality test

```
. import excel "C:\Users\thors\OneDrive\Desktop\stata 1990-2020.xlsx", sheet("S
. swilk USCarry
          Shapiro-Wilk W test for normal data

  Variable |      Obs      W          V        z       Prob>z
-----------+------------------------------------------------------
   USCarry |      362   0.97832    5.458    4.020    0.00003
          Shapiro-Wilk W test for normal data

  Variable |      Obs      W          V        z       Prob>z
-----------+------------------------------------------------------
BestCarryo~l |      362   0.98293    4.299    3.454    0.00028

. import excel "C:\Users\thors\OneDrive\Desktop\stata 1999-2004.xlsx", sheet("S
          Shapiro-Wilk W test for normal data

  Variable |      Obs      W          V        z       Prob>z
-----------+------------------------------------------------------
   USCarry |       72   0.97468    1.594    1.016    0.15477
          Shapiro-Wilk W test for normal data

  Variable |      Obs      W          V        z       Prob>z
-----------+------------------------------------------------------
BestCarryo~l |       72   0.98165    1.156    0.315    0.37630

. import excel "C:\Users\thors\OneDrive\Desktop\stata 2006-2012.xlsx", sheet("S
          Shapiro-Wilk W test for normal data

  Variable |      Obs      W          V        z       Prob>z
-----------+------------------------------------------------------
   USCarry |       84   0.95065    3.526    2.769    0.00282
          Shapiro-Wilk W test for normal data

  Variable |      Obs      W          V        z       Prob>z
-----------+------------------------------------------------------
BestCarryo~l |       84   0.96487    2.510    2.022    0.02159

. import excel "C:\Users\thors\OneDrive\Desktop\stata 2013-2020.xlsx", sheet("S
          Shapiro-Wilk W test for normal data

  Variable |      Obs      W          V        z       Prob>z
-----------+------------------------------------------------------
   USCarry |       86   0.98366    1.191    0.384    0.35056
          Shapiro-Wilk W test for normal data

  Variable |      Obs      W          V        z       Prob>z
-----------+------------------------------------------------------
BestCarryo~l |       86   0.99451    0.400   -2.014    0.97801
```

A.8 Interest spread and LIBOR