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Getting the Carry Trade's Jackpot: Finding Indicators of Carry Crash

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Abstract

This Working Project studies five portfolios of currency carry trades formed with the G10 currencies. Performance varies among strategies and the most basic one presents the worst results. I also study the equity and Pure FX risk factors which can explain the portfolios' returns. Equity factors do not explain these returns while the Pure FX do for some of the strategies. Downside risk measures indicate the importance of using regime indicators to avoid losses. I conclude that although using VAR and threshold regression models with a variety of regime indicators do not allow the perception of different regimes, with a defined exogenous threshold on real exchange rates, an indicator of liquidity and the volatilities of the spot exchange rates it is possible to increase the average returns and reduce drawdowns of the carry trades.

Keywords: Carry Trade, G10 currencies, Drawdown Analysis, Regime Indicators

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I. Introduction

This Working Project explores several questions related to the currency carry trade arbitrage strategy. Firstly, it is studied whether the strategy is profitable or not, especially, after the event of the 2008 global financial crisis. In order to do this, five portfolios of the G10 currencies with different weighting strategies used among literature and by practitioners are investigated. Secondly, the latest literature emphasizes the tail and downside risks intrinsic to the strategy and, thus, several measures of downside risk and, specifically, a drawdown analysis is performed. At last, the final purpose of this work is answering to the following two questions: are there any regime indicator variables that allow to consistently predict a drawdown on the strategy? How can an investor use these regime indicators to improve his final payoff?

To begin with, in financial terms an asset's "carry" is equal to the returns (positive carry) or the costs (negative) of holding such asset, assuming its price does not change. In that sense, it is possible to break down a security's return into three components: the carry, its expected and unexpected price appreciation.[1] Moreover, when "carry trade" is mentioned one is referring to a strategy composed by two or more offsetting positions on an asset's class, where some securities are returning a positive cash-flow while others constitute a liability. This strategy can be exploited over a variety of classes such as global equities and bonds, Treasuries, index options, currencies and commodities. Nevertheless, its most widespread application is on currencies, which is known as the "currency carry trade" and it is argued to date back to the 80's.

In the currency carry trade an investor borrows in a country with a low interest rate and invests in another with high interest rate, gaining the carry this way. Therefore, such

[1] Explanation from Koijen et al. (2013)

strategy has been presenting high returns and long-run Sharp ratios over time, despite recent losses. Additionally, the most puzzling question is that it is based on an international economics' hypothesis known as the uncovered interest rate parity (UIP) which states that nominal interest rate differentials between countries have a direct relationship with market's expectations of exchange rates' changes. That is, in accordance with the UIP a high-yield currency should depreciate by the size of the interest rates' differential, thus, leading to capital losses that would fully offset the gains from the yield advantage. In that sense, consider for instance the most popular pair for the carry trade in recent years: the Japanese yen as funding currency and the Australian dollar as investment currency. Let us consider that the yield in Australia was 6% higher than in Japan in 2007, and then the AUD/JPY spot exchange was expected to depreciate 6% over the next year. However, empirical studies starting from 1980 have consistently proven this wrong as on average the subsequent currency depreciation did not completely offset the carry from the interest rate differential. Finally, this finding is known as the "forward rate bias" as a result of the rejection of the expectations theory hypothesis.

Furthermore, when undergoing a currency carry trade it is preferable to analyze currencies that are not under foreign exchange controls by their governments nor exposed to a low probability of default, which is a risk that an investor is usually not willing to take in this strategy since the only risk he accepts to face is the exchange rate risk. Thus, since the returns for the strategies using the G10 countries remained high until the beginning of the 2008 global financial crisis and the default risk is much lower than in emerging markets the general approach when studying the currency carry trade it is preferred to use a basket of these G10 currencies. In addition, most of the studies use a timespan starting after 1973 due to the collapse of the Bretton Woods system

when the major currencies began to float against each other. Hence, studies have shown that by investing in this strategy an investor can obtain high average returns ranging from 3,96% in basic strategies to 6,60% in more complex ones, when considering a time range of 1976-2013.[2] In that sense, in this Working Project it is intended to investigate the results of several carry trade strategies and the evolution of their performance. Additionally, it is commonly stated that the carry trade strategy was not profitable after the 2008 financial crisis or that the strategy "is not dead but resting"[3]. Taking this into consideration, attention is devoted to a comparison of the results between the pre- and post-crisis periods.

Furthermore, after finding that UIP did not hold on average, researchers focused their attention on the risk factors explaining the currency carry trade returns. Nevertheless, returns from different carry trade strategies have hardly been explained by traditional risk factors, thus, leaving it as a puzzle. Hence, due to the long list of studies on these risk factors in the literature, it was preferred not to emphasize this aspect of the carry trade presenting merely a short analysis of the latter.

Lately, recent studies have focused on an apparent downside of the strategy which is the negative skewness inducing large drawdowns. This pattern has been named as "up by the stairs, down by the elevator" or "picking up nickels in front of a steam roller".[4] Aiming at understanding this component of the carry trade, it was decided to dedicate one chapter of this Working Project to the analysis of four indicators of downside risk.

[2] These are the results of both the EQ and SPW weighting strategies presented in Daniel et al. (2014)
[3] On the 15th of January of 2013, Jame Mackintosh wrote on Financial Times and article with the time: "Carry trade strategy not dead but resting".
[4] Expression used by Breedon (2001) and the economist in 2007, respectively.

In conclusion, as these large drawdowns are related to the "carry crashes", its timing is known to be the "jackpot question of the carry trade".[5] Contrary to the investigation of risk factors explaining the carry trade returns, only a few studies explore the hypothesis of using regime indicators to improve the returns of the strategy. Thus, the present Working Project's final purpose is to find the regime indicator variables which can used to forecast and avoid the carry crashes and, therefore, improve the strategy's profitability.

The following text is organized as it follows: in chapter II a brief Literature Review is presented, while in chapter III an explanation on the construction of the carry trade strategies is presented. Chapter IV presents all the sources for the data used in this Working Project and leads to chapter V where the results of the strategies are commented. Successively, chapters VI and VII show the study of the traditional and the downside risk factors, respectively. Finally, in chapter VIII the regime indicator analysis is studied and in chapter IX the conclusions are displayed.

II. Literature Review

The studies on the failure of the interest rate parity hypothesis are agreed to have started in the late 70's or more specifically in the 80's with papers such as Hansen and Hodrick (1980) where the market efficiency hypothesis for exchange rates is rejected for a period of 50 years before the 1970's. Also, Fama (1984) presents results where the reverse effect expressed by the UIP is verified. Moreover, Daniel et al. (2014) explores four different approaches on the rejection of the unbiasedness of forward rates. Nevertheless, recent literature has focused on two of these explanations: the equilibrium risk premium in the forecastability of the difference between forward rates and future

[5] Expression used by A. Ilmanen in his book "Expected Returns: An Investor's Guide to Harvesting Market Rewards" of 2011.

spot rates (e.g. Hansen and Hodrick (1983)); and in the presence of peso problems which leads to powerless econometric models (e.g. Krasker (1980)).

Simple carry trade strategies have historically presented high average returns and Sharpe ratios as shown in Burnside (2012). Furthermore, more complex strategies determining the weights on a basket of currencies as studied in Daniel et al. (2014) improve the carry trade's performance. Other common strategy is known as High-minus-Low where the investor holds a long position in a number of high-yield currencies while shorting the same number of low-yield.[6] Another way of applying the latter strategy is by using portfolios of currencies instead of a single currency as it was firstly explained in Lustig and Verdelhan (2007).

Risk explanations to the high returns fall into many categories from traditional risk factors to the mentioned "peso problems". The traditional risk factors usually include the Fama and French 3-factor model (1993) as it was used in Burnside (2012) and Daniel et al. (2014). Additionally, Lustig, Roussanov and Verdelhan (2011) use the return on the highest minus the return on the lowest interest rate currency portfolios to explain the cross-sectional variation in average currency excess returns from low to high interest rate currencies. Exchange rate volatility, likewise, seems to be one of the most important factors explaining the risk of carry trade strategies as it is argued that the global FX volatility risk captures more than 90% of the cross-sectional excess returns in five carry trade portfolios in Menkhoff et al. (2012). Also Christiansen, Ranaldo and Söderlind (2011) use FX volatility to explain carry trade abnormal returns. Moreover, another suggested risk indicator in the literature is consumption growth proposed in Lustig and Verdelhan (2007) while using a CCAPM model. More recently Jurek and Xu

[6] Strategy presented in A. Ilmanen's book and used in "*Deutsche Bank G10 Currency Harvest Fund".*

(2013) use options in the currency market to show that option-implied currency risk premia provide an unbiased forecast of monthly currency excess returns.

In addition, a common global risk indicator is also popular among researchers having been proposed by Dahlquist and Hasseltoft (2013) who used the US bond risk premia and demonstrated it to be related to international business cycles. On the other hand, Lustig, Roussanov and Verdelhan (2011) construct a slope "factor" in a model with a country specific and global factors which is related to changes in the global equity market volatility and which identifies common shocks. The equity market returns are also a competitive risk explanation as Campbell et al. (2010) found that many currencies in particular the Australian dollar, Canadian dollar, Japanese yen, and British pound are positively correlated with world stock markets while the euro, the Swiss franc, and the bilateral US-Canadian exchange rate are negatively correlated with the world equity market. Alternatively, Corcoran (2009) demonstrate a correlation between carry trades and target-country equity markets' returns which is negative for high interest rate currencies and positive for low interest rate currencies.

Finally, recent studies have focused on the "peso problems" and more specifically in the downside risks of the carry trade. Farhi et al. (2015) argue that the carry trade is exposed to rare crash states in which high interest rate currencies depreciate. Adding to this, Brunnermeier et al. (2009) claim that carry trades are subject to crash risk where exchange rate movements between high-interest-rate and low-interest-rate currencies are negatively skewed while pointing out that this is due to sudden unwinding of carry trades, which tend to occur in periods where risk appetite and funding liquidity decrease. Also, Gyntelberg and Schrimpf (2011) while studying short-term multicurrency strategies such as the carry trade demonstrate that these strategies exhibit substantial tail risks and that they do not perform regularly during periods of financial

distress in global markets. Still, the authors find that there is an even greater downside risk in equity market investments.

Lastly, recent work has been developed on the hedged carry trade using exchange rate options. Burnside et al. (2011) shows in a clear way how to construct such portfolios, however, despite obtaining a positive skew it yields much lower average returns and Sharpe ratio. Other examples of the hedged carry trade strategy are Caballero and Doyle (2012) who affirm that hedge carry trades with exchange rate options present large return which are not explained by incurring in systemic risk; as well as, Jurek (2013) where by constructing crash-hedged portfolios he shows that peso problems do not explain carry trades' high returns.

III. The Carry Trade portfolios implementation

In this section, the notation and theoretical background that is necessary to proceed to the empirical analysis of the carry trades will be presented. Thereafter, it is shown the procedures to construct the different strategies to be discussed. Let S_t be the level of the exchange rate of dollars per unit of a foreign currency, while F_t. is the forward exchange rate known today for the exchange of currencies one period-ahead. At the same time, the one-period dollar interest rate is represented by $i_t^{\$}$ and let the one-period foreign currency interest rate be i_t^*.

The carry trade involves the lending of a high-interest rate currency by borrowing a low-interest rate currency. It follows the failure of the UIP in the sense that if the exchange rate between two countries does not evaluate or depreciate in order to offset the interest rate differential between the latter, there will be an arbitrage opportunity. Consider below the UIP:

$$\text{UIP: } \left(1 + i_t^{\$}\right) = \frac{E(S_{t+1})}{S_t}\left(1 + i_t^{*}\right) \tag{1}$$

Therefore, the typical studied strategy in the literature is the one where an investor takes a long (short) position in each currency for which the interest rate is higher (lower) than the interest rate in the United States. This strategy is applied when the investor borrows or lends in the money market and, thus, the dollar payoff to the carry trade in the absence of transaction costs is written as such:

$$z_{t+1} = \left[\left(1 + i_t^{*}\right)\frac{S_{t+1}}{S_t} - \left(1 + i_t^{\$}\right)\right] y_t \tag{2}$$

where the position the investor takes in each currency (y_t) is:

$$y_t = \begin{cases} +1 \text{ if } i_t^{*} > i_t^{\$} \\ -1 \text{ if } i_t^{*} < i_t^{\$} \end{cases} \tag{3}$$

Alternatively, an investor can enter in a carry trade strategy by borrowing or investing one dollar in the foreign currency money market. Consider that when the covered interest rate parity holds, if $i_t^{*} > i_t^{\$}$ then $F_t < S_t$, that is, the foreign currency is at a discount in the forward market. On the other hand, if $i_t^{*} < i_t^{\$}$ then $F_t > S_t$ and, thus, the foreign currency is at a premium in the forward market. Therefore, it is also possible to develop a carry trade strategy by entering in a long (short) position in the forward exchange market when the foreign currency is at a discount (premium) in comparison to the dollar. Finally, the dollar payoff to this strategy is as it follows:

$$z_{t+1} = \left[\frac{(S_{t+1} - F_t)}{F_t} \times \left(1 + i_t^{\$}\right)\right] y_t \tag{4}$$

where the position the investor takes (y_t) is:

$$y_t = \begin{cases} +1 \text{ if } F_t < S_t \\ -1 \text{ if } F_t > S_t \end{cases} \quad (5)$$

It is worth to notice that when the covered interest parity holds and without transaction costs, both strategies for the implementation of the carry trade are exactly equivalent. The former seems to have been realized until the onset of the financial crisis in August 2007, according to Coffey et al. (2009). Although, different liquidity conditions in the interest rates and forward exchange markets might dictate higher transaction costs. If the uncovered interest rate parity holds and the forward rates are unbiased, the carry trade profits should average to zero. Still, recall that the definition of the uncovered interest rate parity ignores that the changes in the values of currencies may be exposed to risk factors and, therefore, in this situation a risk premium is observed. Thus, the general procedure to incorporate risk aversion in arbitrage models is to examine the stochastic discount factor (SDF) or pricing kernels.

3.1 Stochastic Discount Factors (SDF) and the Arbitrage Asset Pricing

In order to confirm the fundamentals of no-arbitrage pricing it must be verified that there is a dollar stochastic discount factor, M_{t+1}, that prices the nominal USD denominated excess returns, Z_{t+1}. Furthermore, since the carry trades under study are zero-investment strategies, the no-arbitrage condition is:

$$E_t(M_{t+1} \times Z_{t+1}) = 0 \quad (6)$$

Recalling the covariance composition and applying it to the previous equation it is derived:

$$E_t(Z_{t+1}) = -\frac{Cov(M_{t+1}, Z_{t+1})}{E_t(M_{t+1})} \quad (7)$$

The analysis of the previous equation is highly important in order to study whether there are risk factors capable of explaining the carry trades returns and, thus, producing a stochastic discount factor that will prove the no-arbitrage condition previously specified. In section VI, I will present some candidate risk factors. For a longer explanation on the SDF methodology refer to Burnside (2012), while Menkhoff et al. (2012) develops an explanation on the econometric procedures to follow in the risk factors' regression.

3.2. Constructing the carry trade strategies

In this part of this study it will be presented the five carry trade portfolios with different weighting strategies. Carry trades have been popular for a long time, which led investors to develop different strategies on how to be exposed to each currency. This exposition to each currency is defined by the weight that is allocated to the currency and the most popular is the equally weighted (EW) in that the weights are equal for every currency, where N is the number of available currencies at the period t:

$$w_{j,t}^{EW} = \frac{\text{sign}(i_t^j - i_t^\$)}{N} \tag{8}$$

However, it may be that an investor wants to take more speculative positions in each currency at a time since the positions of the previous strategy tend to be much lower. In order to do it, he can use one carry trade strategy suggested in Daniel et al. (2014) which the authors name as speed-weighting (SPW). The idea is that "the fraction of a dollar invested in a particular currency is determined by the interest differential divided by the sum of the absolute values of the interest differentials". Therefore, this strategy privileges currencies with larger interest rates' differentials while at the same time

allowing the investment to be scaled such that there is one dollar spread across the long and short positons. Therefore, the weights are as it follows:

$$w_{j,t}^{SPW} = \frac{i_t^j - i_t^\$}{\sum_{j=1}^{N_t} |i_t^j - i_t^\$|} \tag{9}$$

Additionally, another common strategy comes by hedging the exchange risk on the EW strategy by acquiring (selling) forward exchange rate contracts on a currency when entering a long (short) position on that currency, accordingly. In that sense, at t+1 the investor is still exposed to the currency value (S_{t+1}) but now the value he holds of the same currency is not the investment in terms of S_t but in F_t. Finally, it is important to keep in mind that for the previous three strategies in a situation where the sum of the currency weights is not equal to 0, the dollar is used to made this correction. In order to perform such strategy I consider the same weights of EW but now the payoffs are as it follows:

$$z_{t+1} = \left[(1 + i_t^*)\frac{S_{t+1}}{F_t} - \left(1 + i_t^\$\right)\right] y_t \tag{10}$$

A different approach which also proved to be highly profitable is suggested by Lustig, Roussanov and Verdelhan (2014) and is called the "Dollar Carry Trade" since "investors go long all foreign currencies when the average foreign currency trades at a forward discount and short all foreign currencies when the average foreign currency trades is at a forward premium." Then, this position is balanced by the investment in the dollar by investing in the US interest rate. Moreover and contrarily to the remaining strategies with the intention of preserving the authors' results equation (4) is used instead of equation (2).

At last, Antti Ilmanen in his book "Expected Returns: An Investor's Guide to Harvesting Market Rewards" of 2011 presents a strategy which here will name as "rankings" once an investor should weight differently his positions on each currency depending on their ranking. That is, the three currencies with highest interest rate differentials will weight 50%, 30% and 20% respectively, while the three currencies with the lowest will have the following ponderations: -50%, -30% and -20%, accordingly. Notice however that for the periods when there is no data for 6 currencies the weights used were 50%, 30%, and their opposites.

3.3. Final strategy payoffs using the transaction costs

In the financial world many arbitrage strategies are known for presenting high returns, however, after accounting for the costs of implementing such strategies an investor perceives that there's no arbitrage opportunity after all. Hence, the consideration of the transaction costs when analyzing the carry trades is ultimately important. However, the discussion is broad in the literature and it is not trivial to choose a reasonable method of accounting the costs an investor is facing when entering his investment's positions.

A popular way to account for these costs and used by Lustig, Roussanov, Verdelhan (2011), as well as by Menkhoff et al. (2012) and by Barroso and Santa-Clara (2013) is to use the bid-ask spreads of the spot and forward exchange rates' prices. Nevertheless, Barroso and Santa-Clara (2013) offers a different costs' construction. This way possesses a problem in that it considers that the investor will be subject to the same costs when rolling his position on the currencies as when he changes this position. Darvas (2009) offers a method that consider these differences in the transaction costs.

Finally, Mancini et al. (2009) documented that frequent trades transact at better prices since they are not always executed at the posted bid or ask quotes. At last, Frazzini et al.

(2012) when studying the trading costs of asset pricing anomalies concludes that actual trading costs are less than a tenth as large as previously studies suggest for many arbitrage strategies.

In order to follow the literature and to obtain the most comparable results it was decided to follow the approach suggested by Lustig, Roussanov, Verdelhan (2011), which is also used in Burnside et al. (2011) just with the difference that the latter does not show this construction in logarithm values. For a more formal procedure I used the values in logarithms, where f_t corresponds to the natural logarithm of the forward exchange rate at time t and s_{t+1} represents the natural logarithm of the spot exchange rate at time t+1:

$$z_{t+1} = (f_t - s_{t+1})w_t \tag{11}$$

When including the transaction costs, the net log currency excess return for an investor who goes long in the foreign currency j is:

$$z_{j,t+1} = \left(f_t^{j\,b} - s_{t+1}^{j\;\;a}\right) \times w_{j,t}, \text{for } w_{j,t} > 0 \tag{12}$$

Under this situation the investor either buys the foreign currency or sells the dollar forward for the bid price in period t, while he sells the foreign currency or buys the dollars at the ask price at t+1 in the spot market. Conversely, if the signal for the strategy orders a different investment:

$$z_{j,t+1} = \left(f_t^{j\,a} - s_{t+1}^{j\;\;b}\right) \times w_{j,t}, \text{for } w_{j,t} < 0 \tag{13}$$

Here the investor can either sell the foreign currency or buy the dollar forward for the bid price in period t, while he buys the foreign currency or sells the dollars at the ask price at t+1 in the spot market.

Notice that one can easily transpose this result for the portfolios using interest rates since the investor when going long on an interest rate must pay the bid price, which is the maximum a buyer is willing to pay; while when shorting an interest rate j one receives the asked price, which is the minimum price a seller is willing to receive. For illustration, below I present the equation for when going long on a currency in the hedged EW strategy:

$$z_{j,t+1} = \ln\left(1 + i_t^{j\,b}\right) + s_{t+1}^{j} - \ln\left(f_t^{j\,b}\right) - \ln\left(1 + i_t^{\$\,a}\right) w_{j,t}, \text{for } w_{j,t} > 0 \quad (14)$$

IV. Data

All the data used to construct the carry trade strategies was obtained using Datastream. For the interest rates, exchange rates and forward exchange rates I used the Eurocurrency data. The analysis starts in February of 1976 but this data is not available for all the currencies from this moment. Due to data availability on the 1-month interest rates bid-ask spreads, the use of each currency in the portfolios using interest rates' differentials started from the beginning of the period for Canada, the Euro, Switzerland, UK and US; from 07/1978 for Japan; for Australia and New Zealand this period starts in 12/1989; and, finally, for Norway and Sweden in 02/1992. However, the dollar carry trade as it uses the 1-month forward rates had different starting dates for each currency: Canada, Norway, Sweden, Switzerland, UK and US are included from the beginning of the analysis; Japan is included from 08/1978; New Zealand from 07/1990 while Australia was from 01/1991 and, lastly, the Euro from its start in 01/1999.

Furthermore, as mostly read in the literature presented before I extend the values for the exchange rate based in dollars using the previous data available which was of a foreign currency unit based in GB's pounds. Note that until 2007 the 1 month forward exchange

rates used were the ones available from Thomson Reuters and similarly to the spot exchange rates they had to be converted from GB's pound to US dollars. From the period onwards the data obtained is delivered by Barclays, unless for the Euro which uses Barclays' values for its whole available period. In addition, when of constructing the EW-HF strategy the forward exchange rates are used to hedge the exchange rate risk as they become available. When using the interest rates and exchange rates I could find a series on Datastream for the Euro, however, when including bid-ask spread quality data was only obtained from its inception for strategies using forward exchange rates. It was decided not to include other currencies apart from the Euro (or the Deutsche mark from the period before its creation) due to the reasons explained in Daniel et al. (2014).

Additionally, for the risk factor analysis the data used is explained in the due section. Lastly, refer to Table 1 for a description of the data used for the regime indicators' analysis including the indicators used, the sources and dates.

V. Results of the Carry Trades

From the broad number of weighting strategies used in the carry trades it was chosen to analyze the results of five, which are explained in section 3.2: the equally-weighted (EW), the speed-weighting (SPW), the equally-weighted hedged by the forward exchange rate (EW-HF), the dollar carry trade and the rankings weighting strategy. Refer to Table 2 for the observation of the correspondent results.

Firstly, it is interesting to analyze how the different strategies yield so different results with average returns ranging from 6,90% to 3,26%, which show a similar dispersion when accounting for the transaction costs. with a range between 5,48% to 3,19% One can perceive that with and without transaction costs for the period under consideration the dollar carry-trade was the strategy with the best performance in terms of average

return (6,9%) which after transaction costs decreases by 1,4%. Nevertheless, considering the Sharpe ratio which is usually preferred due to taking into consideration the systemic risk, before transaction costs the EW-HF strategy would be preferable since it has a Sharpe ratio of 0,97 while the dollar carry trade shows one of 0,81. When accounting for the transaction costs the same situation persists as the former has a Sharpe of 0,80 while the later 0,64.

Additionally, it is interesting also to notice that after transaction costs the dollar carry trade does not show such a big gap in performance when related to the SPW since the latter now has simply 0,3% lower average returns (5,17%) than the dollar carry trade and a lower Sharpe ratio by simply 0,04 (0,60). Moreover, the rankings strategy which presents the second highest average returns before and after transaction costs of 5,49% and 5,33% shows at the same time the second lowest Shape ratios of 0,57 and 0,55, respectively. The last situation is due to the high volatility of the strategy since it only invests in a maximum of 6 currencies while from February of 1999 onwards all the others invest in 10, the date when the Euro is first used in the strategies using forward exchange rates.

Adding to this, it is possible to observe that all the strategies with and without transaction costs seem to have a positive autocorrelation of one lag of 0,11 for the EW strategy, 0,08 for the SPW, 0,15 for the EW-HF and 0,14 for the rankings' one unless for the dollar carry trade. The latter shows a negative but rather small autocorrelation of -0,01 both with and without transaction costs. This may suggest that these four carry trade strategies' returns may be forecastable one-period-ahead which comes as utterly important on the last section VIII when of studying the carry trade regime indicators.

Another interesting discussion is that of the portfolios' profitability after the 2008 financial crisis and for this I calculated the returns of all the strategies for the period after September 2008[7]. It can be observed now that the EW portfolio is no longer profitable even before the transaction costs with a negative average return of -0,34%. Also when considering the EW-HF it was no longer profitable after transaction costs for the post-crisis period with a negative average return of -0,25%. It is also interesting to notice how does the dollar carry trade perform much better in comparison to the other strategies as it gets an average return of 2,27% with a Sharpe ratio of 0,20 while the rankings and SPW strategies got averages returns of 1,73% and 0,83% and Sharpe ratios of 0,14 and 0,06, respectively, before transaction costs. In conclusion, accounting for the transaction costs does not lead to any change on the previous pattern of te results.

Finally, when analyzing each strategy it is always interesting to compare it with the US stock market returns. In order to do this I took the previous values from Kenneth's French website with monthly frequency. The statistics for the US stock market returns are presented in Table 2 alongside the previous statistics. When considering the entire period the market showed average returns of 6,27% which is higher than the returns of all other strategies but the dollar carry trade. Alternatively, the volatility of these returns was also almost the double of the highest volatility among strategies: 16,88% against 9,65% of the rankings portfolio. Hence, if one considers the Sharpe ratios on the moment of taking an investment decision, the US stock market will rank last with a Sharpe of 0,37. Again this situation changes after the 2008 financial crisis since the US average returns are of 9,65% and volatility is equal to 19,14% yielding a Sharpe ratio of 0,51 which is relatively higher than the highest of the carry trade strategies' (0,2), the

[7] I consider the start of the 2008 financial crisis as the day of the Chapter 11 filing by Lehman brothers on the of September of 2008. Burnside et al. (2011), for instance, extends this period by 2 moths but this does not change the results significantly.

one of the dollar carry trade strategy. These results do in fact explain the wide gap between the performance of all the carry trade strategies and the dollar carry trade for the period after the 2008 financial crisis since the latter has a much stronger dependence on the dollar and, thus, it was probably this dependence joined with the good performance of the US stock market which lead to its higher returns. Lastly, I devote the next segment to describe the evolution of the strategies over time.

5.1. Evolution of the strategies over time

The high dispersion between the carry trade statistics alongside such a different performance after the financial crisis suggests they have much different dynamics. In order to observe this it is possible to investigate the evolution of the cumulative returns over time assuming an investor would have 100 dollars at risk in the strategy, which is presented in Graph 1.

The first conclusion is that in the end the dollar carry trade performed much better than the other four strategies, which show a more similar pattern. In the beginning of the period it can be observed that their evolution is pegged, however, from 1984 until mid-1993 the dollar carry trade feels an increased in value which the others did not. This is probably explained by its high dependence on the dollar which on the other strategies apart from the rankings' is used just to level the investments to 0. Still, in the rankings strategy the maximum weight it would be exposed to the dollar is equal to 50% while for the dollar carry trade this value is 100%. Moreover, it is possible to state that the drawdowns among strategies definitely do not follow the same patters. The dollar carry trade strategy has much deeper drawdowns, but also one must notice that the values for its cumulative returns are much higher. Therefore, in order to make a correct analysis it should be pursued a relative drawdown analysis which will be taken in the chapter VII.

Additionally, while the dollar carry trade has smoothly increased in value until mid-2005, the other strategies have had several drawdowns without the upside trends felt by the former, which made them less profitable.

On the other hand, the dollar carry trades felt a strong decrease in value from mid-2005 until the beginning of 2008 which was not felt by its peer strategies despite for a loss in the rankings' approach starting at the same time but finishing right after. In this case what drove returns down was the dependence on the US's performance. Additionally, from the SPW, EW-HF and rankings strategies it was the latter the one which suffered the most with the 2008 financial crisis since before this event it held the highest cumulative returns among the three and in the moment exactly after it, the previous portfolio ranked last.

Finally, it is important to notice that in 2010 and 2012 the dollar carry trade strategy suffered sharp drawdowns that were still not recovered by the beginning of 2015. This result is shared by the SPW and rankings strategies due to having lost a huge share of their cumulative returns with a drawdown in 2012. Nevertheless, the first is currently in a downward trend while the second is on an upward one. As far as the EW and EW-HF are concerned it seems that from a graphical analysis the EW strategy never reached higher values than the ones of 2004 while its hedged version by 2012 had roughly reached the pre-crisis level but due to further drawdowns it could not achieve a higher level of cumulative returns.

In order to have a complete analysis of what lead these strategies' returns to decrease so sharply and to deliver a proper view on risks the strategies face, the next chapter will comprise a brief analysis of common risk factors used in the literature to describe the

carry trade. Consecutively, in chapter VII, I develop a drawdown analysis of the five strategies and the market's returns.

VI. Traditional risk factors analysis

In this section it will be discussed whether the average returns of the carry trade strategies previously described are explained by the exposure to the traditional risk factors or not. In opposition to many studies in the literature here it is not intended to search for an explanation to the carry trades' excess return. Therefore, I will limit the risk factors to two: the Fama-French (1993) 3-factor model and the pure FX risk factor as proposed by Lustig, Roussanov and Verdelhan (2011). Finally, to model this exposition to the risk factors it was run a regression of the carry trade return for each strategy, Z_t over the source of risk, F_t, as it follows:

$$Z_t = \alpha + B'F_t + \varepsilon_t \qquad (15)$$

Furthermore, since the risk factors are explaining the returns, the α component of the regression represents the abnormal return of the strategy, that is, the measure of the average performance of the carry trades that cannot be explained by the unconditional exposure to the risk factors included on the regression.

6.1. Equity Market Risk

In order to analyze if the returns from the carry trade strategies are explained by the equity market risk it was decided to use the three Fama-French (1993) equity market risk factors: (1) excess market return, $R_{MRP,t}$, proxied by the excess return on the market, value-weight return of all CRSP firms incorporated in the US and listed on the NYSE, AMEX, or NASDAQ over the 1-month treasury bill rate; (2) the Small-Minus-Big factor$R_{SMB,t}$, calculated by the average return on the three small market

capitalization stock portfolios minus the average return on the three big portfolios; and (3) the High-Minus-Low factor, $R_{HML,t}$, which is developed by the average return on the two portfolios with high book-to-market value stocks minus the average return on the two low book-to-market value stock portfolios. Refer to Table 5.1. in order to access the regression results.

It can be seen that as it is mostly common in the literature, the 3 Fama-French factors cannot explain the carry trade returns. Firstly, it is mostly relevant to notice that the alpha for every portfolio is rejected to be equal to zero with a t-statistic ranging from 3,00 to 4,89. Thereafter, as it can be observed for each strategy the t-statistic values of the factors coefficients' range from |0,01| to |0,67| and, thus, by not rejecting that these values are statistically different from zero it cannot be proved that they explain the carry trade's returns. Furthermore, the largest R^2 is equal to 0, 004. Hence, the equity risk factors do not explain the carry trade returns.

6.2. Pure FX risk factors

The two pure foreign exchange market risk factors used are proposed by Lustig, Roussanov and Verdelhan (2011) and were further used in Daniel et al. (2014) as explanations for carry trade risk. In their study, 35 currencies are sorted in six portfolios considering the interest rate differential and, after ranking those differentials, the currencies were organized such that the ones with the highest rankings belong to the same portfolio while the ones with the lowest rankings are also joined in a correspondent portfolio. Hence, from this construction they obtained two risk factors: (1) the average returns on all six currency portfolios, $R_{FX-Mean,t}$; and (2) the difference between the returns of the portfolios 6 and 1, $R_{HML-FX,t}$. Additionally, the authors add that the correlation of the first principal component with FX-Mean is 0,99; while the

correlation of the second principal component with HML-FX is 0,94. Refer to Table 5.2. in order to access the regression results.

Here the results obtained from the regression are far different among strategies and, including the transaction costs has a very weak impact in the regressions. To begin with, for all strategies but the dollar carry trade I obtained relatively similar results to Daniel et al. (2014) as they obtain a stronger statistical relation with the HML-FX component, with high t-statistics. Nevertheless, the most important result obtained from these regressions is to notice that it is not rejected that the constant term is equal to 0 for some of the strategies: EW, SPW and rankings both with and without transaction costs. However, only for the EW and rankings portfolios is one of the coefficients rejected to be different from 0 with a confidence level of 95%: the HML-FX factor. This suggests that the returns of the EW and rankings portfolios are fully driven by the HML-FX risk factor. Yet, this result is not surprising given that the construction of these strategies is similar to the carry trade strategy developed in Lustig, Roussanov, and Verdelhan (2014) while the SPW, EW-HF and dollar carry trade are not. The latter explanation is also supported in Daniel et al. (2014) while explaining the strong explanatory power of HML-FX factor. Adding to this, the regressions delivered relatively high R^2 values ranging from 0,06 for the dollar carry trade to 0,71 for the rankings strategy.

Hence, considering everything that was mentioned it is possible to state that strategies such as the equally-weighted and the rankings carry trade can be fully explained by the HML-FX factor similarly to the authors results.

VII. Downside risk analysis

The carry trades are known for their high returns but also for their main drawback: the downside risk. In fact a quick observation of the strategies' statistics would tell us that

all have a negative skewness of -0,37; -0,27; -0,51; -0,14 and -0,70 for the EW, the SPW, the EW-HF, the dollar carry trade and rankings strategies, respectively. The skewness of a distribution describes the asymmetry or lack of symmetry of the returns' distribution around the mean and, thus, it means that if negative, the carry trade returns have a negative higher tail, that is, high drawdowns. In addition, it is very important to relate these values with the ones of the excess kurtosis which were all positive. Therefore, together the results of these two statistical moments present the well-known negative tail risk of the carry trade as the returns follow a leptokurtic distribution which is also skewed to the left.

At last, one should consider that for the same period the market's returns had a much more negative skewness equal to -1,02 with the highest excess kurtosis, suggesting a much higher tail risk. It is puzzling, however, how the EW-HF strategy has a more negative skewness and higher excess kurtosis than its unhedged version. In order to develop a deeper study on the downside risk three different indicators will be explored: the Sortino ratio, the drawdown and the pure drawdown.

7.1. The Sortino ratio

One of the most popular measures of downside risk of an investment is the Sortino ratio which follows the Sharpe ratio in that the only difference is that the former uses solely the volatility of the negative returns, while the latter uses the volatility of the entire sample. Hence, the larger the Sortino ratio the lower the probability of a big loss. Refer to Table 7 in order to observe the results for this indicator for the five portfolios.

Similarly to the previous Sharpe ratio analysis it can be observed that the market had the lowest value for the Sortino ratio which is explained by a higher volatility of negative returns which accounts for a little less than the double of the carry trade strategies since

it is of 3,6% while the one of the rankings strategy is of 2,05%. In that sense, the EW-HF strategy ranks first with a ratio equals to 4,62 while the dollar carry trade follows it with 4,53. The strategy with the lowest value for the Sortino ratio happens to be the EW strategy which makes now more sense than the previous analysis on the skewness, where the latter had a better performance than its hedged version. Alternatively, the market's Sortino ratio is equal to 1,75 suggesting a much larger downside risk than the one of the carry trade strategies.

Ultimately, the values for the strategies after transaction costs change in a proportional way since the volatility of the negative returns increases or remains unchanged for all strategies while the returns decrease in the same manner previously stated. Still, it is relevant to note that the Sortino ratio for all the carry trade strategies after transaction costs remained above the one of the market's before transaction costs denoting once again the high exposure to large drawdowns by the markets' returns.

Nonetheless, as it was previously observed this picture changes drastically if it is considered the period after the 2008 financial crisis. The downside volatility rose for all the strategies but still kept lower than the one of the market since the latter shows a value of 5,06% while the highest downside volatility of the carry trade strategies is 3,50%, for the SPW strategy. However, given the poor results for the average returns the highest Sortino ratio among carry trade strategies as it would be predictable by the higher average returns is the one of the dollar carry trade equal to 0,75 and much lower than the one of the market: 1,92.

To conclude the Sortino analysis it is surprising that for the post-crisis period and before transaction costs the rankings strategy has a higher ratio than the SPW strategy of 0,32 against 0,24 considering its high volatility and skew. Conversely, after accounting for

these costs the SPW strategy performs slightly better with a higher Sortino ratio of 0,19 in comparison to 0,17 of the rankings strategy.

Hence, this indicates that for the period after the 2008, the carry trade strategies are exposed to a higher probability of a large loss than the US market which is not true when considering the entire period of analysis.

7.2. Drawdowns and Pure Drawdowns

The Sortino ratio is a generally examined ratio for the comparison of the downside risk of the strategies. Although, it does not answer some of the important questions of a drawdown analysis such as: which strategy suffered the highest drop in value, or which strategy took more time to recover from a severe fall? In order to answer these questions it was decided to use two indicators used in Daniel et al. (2014), the drawdown and pure drawdown. The drawdown is a broadly used measure defined as the decline of an investment from its historical peak to the lowest through. This is usually measured as a percentage between the peak and through values. It can also be measured as the number of periods it took to get back to the previous peak's value. On the other hand, the pure drawdown is defined as a percentage loss from consecutive negative returns. Again one can measure the number of periods of successive losses. The results for the Drawdown analysis are presented in Table 8 and for the Pure Drawdown in Table 9. Additionally, refer to graphs 3 and 4 for a description of the periods when these Drawdowns and Pure Drawdowns occurred.

In the mentioned tables, the results for the biggest 10 drawdowns and 10 pure drawdowns are shown. Once again, the market registers the highest level of downside risk with the drawdown of strongest magnitude reaching 49% which lasted for 40 months as it started in October of 2007 and finished in January of 2011 which

representing the late global financial crisis' losses. Also interesting is to observe that the second biggest drawdown finished not much time before the beginning of the first since it was equal to 47%, started in March of 2000 with the dot com bubble and only finished in April of 2007, lasting for a much longer period of 86 months. As far as pure drawdowns are concerned the two largest for the market were equal to 34% and 33%, both lasting 3 months and starting in September 2009 and November 1987, respectively.

When looking at the carry trade strategies, it is interesting to notice that the largest drawdown among carry trade strategies is not the one of the EW strategy equal to 24% which had the lowest value for the Sortino ratio, but the rankings carry trade's one of 36%. However, despite these two drawdowns being the strongest among the 10 biggest for all the strategies, the longest is in fact the one of the EW strategy lasting 110 months, given that it started in December of 2005 and it did not finish by January of 2015, against 68 months of the rankings strategy which started in July of 2007 and finished in February of 2013.

Additionally, it is surprising to note that the strongest pure drawdown of the rankings strategy is even stronger and longer than the market's: 39% against 34% and lasting 8 months in comparison to 3 months for the market's strategy. Moreover considering the loss in dollars if both strategies were started with 100 dollars, they would feel the same loss of 249$ which is a utter negative sign for the rankings strategy given the difference on the final cumulative returns between the strategies.

Besides, before transaction costs the strategy with the smallest drawdown with the maximal magnitude was the EW-HF with a drawdown of 19% which lasted 46 months and, thus, also the shortest. In second place ranks the dollar carry trade with a drawdown of 22% lasting 59 months. Both strategies felt this drawdown also in the late

global financial crisis. As far as the second strongest drawdown is concerned the performance remains the same suggesting that the EW-HF and the dollar carry trade have both a better resistance to the downside risk. Furthermore, adding the transaction costs to this picture the drawdowns are stronger and longer, however, it does not make any of the strategies to perform better than others at the first magnitude drawdown nor second. Finally, the EW strategy is less exposed to the downside risk than the SPW as far as drawdowns are concerned.

When looking at the results from the pure drawdowns to the carry trade strategy it is surprising how now the dollar carry trade performs so much better than the EW-HF strategy since their both pure drawdown with the maximum magnitude lasts 5 months but the one of the latter accounts only for 9% compared to 17% of the EW-HF carry trade. In addition to this, if one considers that both strategies were initially invested 100 dollars this continued lost would amount to 119$ for the dollar carry trade pure drawdown and 102$ for the EW-HF' one. It is not surprising that the dollar carry trade had still a higher loss given that it showed a much higher return for almost the entire period and, thus, it would still be expected that such difference in loss would be higher.

The most unexpected part is that while this pure drawdown was felt at the same time as the maximum drawdown for the EW-HF strategy, the same cannot be said for the dollar carry trade once it finished in March of 2006 while the maximum drawdown was felt during the 2008 financial crisis. Furthermore, even the second largest pure drawdown for the latter strategy ended in March of 1985 and the second biggest drawdown was felt from 11/2010 and still proceeds by 01/2015 which may indicate that there is no relationship between the pure drawdowns and the drawdowns. The same conclusions are later found in the EW-HF strategy since the period of the second biggest drawdown

(05/1985-12/1988) does not correspond to the period of the second strongest pure drawdown (finishing in 02/1993).

Among the other strategies, when looking at the pure drawdowns of the SPW and the EW there are no big surprises since the SPW continues to be more exposed to this form of downside risk with the maximum pure drawdown equal to 26% while the one of EW is equal to 19%. What can be odder in this situation is that both last the same number of periods: 6 months, suggesting that despite smaller in magnitude, the EW is exposed to long periods of negative returns.

At last I explore the periods at which the biggest drawdowns and pure drawdowns happened so to observe if it is possible to find whether there is a relationship among these indicators or not as previously seen in the dollar carry trade and EW-HF strategies. On the one hand, in fact for all the strategies the biggest drawdown and pure drawdown occurred during the late financial crisis. On the other hand, the second and third strongest drawdowns for the SPW and rankings' strategies were not at the same time of the pure drawdown: the second biggest drawdown for the SPW strategy was during 07/1985 and 03/1990 while its second strongest pure drawdown finished in 02/1993; as far as the rankings strategy is concerned the second largest drawdown was during the same period of the SPW's strategy while the second largest pure drawdown was in 03/1993 as it lasted one more period than the former strategy. Yet, the third strongest drawdown was felt at different periods among the two strategies.

In conclusion, it is possible to affirm that the carry trade strategies are exposed to strong and long drawdowns, as well as, pure drawdowns that are still lower than the market's one. Furthermore, different indicators suggest different results for the strategies in that one cannot conclude which strategy is less exposed to the downside risk by using all the

indicators at the same time. Still, the EW-HF and the dollar carry trade seem to be the best candidates as the carry trade strategies to be less exposed to tail risk and drawdowns. This analysis motivates the relevance of answering to the question initially asked: how can one get the timing and, therefore, hedge from these events which strongly drive returns down? In order to answer this question in the following chapter it will be developed a study on the possible regime indicators capable of informing an investor of the time a drawdown will occur.

VIII. Regime Indicators

In his book "Expected Returns: An Investor's Guide to Harvesting Market Rewards" of 2011, Antti Ilmanen describes the problem of the carry trade as being the downside risk, which is proved by the analysis on the previous section. Furthermore, once it is being considered an arbitrage strategy these drawdowns will lead to the unwind of the carry trade positions. As far as these unwinds have been studied, historically they are known for having lasted long enough to make it possible for investors to use backward-looking indicators valuable in the prediction of next week or next month carry trade performance. Therefore, carry trade returns are known for exhibiting short-term persistence similarly to what was suggested by their autocorrelation and, thus, a study of the rearview mirror indicators and stop-loss discipline is highly valuable.

In that sense, the mentioned author presents the possibility of using some variables that allow one investor to avoid such losses which he names as regime indicators or conditioners. The variables he presents are: overcrowded carry positions, overvalued exchange rates from high-yield currencies, rising volatility in exchange rates, tightening liquidity conditions especially in low-yielding "funding currency" currencies and the changes in the stock markets' returns for each currency. All the last indicators have also

been used in other literature either by providing a signal for the carry trade positions or as risk factors for the carry trade returns: overcrowded carry positions and tightening liquidity are both used in Brunnermeier et al. (2009), overvalued exchange rates from high-yield currencies as part of the PPP condition is used in Barroso and Santa-Clara (2013), the stock market's returns is used in Campbell et al. (2010); and, finally, the volatility of exchange rates is used by Bhansali (2007). Additionally, I preferred not to use global factors also suggested by Ilmanen and used in the literature, such as the return of the MSCI World by Bakshia and Panayotov (2013) or the US Consumption growth by Lusting and Verdelhan (2007). The motivation for this choice is that I want to use indicators that can be directly related with the payoffs of each currency in the portfolio of currencies, while usually global indicators are applied when relating the risk factor to the return of the portfolio of currencies.

Consecutively, when determining to which strategy should this study be performed it was chosen the EW-HF strategy. This decision took into consideration four main factors: (1) it is one of the most well-known and used strategies; (2) it has a direct exposure on the forward exchange rate, which is important when analyzing the relationship with the future positions' variable; (3) by being equally-weighted, the positions are much more flexible to change in comparison, for instance, with the dollar carry trade which has a much higher dependence on the dollar's performance; and (4) despite having the strongest Sharpe ratio when considering the entire period, it presents negative returns after the 2008 financial crisis.

Finally, in the next part of this chapter I describe the construction of the regime indicators and how they provide the stop-loss sign when taking the investment decision on each currency.

8.1. The regime indicators' variables

To begin with, when developing the signal for the speculation on overcrowded carry positions I used the variable created by Brunnermeier et al. (2009):

$$\text{Overcrowded Position}_t = \frac{\text{Fut. long}_t - \text{Fut. short}_t}{\text{Tot. Fut. Positions}_t} \qquad (16)$$

The authors use the futures position of non-commercial traders' data from the Commodity Futures Trading Commission (CFTC) and the intuition is that when this value gets too high (low) it means that the carry positions are overcrowded for the investing (borrowing) currency and, thus, the probability of a carry crash to happen increases. The authors use the forward exchange rate positions noting that many speculators implement the carry trade by actually borrowing and trading in the spot currency market.

Moreover, when considering whether a currency is overvalued or not the analysis was limited for Australia, Canada, New Zealand and UK by following Ilmanen's advice on applying it only to the high yield currencies and as it can be seen from Table 3 these are the currencies that were the most used for investing purposes. The indicator used was the real exchange rate and, thus, if the real exchange rate is higher than 1 the currency is overvalued and, undervalued if lower.

Analogously, the tightening liquidity conditions indicator should be used in low-yielding "funding currencies" and, therefore, it was solely applied to Japan and Switzerland since they were the most used for borrowing purposes as it can also be observed in Table 3. Here in the calculation of the liquidity conditions it was decided to use the TED spread applied to these countries as suggested in Brunnermeier et al. (2009), that is, the difference between the shortest term LIBOR rate available (3M) and

the risk-free rate, which is the shortest Treasury note, available for these countries. The intuition given by the authors is that the LIBOR rate reflects uncollateralized lending in the interbank market, which is subject to default risk, while the short term T-Bill rates can generally be considered as risk-less since they are usually guaranteed by the governments. Hence, when banks face liquidity problems the TED spread typically increases, and the T-Bill yield often falls due to a flight-to-liquidity" or flight -to-quality".

Finally, the stock market indices used were the country's main index for a given currency and it is available for all currencies from a certain period described in Table 1. Additionally, the monthly volatility of the exchange rates is also available for all the currencies and it was calculated taking into consideration the daily values of the exchange rates.

The next part of this chapter describes the econometric models used to find the correct signaling provided by the regime indicators when of weighting each currency on the EW-HF strategy.

8.2. Econometric model for the threshold signaling value

In order to use the previous indicators to provide us with the correct "valuation filter" sign, that is, with the prediction of a "carry crash", what one must find is the threshold value that makes those indicators to drive the carry trade returns down. The insight necessary for this study is that for the different regime indicators there may be two regimes: one where the values of these indicators have a positive relationship with the carry trade returns and other where such relationship is negative. As an example one can consider that there is a level for the Australian's real exchange rate that makes the payoffs of the Australian's component of the carry trade to be highly profitable;

however, once passing this level, that is, when the currency gets highly overvalued or undervalued an increase of the real exchange rate has now a negative impact over these payoffs.

At the moment of deciding which model to use for this application, an investigation at the literature on this topic did not show any promising result. This is due to the fact that most of the papers on the carry trade are focused on determining the risk factors affecting its payoffs and do not use different regimes. Nevertheless, Gubler (2014) uses a multivariate threshold model when analyzing the carry trades based on the USD/CHF and EUR/CHF currency pairs. However, here the author does not have a portfolio of currencies like the one of the EW-HF strategies which requires a different analysis due to the relationships between the currencies' payoffs. Additionally, the author provides a review of the most important papers using such models. Alternatively, Jordà and Taylor (2012) use a nonlinear regime-dependent model in their approach but on the moment of determining the threshold they do it exogenously. Finally, Clarida et al. (2009) also uses a regime-switching model considering the exchange rate volatility as exogenous variable. However, the latter defined these regimes in terms of the quartiles of the empirical distribution of volatility over the sample period.

Hence, by not having a common procedure defined among the literature a different process was taken. This process accounts for two phases: firstly a series of VAR models were obtained describing the relationship among each of the regime indicators and the payoffs of every currency in the carry trade strategy under analysis; and secondly after analyzing the results from the first phase, a threshold autoregressive model is run for the currencies which had statistically and economically significant coefficients. Additionally, it is important to note that due to fast market's changes it is only reasonable to consider values of the indicators lagged by one month. Also, from the

structural definition of the VAR model, it was necessary to include two autoregressive components of the endogenous variables so it was decided to use the 1 and 2 months lagged. Refer to Appendix A for a detailed description of these models.

Finally, it was decided to use the period from 03/1999-12/2003 for the regression since it is a period when all the returns are available and which allows the thresholds to be placed before the 2008 financial crisis using the period when the strategies had a regular good performance. Hence, such timespan leaves still time for using the threshold during profitable years when making an out-of-sample analysis. In conclusion, from this two-step approach one is able to obtain the threshold values which give the stop-loss signal for each regime indicator for a given currency. Refer to Tables 6.1.-6.5. to observed the results of the mentioned regressions.

8.3. Results for the VAR and Threshold regression models

Starting this analysis with the VAR of the overcrowded future positions (Table 6.1) it seems that the only currency where the speculative positions and its carry trade returns have a statistical significant relation is the UK but with a coefficient of 0,00 and a t-stat of -2,36 and, thus, statistically significant at a confidence level of 95%. Also, it seems that a small number of other relationships are found but these do not hold in fact any theoretical ground given that either the statistical significance or the sign of the coefficient do not suggest any further investigation. Therefore, despite the statistical significance of the U.K.'s future positions variable, due to a coefficient of 0,00 the Threshold regression model was not applied for the latter. Hence, this results suggest that there is no threshold value for the future positions on forward exchange rate that can help one investor predicting future carry crashes in the EW-HF strategy for the period under analysis.

Sequentially, when studying the real exchange rate indicator, I obtain from the VAR results (Table 6.2) that only the values for New Zealand seem to be statistically significant with a t-statistic of -2,23 and a coefficient of -0,02, which is the expected signal. Apart from this, the real exchange rates of Australia, Canada, New Zealand and UK have statistically significant impact at a 95% confidence level on other currencies but not on its own, which is not the expected result. In addition, some of these coefficients are also positive which is not the suggested by the literature and, thus, the threshold regression is only performed for the New Zealand dollar. Finally, when running this regression the coefficient not only shows a positive signal (0,01) but it is not statistically significant for a confidence level of 95%. Furthermore, no thresholds are selected for the regression, suggesting there are no statistically significant different regimes for this period and strategy.

When observing the results on the VAR of the TED Spread (Table 6.3) similar results are obtained given that now, however, neither Japan nor Switzerland payoffs show a relationship with their TED spreads. Still, it is interesting to observe that the Swiss TED spread has a negative and strong statistically significant relationship with the returns from Australia, Canada and New Zealand. These are three of the four considered high-yield currencies and such effect could mean that an increase in the Ted Spread in Switzerland reduces the liquidity of this carry trade strategy and, thus, not allowing for such a high investment on these currencies. These results suggest a further analysis of the relationship between the payoffs of these three currencies and the Swiss' TED again lagged one month. Nonetheless, the results from the Threshold regression do not retrieve any interesting result since none of the regressions obtained a threshold value and despite all the coefficients have kept the negative sign, only the one of the Australian payoffs was statistically significant with a t-statistic of 2,40.

Moreover, using this procedure for the market indices the time spam is limited to start in March of 2001 due to data on the New Zealand's stock market. As far as the VAR (Table 6.4) is concerned apart from a small number of relations between different carry trade payoffs and market indices, the only statistically significant relationship obtained was again for the New Zealand's payoffs and its market index with a coefficient equal to 0,08 and a t-stat of 4,09. This is the signal that is expected and, therefore, the Threshold regression is also produced; however it shows completely different results from what the VAR suggested, given that now the coefficient is negative (-0,02) but also not statistically significant with a t-stat of -1,03.

Furthermore, the VAR regression (Table 6.5) for the volatility of the spot exchange rates does not bring any surprises from the previous results once only the volatility of the Swedish krone has a statistically significant relation with the Swedish carry trade payoffs. Although, such relationship is positive which is against the main notion that the volatility of the exchange rates has a negative impact on the carry trade results. Still, the Threshold regression was carried on and surprisingly the positive relationship persisted both with a very high coefficient of 2,26 and statistical significance with a t-statistic of 4,36 but no threshold value was obtained. In conclusion, it seems that neither the market indices regressions nor the volatility of the spot exchange rates can provide a threshold value for their regime indicators.

To finish with this analysis, it could not be found the existence of different regimes among the selected variables when applied to the EW-HF carry trade strategy and during the period of 03/1999 and 12/2003. The reasons may be that it is a short time spam and there were no strong asymmetries in the variables as in other periods. Also, there is the hypothesis that the high idiosyncratic risk in each currency undermines the statistical significance of the regime indicator variables. However, due to data

availability and the event of the 2008 financial crisis it would be the most relevant period to use. Still, it is worth to note that these results follow the insights of Ilmanen in the book previously mentioned as the author notices that usually these regime indicators are not robust. In that sense, in the next part of this chapter it was decided to use exogenous thresholds based on theoretical grounds and other literature review.

8.4. Exogenous thresholds and final results

On the moment of deciding which threshold to use for each regime indicator variable, it was taken into consideration the expected influence of such variable on the carry trade's returns from the results in the literature motivating the use of each regime indicator.

Firstly, for overcrowded future positions indicator it is expected that if there is a big change of its value there will be a "carry crash". Hence, it was considered that if the percentage change in this variable in the previous period overpasses the threshold of 100%, so that it only captures situations where positions pass from long to short or the opposite, the trade at that currency is stopped. Secondly, when considering the real interest rate the investment on Australia, Canada, New Zealand or UK is stopped if in the previous period the currency was overvalued. Thirdly, the signal provided by this TED spread regime indicator for Japan and Switzerland assumes that when this value exceeds its historical mean until that moment, the borrowing in this country should be stopped. Fourthly, the regime indicator of the volatility of the spot exchange rates is applied to all the currencies in the same fashion as the one of the TED spread. Finally, as far as the stock market' indices are concerned the signal suggested is that if there is a decrease in the stock market's returns for a given currency in the previous period, one does not invest in that currency in that period.

Similarly, instead of having only a stop-loss signal it was also applied a reverse position signal to all the regime indicators. Note that each of these strategies will be from now on named as optimized (OPT) followed by an indication of the regime indicator that optimized it, for example, strategy optimized by the TED spread will be named as OPT-TED(0) if the indicator stops the position on the currency and OPT-TED(-1) if it reverts the latter. Refer to Table 4.1. to observe the results for these strategies before accounting for the transaction costs

To begin with it is important to notice that for the overall period all the regime indicators when reversing the position lowered the average returns. The same is not true once looking at the original idea of the regime indicators to be used as a stop-loss indicators since the real exchange rate, the TED spread and the volatility when used individually as regime indicators improve the average returns by 0,29%, 0,06% and 0,37%, respectively. However, only the strategy using the volatility as a regime indicator increases the Sharpe ratio from 0,97 to 1,08. In addition to this, the most surprising effect from this analysis is to notice that if it is considered only the period after the 2008 financial crisis all the regime indicators increase both the average returns and the Sharpe ratio unless for the OPT-VOL(-1) strategy. Most interestingly is even to realize that after the 2008 financial crisis the regime indicator which worked better was in fact the one of the equity markets index with a stop-loss discipline having an average return of 3,03% and Sharpe ratio of 0,29 compared with the normal strategy values of 0,37% and 0,05, respectively.

The previous results motivated the analysis of joining the indicators which increased the average returns for the overall period, in order to see whether they perform better together or not. Refer to Table 4.2. for a description of these results and to Graph 2 for

the cumulative returns of the best performing carry trade strategy optimized by a regime indicators.

Firstly, it was decided to join the TED spread with the real exchange rate (RER) regime indicators both with the stop-loss procedure. As it was expected the results improved now given that the average returns are roughly better when comparing with OPT-RER(0) from 5,28% to 5,30% with a small decrease of 0,02 in the Sharpe ratio motivated by the increase in volatility brought by the Ted Spread component. This effect is expected since it reduces the number of borrowing currencies. Finally when including the three regime indicators that increased the overall average returns, which will be named as OPT-RER&TED&VOL(0), the averages results highly increase to the value of 5,71% with a Sharpe ratio of 1,05 which compares with 4,99% and 0,97 of the strategy when using no regime indicators. When considering only the period after the late financial crisis the difference broadens even more as the former strategy has average returns of 1, 52% and a Sharpe ratio of 0,22 compared with 0,37% and 0,05 of the baseline EW-HF strategy, respectively. Lastly, when accounting for the transaction costs the differences are kept the same unless for the fact that now when using the mentioned regime indicators the strategy becomes profitable after transaction costs in the period after the 2008 crisis with an average return of 0,69% and a Sharpe ratio of 0,09.

In order to understand how the downside risk is affected when using regime indicators in the carry trade strategies I apply the analysis of the previous chapter to the OPT-RER&TED&VOL (0) strategy. Refer to Table 7, 8 and 9 for an observation of the Sortino ratio, drawdown and pure drawdown statistics, respectively; and Graphs 3 and 4 for the evolution of the drawdowns and pure drawdowns. When comparing the skewness, now this strategy holds the value closest to 0 and equal to -0,08 which makes

the EW-HF strategy which had the second lowest skewness to have now the highest. Furthermore, when it comes to the Sortino ratio when considering the whole period the same situation is kept since it was already the highest, now it simply increases from 4,62 to 5,3. However, when considering just the period after the 2008 crisis despite having largely increased by the regime indicators could not be higher than the dollar carry trade's one: 0,6 against 0,75, before transaction costs. Still, it is very interesting to notice that considering just this period, before the EW-HF strategy ranked 4th in this ratio, while now when using the regime indicators it has the 2nd best showing a better performance than the SPW and rankings' strategies.

When analyzing the drawdown and pure drawdown measures I also recall the large drops of these values indicating the positive effect that regime indicators have in the strategy: without the transaction costs the biggest drawdown was reduced from 19% to 17%, continuing to be the strategy with the lowest drawdowns among those with the strongest magnitude. Oppositely, despite the largest pure drawdown having fell from 17% to 12% before transaction costs it is still higher than the correspondent value of the dollar carry trade strategy which is equal to 9%. It is also important to note that after accounting for the transaction costs the values for the drawdowns and pure drawdowns increased but again in a similar fashion across strategies. In conclusion, it is especially puzzling to notice that the strongest drawdown of the strategy optimized by the regime indicators was not the one of its baseline strategy which was during the financial crisis. In fact this drawdown was felt during 05/1985 and 01/1989 with a magnitude of 17%, while for the baseline strategy this drawdown was felt during one month less but with a smaller magnitude of 10%. This situation describes one of the risks of using the regime indicators mentioned by Antti Ilmanen which is that despite of on average they increase the return of the carry trade, they can also give false alarm signs such as this one.

To sum up, over the entire period only the real exchange rate, the TED spread and the volatility of the spot exchange rates behaved has value-increasing regime indicators when using a stop-loss discipline and not as reverting positions. Alternatively, after the 2008 financial crisis all the regime indicators, but the one using the volatility of exchange rates while reversing the investments, if used would have increased the value of the carry trade strategy. It is also interesting to notice that for the period after the crisis when using the indicators as reversing positions, the TED spread and overcrowded future positions regime indicators perform better than when using a stop-loss discipline which is not true if considering the entire period. Although, the best regime indicator for this period as previously stated is the market indices returns when using this stop-loss discipline.

9. Conclusions

This Working Project provides a review on five different carry trade strategies never analyzed together in the literature. Similarly to Daniel et al. (2014) I conclude that the basic equally weighted carry trade shows the lowest average returns among strategies equal to 3,26% before accounting for transaction costs. Hedging the exchange rate risk of this strategy by purchasing/selling forward contracts on exchange rates increases the profitability of the strategy to 4,99%. More complex strategies such as the speed-weighting and rankings lead to higher average returns of 5,28% and 5,49%, respectively. For the considered time span of 1976-2015 the most profitable portfolio with corresponding average returns of 6,90% was the dollar carry trade which has a higher exposure to the dollar. Only the latter presents higher average returns than the US market, 6,27%, however, all present a higher Sharpe ratio.

When considering transaction costs the two strategies which lost a higher portion of their returns are the ones using the forward exchange rate: the equally weighted hedged with forwards and the dollar carry trade. This result suggests that if the investor wishes to use forward exchange rates on his carry trade portfolio he should consider cost-minimizing strategies. Another important remark from this Working Project is to notice that despite carry trades having lost their high-profit profile exhibited from the beginning of the 2000's until the global financial crisis, they are still profitable after transaction costs. Three of the five considered strategies had positive returns with the dollar carry trade portfolio achieving the highest average return of 2,27%.

As far as the risks of the carry trades are concerned I obtained similar results to the literature. First, for all the five strategies I find the commonly stated result that the Fama-French (1993) three equity market risk factors are not able to explain the carry trades' returns. The second finding is also in accordance with the literature when considering the Pure FX risk factors presented in Lustig, Roussanov and Verdelhan (2011). It was obtained that three of the five portfolios can be explained by the HML-FX factor which is a carry trade return obtained from a very broad set of currencies. Additionally, some strategies that have a more similar construction to the portfolios presented by the latter authors seem to be fully driven by the same risk factors: the equally-weighted and the rankings carry trade without and without transaction costs.

I also do an analysis of the strategies' downside risk and conclude that different measures indicate contrasting results on which portfolio is less exposed to this source of risk. Nevertheless, it is interesting to notice that the dollar carry trade, which presented the highest average returns, is the strategy which had highest values for the Sortino ratio, as well as, lower Drawdowns and Pure Drawdowns together with the portfolio of equally weighted hedged with forward exchange rate contracts. Furthermore, the market

presented the worst statistics when compared with the five currency carry trade portfolios. This brings new insights to the literature on whether considering investing in the market or in a carry trade strategy since I show that despite having large and long negative returns, the carry trades are still less exposed to downside risk than the market.

Another novelty I developed is the study of the regime indicators predicting carry crashes and, therefore, enhancing average returns in the equally weighted strategy hedged by forward exchange rate contracts. Among scientific papers there is a variety of risk factors explaining carry trade returns and, thus, I collected five of these variables to use as regime indicators. Furthermore, in the literature there are few works applying regime indicators to the carry trades regime and there is no common econometric approach established. Considering a two-step process using first a Vector Autoregressive model with currencies and risk factors and; secondly a Threshold Regression model with the statistically and economically significant variables, no thresholds for any of the five regime indicators were found. Nevertheless, when defining specific thresholds for each variable as to stop the use of a currency or revert the position on the latter I obtained promising results.

Firstly, I discovered that when considering the entire period from 1976-2015 the real exchange rate, the TED spread and the volatility of the spot exchange rates when used together and with a stop-loss discipline increase the average returns from 4,99% to 5,71%. Secondly, using these regime indicators allowed the strategy to have positive average returns after the 2008 financial crisis of 0,69% compared with the -0,25% when not using regime indicators. Still, the latter did not allow the strategy to present higher average returns than the dollar carry trade portfolio, unless for the period after the 2008 global financial crisis when of using the equity markets' returns with a stop-loss discipline as regime indicator. Using this last procedure lead to an average return of

3,03% comparing with the 2,27% of the dollar carry trade, before accounting for the transaction costs.

Finally, I realized that when using regime indicators the drawdowns and pure drawdowns were reduced on average, however, during 05/1985 and 01/1989 the drawdown for the strategy increased from 10% to 16%. This result shows the main problem of using regime indicators which is the fact that despite on average improving the portfolios performance it can also induce false alarms leading to non-robust results. A possible explanation for this event is the choice of methodology when applying the thresholds. Therefore, it is recommended that further research is taken on the appropriate econometric models to use when of considering regime switches. It is for that matter advised to use a rolling-windows process due to the broad differences of the carry trades' profitability over time alongside a more complex T-VAR model. In conclusion, it is clear that even after the instable period after the 2008 financial crisis it is still possible to profit from this market inefficiency and the use of regime indicators enhance the strategy's profitability.

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11. Tables and Figures

Table 1: Information on the Regime Indicators' data

Non-commercial Future Positions		
Name	Source	Data availability
Australia	CME	01-04-1995
Canada	CME	01-04-1995
Euro	CME	01-02-1999
Japan	CME	01-04-1995
New Zealand	CME	01-02-1999
Swiss	CME	01-04-1995
UK	CME	01-04-1995
Real Exchange rate		
Name	Source	Data availability
Australia	IMF IFS	01-12-1979
Canada	IMF IFS	01-01-1979
New Zealand	IMF IFS	01-01-1979
UK	IMF IFS	01-01-1979
TED Spread		
Name	Source	Data availability
Japan 3-Month LIBOR	FRED Saint Louis	01-01-1986
Japan 3-Month T-bill	IMF IFS	01-01-1986
Switzerland 3-Month LIBOR	FRED Saint Louis	01-01-1989
Switzerland 3-Month T-bill	IMF IFS	01-01-1986
Stock Market Indices		
Name	Source	Data availability
Australia ASX 200	ASX/S&P	01-06-1992
Canada TSX 60	S&P/TSX	01-03-1982
Euro Stoxx 50 and DAX 30	STOXX and DEUTSCHE BOERSE	DAXX30 from 02/1976 until 01/1987 and STOXX 50 onwards.
Japan NIKKEI 225	NIKKEI	01-02-1976
New Zealand NZX 50	NZX	01-01-2001
Norway Oslo OBX	Oslo Bors	01-02-1987
Sweden OMX 30	Nasdaq OMX	01-02-1986
Swiss SMI	SWX SWISS EXCHANGE	01-07-1988
UK FTSE 100	FTSE	01-02-1978
US S&P 500	S&P	01-02-1976

Table 2: Summary Statistics on the Carry Trade Strategies' returns

The following table presents the results for the presented carry strategies for the period between 02/1976 and 01/1999. The availability of each currency for every strategy is described in the data section.

Without Transaction Costs

	EW	SPW	EW-HF	Dollar Carry	Rankings	Market
Mean	3,26%	5,28%	4,99%	6,90%	5,49%	6,27%
Vol	6,20%	8,63%	5,15%	8,55%	9,65%	16,88%
Excess Kurtosis	1,39	1,73	1,86	0,71	1,90	3,54
Skew	-0,37	-0,27	-0,51	-0,14	-0,70	-1,02
Autocorr.	0,11	0,08	0,15	-0,01	0,14	0,07
Sharpe rat.	0,53	0,61	0,97	0,81	0,57	0,37
# Months Negative returns	189	181	160	180	175	187
# Months Positive returns	278	286	307	287	292	280
Max Prof.	6,13%	8,99%	5,43%	8,89%	9,33%	11,75%
Max Loss	-6,71%	-8,56%	-6,18%	-7,90%	-12,62%	-26,45%
Mean 1976-2008	3,99%	6,18%	5,92%	7,83%	6,24%	5,28%
Vol 1976-2008	5,79%	7,59%	4,64%	8,17%	9,03%	16,91%
Sharpe rat. 1976-2008	0,69	0,81	1,28	0,96	0,69	0,31
Mean 2008-2015	-0,34%	0,83%	0,37%	2,27%	1,73%	9,69%
Vol. 2008-2015	8,08%	12,88%	7,25%	11,08%	12,59%	19,14%
Sharpe rat. 2008-2015	-0,04	0,06	0,05	0,20	0,14	0,51

WithTransaction Costs

	EW	SPW	EW-HF	Dollar Carry	Rankings
Mean	3,19%	5,17%	4,12%	5,48%	5,33%
Vol	6,22%	8,65%	5,15%	8,54%	9,67%
Excess Kurtosis	1,34	1,72	1,86	0,73	1,89
Skew	-0,31	-0,26	-0,51	-0,14	-0,71
Autocorr.	0,11	0,08	0,15	-0,01	0,13
Sharpe rat.	0,51	0,60	0,80	0,64	0,55
Negative returns	191	183	172	193	179
Positive returns	276	284	295	274	288
Max Prof.	6,13%	8,99%	5,40%	8,80%	9,29%
Max Loss	-6,71%	-8,57%	-6,27%	-7,97%	-12,65%
Mean 1976-2008	3,93%	5,97%	5,01%	6,30%	6,15%
Vol 1976-2008	5,81%	7,27%	4,64%	7,94%	9,04%
Sharpe rat. 1976-2008	0,68	0,82	1,08	0,79	0,68
Mean 2008-2015	-0,44%	0,41%	-0,25%	0,97%	1,22%
Vol. 2008-2015	8,10%	12,06%	7,26%	11,08%	12,61%
Sharpe rat. 2008-2015	-0,05	0,03	-0,03	0,09	0,10

Graph 1: Cumulative Payoffs of the Carry Trade Strategies

The following graph present the cumulative returns for the five strategies and the market presented in the previous table without transaction costs and following exactly the same specifications as above.

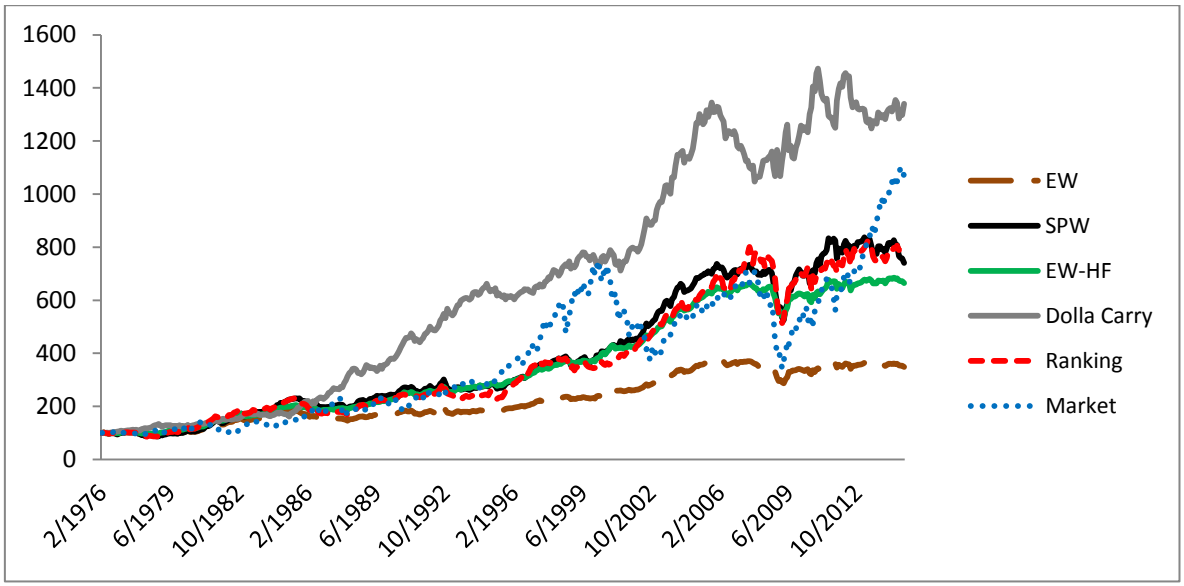


Table 3: Summary Statistics of the payoffs per currency in the EW-HF strategy

The following table shows a division between currencies first regarding the interest rate difference with the dollar and the changes on the spot interest rate and then an analysis over some statistics of the EW-HF carry trade strategy.

	AUD	GBP	CAD	SEK	SWF	EUR	JPY	NOK	NZD
i*t-1 - it-1	1,49%	1,91%	0,78%	0,06%	-2,74%	-0,06%	-2,65%	0,49%	1,78%
ΔSt	-0,46%	-0,13%	-0,15%	-0,89%	3,22%	-0,17%	3,07%	-0,24%	-0,04%
Payoff	1,00%	1,32%	0,89%	0,60%	-0,08%	0,19%	0,26%	0,32%	1,15%
Skewness	-0,44	0,23	-0,02	-0,12	-0,44	-0,09	-0,60	-0,30	-0,45
# Mths Inv. Curr.	257	401	324	137	56	102	43	155	274
# Mths s Borr. Curr.	45	67	139	103	412	89	394	85	28
#Mths Inv. Curr. %	85,10%	85,68%	69,98%	57,08%	11,97%	53,40%	9,84%	64,58%	90,73%
#Mrhs Borr. Curr. %	14,90%	14,32%	30,02%	42,92%	88,03%	46,60%	90,16%	35,42%	9,27%

Table 4.1.: Summary Statistics of the regime indicators' Optimized Carry Trade strategies

The following table presents the results for the EW-HF carry trade strategy using the different regime indicators specifications for the period between 02/1976 and 01/1999. The availability of each currency for every strategy is described in the data section while the availability of each regime indicator is shown in Table 1.

	Without Transaction Costs										
	EW-HF	OPT-RER(0)	OPT-TED(0)	OPT-FUT(0)	OPT-VOL(0)	OPT-MKT(0)	OPT-RER(-1)	OPT-TED(-1)	OPT-FUT(-1)	OPT-VOL(-1)	OPT-MKT(-1)
Mean	4,99%	5,28%	5,05%	4,82%	5,36%	0,49%	4,47%	4,74%	4,86%	4,26%	-0,77%
Vol	5,15%	5,43%	5,39%	5,15%	4,95%	9,20%	4,95%	5,43%	5,13%	4,60%	6,89%
Excess Kurtosis	1,86	1,48	3,15	1,83	1,60	2,46	0,88	2,91	1,88	1,52	3,34
Skew	-0,51	-0,39	-0,60	-0,50	-0,15	-0,13	-0,03	-0,61	-0,49	-0,41	-0,07
Sharpe rat.	0,97	0,97	0,94	0,94	1,08	0,05	0,90	0,87	0,95	0,93	- 0,11
# Months Negative returns	160	165	162	163	147	214	175	165	163	158	237
# Months Positive returns	307	302	305	304	313	229	292	302	304	309	230
Max Prof.	5,43%	5,43%	6,67%	5,43%	5,75%	13,38%	5,43%	6,58%	5,43%	4,95%	7,91%
Max Loss	-6,18%	-5,72%	-7,34%	-6,18%	-4,50%	-10,95%	-3,97%	-7,03%	-6,18%	-4,44%	-10,42%
Mean 1976-2008	5,92%	6,08%	6,04%	5,81%	6,33%	-0,16%	5,30%	5,61%	5,83%	5,17%	-1,06%
Vol 1976-2008	4,64%	5,08%	4,47%	4,51%	4,42%	8,41%	4,75%	4,55%	4,49%	4,20%	6,00%
Sharpe rat. 1976-2008	1,28	1,20	1,35	1,29	1,43	-0,02	1,12	1,23	1,30	1,23	-0,18
Mean 2008-2015	0,37%	1,58%	0,71%	0,58%	1,09%	3,03%	0,96%	0,87%	0,64%	0,31%	0,78%
Vol. 2008-2015	7,25%	6,04%	7,69%	6,72%	6,07%	10,47%	4,98%	7,69%	6,71%	5,25%	8,89%
Sharpe rat. 2008-2015	0,05	0,26	0,09	0,09	0,18	0,29	0,19	0,11	0,10	0,06	0,09

Table 4.2.: Summary Statistics of the regime indicators' Optimized Carry Trade

This table presents the results of the EW-HF carry trade strategy when optimized by more than one regime indicator on the left and the comparison between the EW-HF strategy and its optimized version by three regime indicators returns after accounting for the transaction costs. The availability of each currency for every strategy is described in the data section while the data for each regime indicator is shown in Table 1.

	Without Transaction Costs		WithTransaction Costs	
	OPT-TED&RER(0)	OPT-TED&RER&VOL(0)	EW-HF	OPT-TED&RER&VOL(0)
Mean	5,30%	5,71%	4,12%	4,88%
Vol	5,57%	5,44%	5,15%	5,43%
Excess Kurtosis	2,50	2,50	1,86	2,56
Skew	- 0,50	- 0,08	- 0,51	- 0,07
Sharpe rat.	0,95	1,05	0,80	0,90
# Months Negative returns	165	156	172	162
# Months Positive returns	297	300	295	294
Max Prof.	6,67%	7,86%	5,40%	7,84%
Max Loss	- 6,82%	- 5,72%	-6,27%	-5,77%
Mean 1976-2008	6,24%	6,63%	5,01%	5,73%
Vol 1976-2008	4,88%	4,78%	4,64%	4,97%
Sharpe rat. 1976-2008	1,28	1,39	1,08	1,15
Mean 2008-2015	1,20%	1,52%	- 0,25%	0,69%
Vol. 2008-2015	7,20%	6,96%	7,26%	7,49%
Sharpe rat. 2008-2015	0,17	0,22	- 0,03	0,09

Graph 2: Cumulative Payoffs of the EH-FW, Dollar carry trade and OPT-TED&RER&VOL (0) strategies

The following graph present the cumulative returns for EH-FW, Dollar carry trade and OPT-TED&RER&VOL (0) strategies before accounting for transaction costs.

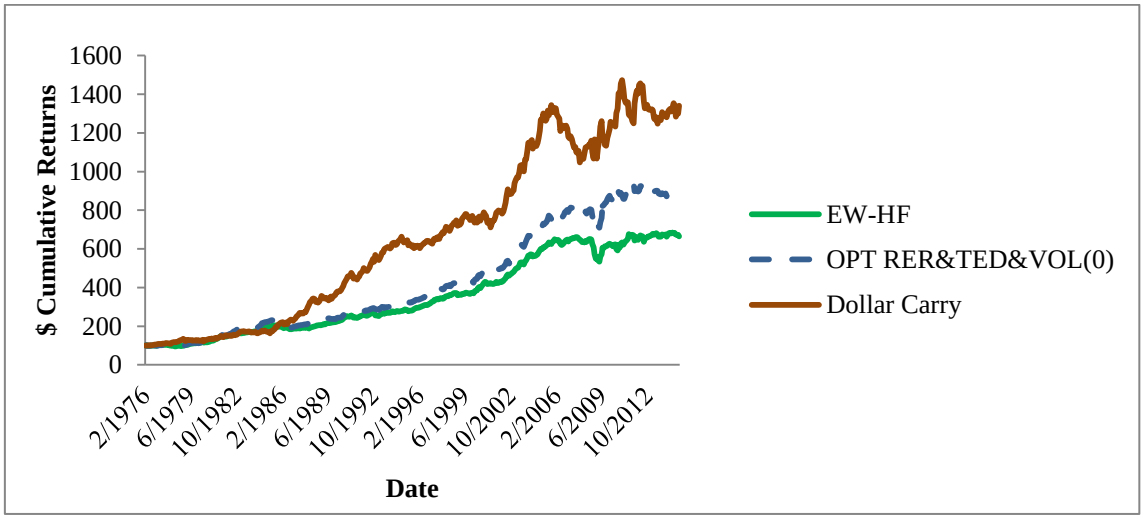


Table 5.1.: Carry Trade Exposure to the 3 Fama-French factors

This table presents the results for the regression of the carry trades returns over the 3 Fama-French factors. The sample period goes from all over the strategies period of implementation: 02/1976 to 01/2015. Autocorrelation and heteroscedasticity consistent t-statistics from OLS are in brackets.

	EW	EW (NET)	SPW	SPW (NET)	EW-HF	EW-HF (NET)	Dollar Carry	Dollar Carry (NET)	Ranking	Ranking (NET)
Alpha	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[3,08]	[3,00]	[3,64]	[3,55]	[4,32]	[3,57]	[4,89]	[3,96]	[3,25]	[3,15]
MRP	0,00	-0,00	0,00	0,00	0,00	0,00	- 0,02	- 0,02	0,01	0,01
t-stat	[0,01]	[-0,01]	[0,15]	[0,15]	[0,06]	[0,04]	[-0,52]	[-0,53]	[0,43]	[0,42]
HML	0,02	0,02	0,02	0,02	0,01	0,01	0,00	0,00	0,06	0,06
t-stat	[0,51]	[0,52]	[0,57]	[0,58]	[0,43]	[0,45]	[-0,1]	[-0,1]	[0,12]	[0,12]
SMB	- 0,01	- 0,01	- 0,02	- 0,02	- 0,02	- 0,02	0,01	0,01	0,03	0,03
t-stat	[-0,34]	[-0,33]	[-0,55]	[-0,55]	[-0,64]	[-0,67]	[0,25]	[0,19]	[0,57]	[0,57]
R-square	0,001	0,001	0,002	0,002	0,002	0,002	0,001	0,001	0,004	0,004

Table 5.2.: Carry Trade Exposure to the Pure FX risk factors

This table presents the results for the regression of the carry trades returns over the 2 Lustig, Roussanov, and Verdelhan (2011). The sample period is all the data available for the risk factors: 11/1983 to 11/2013. Autocorrelation and heteroscedasticity consistent t-statistics and p-values from OLS.

	EW	EW (NET)	SPW	SPW (NET)	EW-HF	EW-HF. (NET)	Dollar Carry	Dollar Carry (NET)	Ranking	Ranking (NET)
Alpha	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00
t-stat	[0,85]	[0,65]	[1,68]	[1,46]	[3,22]	[2,41]	[4,26]	[3,55]	[0,39]	[0,09]
FX Mean	0,02	0,02	0,11	0,11	0,07	0,07	0,21	0,21	- 0,04	- 0,04
t-Statistic	[0,24]	[0,25]	[1,23]	[1,23]	[1,23]	[1,23]	[2,18]	[2,18]	[-0,76]	[-0,75]
HML FX	0,34	0,34	0,50	0,50	0,28	0,28	- 0,09	- 0,09	0,81	0,81
t-stat	[9,23]	[9,30]	[1,16]	[1,17]	[8,91]	[8,92]	[-1,4]	[-1,4]	[2,45]	[2,49]
R-square	0,32	0,32	0,40	0,40	0,33	0,33	0,06	0,06	0,71	0,71

Table 6.1.: Regression results for the VAR and Threshold Model of the EW-HF strategy payoffs and the overcrowded future positions

In the following tables it is presented first the VAR including the payoffs for each currency of the EW-HF strategy and the forward exchange rate positions lagged one month for the available countries as specified in the data section. Secondly, the results for the Threshold model regression between the UK's payoffs for the latter strategy and the UK's future positions lagged one month. Notice that despite the model includes the first and second lagged autoregressive value of the dependent variables, these values are not presented due to space limitations. Both regressions use a time sample from 03/1999-12/2003.

	AUSTRA.	CAN.	EURO	JAP.	NEW Z.	NOR.	SWED.	SWISS	UK	US
Alpha	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[-0,32]	[-2,04]	[0,25]	[0,94]	[0,35]	[-0,82]	[-0,01]	[0,84]	[-0,69]	[-0,16]
Fut.Australia(-1)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[-0,05]	[0,93]	[-0,95]	[-0,27]	[-0,71]	[-0,79]	[-0,70]	[0,21]	[-1,05]	[-0,22]
Fut.Canada(-1)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[1,08]	[0,83]	[0,97]	[-1,13]	[0,17]	[0,20]	[0,00]	[-0,12]	[0,19]	[-1,19]
Fut.Euro(-1)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[0,24]	[2,40]	[0,55]	[-0,28]	[0,39]	[1,08]	[1,39]	[-1,33]	[1,30]	[-2,06]
Fut.Japan(-1)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[0,68]	[1,01]	[-0,58]	[-0,61]	[0,31]	[-1,05]	[-0,06]	[0,76]	[0,49]	[-0,03]
Fut.NewZ.(-1)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[0,51]	[1,89]	[-0,02]	[-0,78]	[0,07]	[1,28]	[0,42]	[-0,51]	[0,73]	[0,97]
Fut.Switz.(-1)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[0,00]	[-1,47]	[0,89]	[1,11]	[0,05]	[-1,09]	[0,48]	[0,98]	[-0,36]	[0,23]
Fut.UK(-1)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[-0,82]	[-2,84]	[-1,58]	[-0,69]	[-0,61]	[-1,73]	[-2,31]	[0,64]	[-2,35]	[0,76]
Fut.US(-1)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[0,18]	[-1,75]	[-0,59]	[-1,06]	[-0,59]	[-1,11]	[-1,61]	[-0,13]	[-1,78]	[-0,19]
R-square	0,44	0,50	0,40	0,52	0,52	0,41	0,43	0,39	0,46	0,95
Adj.R-square	-0,11	0,02	-0,18	0,05	0,05	-0,15	-0,12	-0,20	-0,06	0,91

Table 6.2.: Regression results for the VAR and Threshold Model of the EW-HF strategy payoffs and the Real exchange rate

In the following tables it is presented first the VAR including the payoffs for each currency of the EW-HF strategy and the Real exchange rate (RER) lagged one month for Australia, Canada, New Zealand and UK. Secondly, the results for the Threshold model regression between New Zealand's payoffs for the latter strategy and the its RER lagged one month. Notice that despite the model includes the first and second lagged autoregressive value of the dependent variables, these values are not presented due to space limitations. Both regressions use a time sample from 03/1999-12/2003.

	AUSTR.	CAN.	EURO	JAP.	NEW Z.	NOR.	SWED.	SWISS	UK	US
Alpha	0,01	0,00	0,00	0,00	0,01	0,00	0,01	0,00	0,00	0,00
t-stat	[2,53]	[0,97]	[0,70]	[0,52]	[2,41]	[0,61]	[1,39]	[0,77]	[0,75]	[0,16]
RER_AUSTRALIA(-1)	-0,01	-0,01	-0,01	-0,04	0,03	0,00	-0,01	0,00	-0,01	0,01
t-stat	[0,78]	[1,36]	[0,45]	[1,86]	[1,67]	[0,09]	[0,41]	[0,20]	[0,67]	[1,77]
RER_CANADA(-1)	0,06	0,02	0,01	0,05	0,01	-0,01	0,03	0,01	0,02	-0,01
t-stat	[2,58]	[1,84]	[0,80]	[2,03]	[0,41]	[0,67]	[1,29]	[0,54]	[0,96]	[2,00]
RER_NEW_ZEALAND(-1)	0,00	0,01	0,00	0,00	-0,02	0,01	-0,01	0,01	0,01	0,00
t-stat	[0,07]	[1,10]	[0,50]	[0,07]	[-2,32]	[0,97]	[-0,60]	[0,61]	[0,82]	[0,00]
RER_UK(-1)	0,01	0,01	0,01	0,00	0,00	0,01	0,00	0,00	0,01	0,00
t-stat	[2,25]	[2,07]	[1,98]	[0,03]	[0,12]	[2,49]	[0,67]	[0,36]	[1,20]	[1,27]
R-squared	0,32	0,18	0,25	0,31	0,32	0,24	0,13	0,23	0,21	0,92
Adj.R-squared	0,11	-0,08	0,02	0,09	0,11	0,01	-0,14	0,00	-0,03	0,90

	New Z.
RER New Z.(-1)	0,01
t-stat	[1,92]
Non-Threshold Variables	
Alpha	0,00
t-stat	[2,77]
R-squared	0,06
AdjustedR-squared	0,04

Table 6.3.: Regression results for the VAR and Threshold Model of the EW-HF strategy payoffs and the Ted spread

In the following tables it is presented first the VAR including the payoffs for each currency of the EW-HF strategy and the TED spread lagged one month for the Japan and Switzerland. Secondly, the results for the Threshold model regression between the Australia, Canada and New Zealand's payoffs for the latter strategy and the TED spread of Switzerland lagged one month. Notice that despite the model includes the first and second lagged autoregressive value of the dependent variables, these values are not presented due to space limitations. Both regressions use a time sample from 03/1999-12/2003.

	AUSTRA.	CAN.	EURO	JAP.	NEW Z.	NOR.	SWED.	SWISS	UK	US
Alpha	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
t-stat	[3,16]	[2,12]	[2,02]	[0,42]	[3,44]	[1,77]	[2,83]	[0,62]	[0,56]	[0,66]
TEDJapan(-1)	-0,45	-0,06	-0,93	-0,11	-0,56	-0,19	-0,79	-0,12	-0,73	-0,16
t-stat	[0,68]	[0,13]	[1,51]	[0,18]	[0,87]	[0,27]	[1,27]	[0,18]	[1,53]	[1,09]
TEDSwiss(-1)	-1,23	-0,52	-0,25	0,42	-1,04	-0,37	-0,39	-0,16	0,07	-0,01
t-stat	[3,10]	[1,99]	[0,66]	[1,20]	[2,73]	[0,86]	[1,04]	[0,39]	[0,24]	[0,14]
R-squared	0,52	0,26	0,35	0,44	0,59	0,23	0,32	0,30	0,36	0,94
Adj.R-squared	0,22	-0,20	-0,07	0,08	0,33	-0,26	-0,11	-0,14	-0,04	0,90

	Austr.	Can.	New Z.
TED Swiss(-1)	-0,92	-0,17	-0,65
t-stat	[2,40]	[1,37]	[1,23]
Non-Threshold Variables			
Alpha	0,00	0,00	0,00
t-stat	[3,02]	[2,07]	[2,25]
R-squared	0,11	0,02	0,05
AdjustedR-squared	0,09	0,01	0,03

Table 6.4.: Regression results for the VAR of the EW-HF strategy payoffs and the major stock market indices' returns

In the following tables it is presented first the VAR including the payoffs for each currency of the EW-HF strategy and the returns of each currency's stock market index's return lagged one month. Notice that despite the model includes the first and second lagged autoregressive value of the dependent variables, these values are not presented due to space limitations. Both regressions use a time sample from 03/1999-12/2003.

	AUSTRA.	CAN.	EURO	JAP.	NEW Z.	NOR.	SWED.	SWISS	UK	US
Alpha	0,01	0,01	0,01	-0,01	0,01	0,01	0,01	0,00	0,00	0,00
t-stat	[3,03]	[1,89]	[1,26]	[1,26]	[9,93]	[0,99]	[1,64]	[0,92]	[0,52]	[0,97]
IndexAustralia(-1)	0,09	0,05	0,11	-0,18	-0,06	-0,04	0,03	-0,09	0,01	0,00
t-stat	[0,82]	[0,42]	[0,78]	[1,19]	[1,30]	[0,16]	[0,18]	[0,61]	[0,08]	[-1,04]
IndexCanada(-1)	-0,07	-0,02	-0,08	0,10	-0,08	-0,08	-0,06	0,07	-0,04	0,00
t-stat	[1,73]	[0,52]	[1,44]	[1,88]	[4,80]	[0,96]	[1,07]	[1,47]	[1,33]	[3,78]
IndexEuro(-1)	-0,05	-0,06	-0,06	0,00	-0,11	-0,11	-0,08	0,07	-0,03	0,00
t-stat	[0,77]	[0,71]	[0,63]	[0,03]	[3,81]	[0,78]	[0,83]	[0,82]	[0,49]	[-1,13]
IndexJapan(-1)	-0,03	-0,01	-0,05	0,05	-0,04	-0,03	-0,03	0,06	-0,02	0,00
t-stat	[1,09]	[0,43]	[1,26]	[1,47]	[3,43]	[0,56]	[0,74]	[1,79]	[0,99]	[-1,64]
IndexNewZ.(-1)	0,00	0,00	-0,04	0,02	0,08	0,02	0,01	0,03	-0,01	0,00
t-stat	[0,02]	[0,05]	[0,59]	[0,32]	[4,09]	[0,15]	[0,18]	[0,42]	[0,17]	[-0,10]
IndexNorway(-1)	0,05	0,03	0,03	-0,03	0,10	0,08	0,05	-0,04	0,02	0,00
t-stat	[1,41]	[0,73]	[0,68]	[0,62]	[6,32]	[1,05]	[1,04]	[0,80]	[0,62]	[-0,84]
IndexSweden(-1)	0,00	0,00	0,00	0,05	-0,01	0,00	0,02	0,01	0,02	0,00
t-stat	[0,02]	[0,06]	[0,00]	[0,76]	[0,71]	[0,04]	[0,32]	[0,17]	[0,54]	[-0,53]
IndexSwiss(-1)	-0,08	-0,05	0,00	-0,06	-0,07	0,00	-0,04	-0,05	0,01	0,01
t-stat	[1,32]	[0,67]	[0,01]	[0,72]	[2,95]	[0,01]	[0,49]	[0,61]	[0,15]	[3,17]
IndexUK(-1)	-0,06	-0,04	0,06	0,11	-0,04	0,09	0,07	-0,10	0,08	0,00
t-stat	[0,47]	[0,29]	[0,38]	[0,69]	[0,93]	[0,40]	[0,46]	[0,72]	[0,83]	[-0,69]
IndexUS(-1)	0,19	0,15	0,03	-0,10	0,30	0,07	0,03	0,01	-0,05	0,00
t-stat	[1,55]	[1,09]	[0,16]	[0,62]	[6,06]	[0,26]	[0,20]	[0,06]	[0,52]	[0,80]
R-squared	0,95	0,79	0,87	0,86	0,99	0,73	0,86	0,89	0,91	0,99
Adj.R-squared	0,45	-0,14	-0,47	-0,54	0,90	-0,96	-0,58	-0,23	0,01	0,97

Table 6.5.: Regression results for the VAR and Threshold Model of the EW-HF strategy payoffs and the volatility of the spot exchange rates

In the following tables it is presented first the VAR including the payoffs for each currency of the EW-HF strategy and the volatility of the spot exchange rates lagged one month. Secondly, the results for the Threshold model regression between the Swedish payoffs for the latter strategy and its spot exchange rate volatility lagged one month. Notice that despite the model includes the first and second lagged autoregressive value of the dependent variables, these values are not presented due to space limitations. Both regressions use a time sample from 03/1999-12/2003.

	AUSTRA.	CAN.	EURO	JAP.	NEW Z.	NOR.	SWED.	SWISS	UK	US
Alpha	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00
t-stat	[1,29]	[0,99]	[0,24]	[0,81]	[1,32]	[1,04]	[1,53]	[3,03]	[0,68]	[0,31]
Vol.AUD(-1)	0,00	0,00	0,01	0,16	-0,12	-0,32	-0,20	-0,06	-0,03	-0,06
t-stat	[0,01]	[0,02]	[0,05]	[0,61]	[0,41]	[1,13]	[0,89]	[0,22]	[0,13]	[0,92]
Vol.CAD(-1)	-0,46	-0,13	-0,40	-0,13	-0,46	0,10	-0,55	0,10	-0,23	0,05
t-stat	[1,46]	[0,65]	[1,35]	[0,42]	[1,36]	[0,28]	[2,10]	[0,34]	[0,95]	[0,62]
Vol.EURO(-1)	0,75	0,27	0,23	0,14	0,44	0,43	0,34	-0,27	-0,13	-0,04
t-stat	[2,64]	[1,52]	[0,84]	[0,51]	[1,44]	[1,43]	[1,42]	[0,98]	[0,57]	[0,60]
Vol.GBP(-1)	-0,03	-0,04	-0,15	0,00	-0,12	-0,14	-0,14	0,00	-0,01	0,02
t-stat	[0,31]	[0,74]	[1,63]	[0,01]	[1,15]	[1,34]	[1,69]	[0,01]	[0,07]	[0,88]
Vol.NOK(-1)	0,10	0,00	0,12	-0,18	0,18	0,62	0,18	-0,58	0,32	-0,29
t-stat	[0,73]	[0,00]	[0,95]	[1,29]	[0,12]	[0,42]	[0,16]	[0,43]	[0,29]	[0,91]
Vol.NZD(-1)	-0,18	-0,08	0,15	-0,21	0,26	0,23	0,18	-0,18	0,09	0,03
t-stat	[0,79]	[0,57]	[0,71]	[0,92]	[1,05]	[0,96]	[0,93]	[0,81]	[0,50]	[0,61]
Vol.SEK(-1)	0,68	0,19	0,11	0,93	0,16	-0,28	3,11	0,19	0,16	-0,13
t-stat	[0,38]	[1,71]	[0,65]	[0,53]	[0,82]	[0,15]	[2,10]	[1,10]	[1,21]	[0,31]
Vol.SWF(-1)	-0,10	-0,37	-0,29	-0,13	-0,74	-0,16	-0,54	-0,06	0,15	0,07
t-stat	[2,94]	[1,73]	[0,87]	[0,37]	[1,95]	[0,44]	[1,84]	[0,16]	[0,54]	[0,87]
Vol.YEN(-1)	-0,16	-0,18	-0,28	-0,18	-0,49	0,18	-0,49	-0,32	-0,17	0,10
t-stat	[1,11]	[2,03]	[0,20]	[0,12]	[0,31]	[1,16]	[0,41]	[2,35]	[0,15]	[0,30]
R-squared	0,65	0,54	0,51	0,48	0,62	0,45	0,61	0,55	0,46	0,95
Adj.R-squared	0,29	0,06	0,01	-0,06	0,23	-0,12	0,21	0,08	-0,09	0,90

	Sweden
Vol. SEK(-1)	2,26
t-stat	[4,36]
Non-Threshold Variables	
Alpha	0,00
t-stat	[4,36]
R-squared	0,21
Adjusted R-squared	0,19

Table 7: Sortino ratio values for relevant Carry Trade strategies

In the following tables it is presented first Sortino ratio with and without transaction costs for all the five studied carry trade strategies and the OPT-RER&TED&VOL(0) strategy, as well as, for the market's for the period between 02/1976 and 01/2015.

	WithoutTransactionCosts						
	EW	SPW	EW-HF	Dollar Carry	Ranking	Market	OPT-RER&TED &VOL(0)
Mean	3,26%	5,28%	4,99%	6,90%	5,49%	6,27%	5,71%
Negative Vol.	1,24%	1,71%	1,08%	1,52%	2,05%	3,58%	1,08%
Sortino rat.	2,62	3,08	4,62	4,53	2,69	1,75	5,30
Mean 2008-2015	-0,34%	0,83%	0,37%	2,27%	1,10%	9,69%	1,25%
Negative Vol .2008-2015	2,24%	3,50%	2,02%	3,03%	3,43%	5,06%	2,08%
Sortino rat. 2008-2015	-0,15	0,24	0,18	0,75	0,32	1,92	0,60

	WithTransactionCosts					
	EW	SPW	EW-HF	Dollar Carry	Ranking	OPT-RER&TED &VOL(0)
Mean	3,19%	5,17%	4,12%	5,48%	5,33%	4,88%
Negative Vol.	1,24%	1,72%	1,08%	1,54%	2,05%	1,08%
Sortino rat.	2,57	3,01	3,83	3,55	2,60	4,53
Mean 2008-2015	-0,44%	0,66%	-0,25%	1,45%	0,59%	0,69%
Negative Vol. 2008-2015	2,25%	3,50%	2,02%	3,03%	3,44%	2,08%
Sortino rat. 2008-2015	-0,20	0,19	-0,12	0,48	0,17	0,33

Table 8: Drawdown for relevant Carry Trade strategies

In the following tables it is presented the 10 strongest Drawdown with and without transaction costs for all the five studied carry trade strategies and the OPT-RER&TED&VOL(0) strategy, as well as, for the market's for the period between 02/1976 and 01/2015.

Without Transaction Costs

EW				SPW				EW-HF				Dollar Carry				Ranking				Market				OPT-RER&TED&VOL(0)			
Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$
1	23,99%	110	90	1	28,86%	58	213	1	19,32%	46	128	1	22,14%	59	298	1	35,81%	68	287	1	49,39%	40	503	1	16,55%	44	38
2	21,35%	71	39	2	18,49%	45	43	2	10,11%	39	21	2	15,27%	51	225	2	27,27%	57	63	2	47,48%	86	475	2	12,77%	24	104
3	11,11%	38	21	3	15,51%	29	16	3	8,39%	23	9	3	9,81%	12	77	3	21,37%	43	62	3	32,21%	29	48	3	8,18%	45	77
4	10,31%	28	11	4	14,12%	43	43	4	8,10%	17	22	4	9,46%	25	13	4	15,97%	25	16	4	28,54%	23	76	4	6,37%	9	12
5	9,00%	17	17	5	11,53%	24	97	5	5,82%	21	39	5	9,06%	34	60	5	11,95%	30	46	5	20,75%	19	58	5	5,15%	20	5
6	6,28%	13	10	6	9,62%	21	80	6	5,45%	15	9	6	8,65%	8	15	6	10,98%	15	21	6	18,32%	23	30	6	4,49%	11	36
7	5,66%	7	6	7	8,55%	11	23	7	5,21%	10	13	7	7,12%	9	34	7	10,09%	13	71	7	17,27%	10	184	7	4,45%	8	39
8	5,30%	8	7	8	8,50%	18	33	8	4,48%	14	29	8	6,56%	11	23	8	9,47%	22	78	8	16,92%	5	127	8	4,05%	8	36
9	4,19%	18	10	9	8,09%	8	12	9	3,81%	6	5	9	6,39%	7	22	9	6,87%	12	7	9	14,08%	19	15	9	3,96%	15	17
10	4,14%	17	11	10	7,22%	9	13	10	3,36%	8	10	10	6,02%	16	10	10	6,77%	8	11	10	13,17%	6	16	10	3,56%	7	10

With Transaction Costs

EW				SPW				EQ-HF				Dollar Carry				Ranking				OPT-RER&TED&VOL(0)			
Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$	Scl.	Mag. DD	#Mths	Los.$
1	24,34%	110	90,4	1	29,18%	59	209,0	1	20,21%	46	101,6	1	23,52%	59	203,3	1,0	36,01%	69	280,4	1	17,07%	45	35,5
2	21,42%	89	40,8	2	18,64%	43	44,4	2	10,84%	43	19,8	2	17,07%	51	154,7	2,0	27,34%	57	65,7	2	13,70%	29	85,6
3	11,43%	42	22,3	3	15,74%	30	16,1	3	9,52%	23	9,7	3	12,73%	32	16,1	3,0	23,68%	44	70,5	3	10,50%	45	74,9
4	10,50%	29	10,7	4	14,61%	45	44,5	4	8,41%	21	19,6	4	11,04%	34	59,0	4,0	16,09%	26	16,5	4	6,61%	9	11,4
5	6,20%	13	9,9	5	11,81%	24	95,1	5	6,34%	45	31,9	5	10,45%	36	50,0	5,0	12,08%	30	45,5	5	6,17%	35	6,2
6	5,54%	7	6,1	6	9,74%	21	78,3	6	5,78%	18	9,1	6	9,37%	26	14,0	6,0	10,83%	15	21,6	6	4,86%	13	30,1
7	4,93%	7	6,9	7	8,81%	11	24,8	7	5,50%	11	12,0	7	7,72%	10	28,0	7,0	10,20%	22	80,3	7	4,63%	8	30,7
8	4,25%	18	10,0	8	8,55%	18	32,6	8	4,84%	16	24,1	8	7,22%	12	20,3	8,0	10,14%	13	69,1	8	4,38%	16	15,1
9	4,20%	17	11,1	9	7,68%	8	11,5	9	3,89%	7	4,4	9	6,82%	7	18,6	9,0	6,93%	12	7,0	9	4,16%	8	28,2
10	3,30%	12	3,3	10	7,14%	9	12,7	10	3,63%	17	12,4	10	5,52%	4	7,4	10,0	6,36%	6	7,7	10	3,90%	8	9,8

Table 9: Pure Drawdown for relevant Carry Trade strategies

In the following tables it is presented the 10 strongest Pure Drawdown with and without transaction costs for all the five studied carry trade strategies and the OPT-RER&TED&VOL(0) strategy, as well as, for the market's for the period between 02/1976 and 01/2015.

Without Transaction Costs

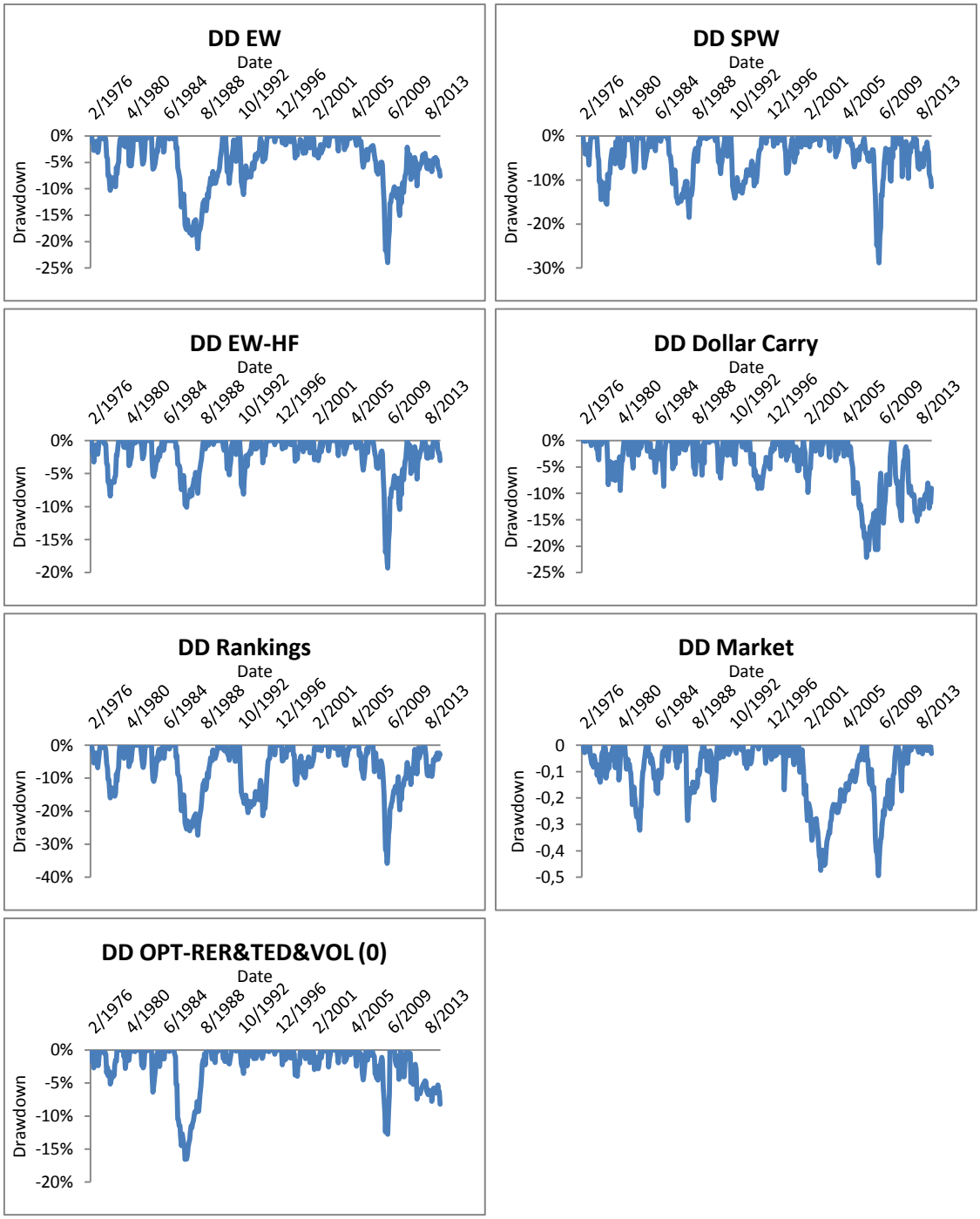
EW				SPW				EQ-HF				Dollar Carry				Ranking				Market				OPT-RER&TED&VOL(0)			
Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$
1	19,41%	6	63,2	1	25,53%	6	160,9	1	16,97%	5	101,6	1	9,45%	5	119,9	1	39,47%	8	248,8	1	34,33%	3	249,1	1	12,18%	5	92,4
2	12,35%	6	21,0	2	15,23%	5	42,6	2	8,45%	5	22,2	2	9,04%	5	15,4	2	19,41%	6	51,0	2	33,60%	3	75,7	2	6,58%	2	11,9
3	11,78%	5	21,4	3	11,44%	6	24,9	3	6,85%	6	13,4	3	8,90%	2	99,4	3	18,98%	6	38,7	3	21,97%	4	142,4	3	5,72%	1	12,2
4	7,92%	4	12,5	4	10,99%	4	10,7	4	6,07%	4	6,1	4	8,73%	2	11,2	4	12,98%	4	23,9	4	21,17%	5	51,8	4	5,56%	2	50,0
5	7,53%	4	7,4	5	10,87%	6	85,1	5	5,61%	3	9,4	5	8,58%	4	121,1	5	12,78%	3	31,0	5	19,78%	4	139,9	5	5,34%	3	12,0
6	6,97%	2	12,5	6	9,57%	2	76,0	6	5,24%	4	9,9	6	8,46%	2	117,2	6	11,77%	2	80,4	6	18,96%	5	183,7	6	4,77%	2	34,7
7	6,75%	3	10,2	7	9,52%	3	18,8	7	5,16%	2	31,4	7	8,44%	5	110,0	7	11,63%	3	21,3	7	18,93%	3	169,6	7	4,62%	4	9,3
8	6,48%	2	9,8	8	9,05%	2	49,7	8	5,08%	3	33,2	8	8,36%	2	93,1	8	10,30%	4	10,0	8	18,54%	2	126,7	8	4,57%	2	42,0
9	5,81%	2	6,2	9	8,88%	3	33,0	9	4,48%	2	24,5	9	7,90%	1	95,8	9	9,73%	5	76,5	9	18,22%	2	103,1	9	4,54%	4	9,0
10	5,78%	2	19,1	10	8,86%	3	69,8	10	4,48%	2	29,4	10	7,42%	4	56,4	10	8,55%	3	15,0	10	18,10%	4	22,8	10	4,00%	3	31,1

With Transaction Costs

EW				SPW				EQ-HF				Dollar Carry				Ranking				OPT-RER&TED&VOL(0)			
Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$	Scl.	Mag. PD	#Mths.	Los.$
1	19,52%	6	62,4	1	25,64%	6	156,5	1	17,29%	5	78,1	1	9,81%	5	79,7	1	39,68%	8	242,7	1	12,45%	5	71,9
2	12,36%	6	21,7	2	15,79%	5	44,5	2	9,20%	7	8,9	2	9,60%	2	11,6	2	20,43%	6	55,0	2	6,84%	2	11,4
3	12,13%	5	22,3	3	11,42%	6	25,7	3	8,79%	5	19,6	3	9,57%	5	13,6	3	18,94%	6	40,2	3	5,77%	1	11,0
4	7,93%	4	13,0	4	11,01%	4	10,6	4	7,23%	6	12,7	4	9,05%	2	63,1	4	16,85%	7	15,7	4	5,56%	2	37,7
5	7,58%	4	7,4	5	10,96%	6	82,2	5	5,96%	3	9,1	5	8,85%	4	76,8	5	12,95%	4	24,8	5	5,43%	3	11,0
6	7,11%	2	13,1	6	9,60%	3	19,5	6	5,43%	4	9,1	6	8,79%	5	70,2	6	12,79%	3	31,0	6	4,84%	2	26,8
7	6,82%	3	10,6	7	9,58%	2	73,3	7	5,22%	2	23,8	7	8,60%	2	72,3	7	11,81%	2	78,0	7	4,84%	4	8,8
8	6,40%	2	9,9	8	9,08%	2	48,2	8	5,19%	3	25,2	8	8,51%	2	59,4	8	11,46%	3	21,6	8	4,72%	4	8,3
9	5,74%	2	18,6	9	8,94%	3	32,6	9	4,58%	2	18,8	9	7,97%	1	60,2	9	10,21%	5	76,4	9	4,55%	1	31,6
10	5,72%	3	19,8	10	8,91%	3	67,6	10	4,57%	2	22,3	10	7,90%	4	40,3	10	8,64%	3	15,8	10	4,19%	3	25,2

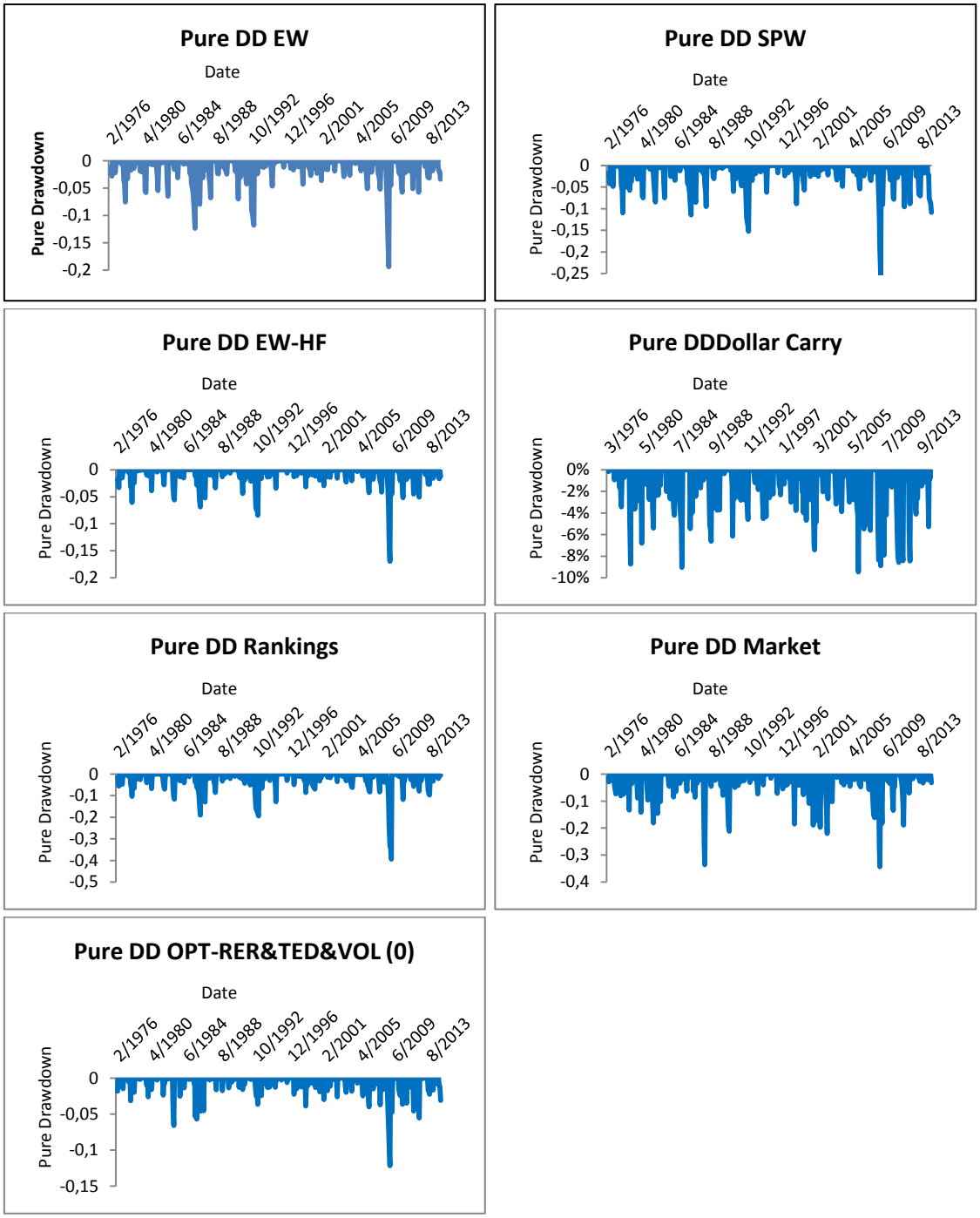
Graph 3: Drawdown for relevant Carry Trade strategies

In the following graphs it is presented the Drawdowns without transaction costs for all the five studied carry trade strategies and the OPT-RER&TED&VOL(0) strategy, as well as, for the market's for the period between 02/1976 and 01/2015.



Graph 4: Pure Drawdown for relevant Carry Trade strategies

In the following graphs it is presented the Pure Drawdowns without transaction costs for all the five studied carry trade strategies and the OPT-RER&TED&VOL(0) strategy, as well as, for the market's for the period between 02/1976 and 01/2015.



Appendix A

VAR Model

The vector autoregressive model used was of order two due to the system's requirements, denoted as VAR (2), is as follows:

$$y_{t,j} = \alpha_{1,j} y_{t-1,j} + \alpha_{2,j} y_{t-2,j} + \beta_k x_{t-1,k} + \varepsilon_t \quad (17)$$

Where $y_t$is a j vector of endogenous variables, x_{t-1} a is k vector of exogenous variables, α_1, α_2 and β are matrices of coefficients to be estimated, and ε_t is a vector of innovations that may be contemporaneously correlated among themselves but uncorrelated with their own lagged values and also uncorrelated with all of the right-hand side variables. Therefore, in this Working Project $y_{t,j}$ represents the carry trade return at period t for the currency j, while $x_{t-1,k}$ represents the regime indicator k at the period t-1. Vector autoregressive models (VAR) were advocated in Sims (1980).

Threshold Regression Model

On the other hand, the threshold regression model used is as it follows:

$$y_t = \begin{cases} \alpha + \beta_1 x_{t-1} + \varepsilon_t \; if \; x_{t-1} > \gamma \\ \alpha + \beta_2 x_{t-1} + \varepsilon_t if \; x_{t-1} \leq \gamma \end{cases} \quad (18)$$

Where y_t is the endogenous variable, x_{t-1} is the exogenous variable lagged one period, β_n is the coefficient to be estimated under regime n, ε_t is the error value of the regression, and γ is the threshold value to be estimated.

For further explanations on threshold models one can consider Hansen (2000). Furthermore, the author acknowledges the use of threshold models by the development of the Threshold Autoregressive (TAR) model of Tong (1983, 1990).