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THE PROFITABILITY OF CARRY TRADE: AN EMPIRICAL ANALYSIS.

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INTRODUCTION

Carry trade is one of the most widespread speculative activities in the foreign exchange (FX) market, which has gained a growing popularity among investors during the last decades, due to the significantly positive profitability observed through years. Basically, the strategy consists of an investment in a high-yielding currency, referred to as “investment currency”, entirely funded by a short position in another currency associated with a lower interest rate, defined as “funding currency”. Thus, carry trade profits from the positive interest rate differential between two currencies, while speculating on movements in the related exchange rate: the investor entering the strategy receives an interest rate from its investment that is higher than the interest rate paid on its debt, thus earning the differential; at the same time, the return to the position is affected by variations in the spot exchange rate between the currencies involved during the investment period. The excess return to a carry trade strategy is therefore made up of two components, namely, the interest differential, which is risk free, and the appreciation/depreciation of currencies, subject to exchange rate risk.

According to international finance theory, and in particular to the framework provided by the Uncovered Interest Parity and the Forward Rate Unbiasedness, the carry trade should not be profitable on average, since the high-yielding currency is expected to experience a depreciation that should exactly offset the gains deriving from the interest rate differential, so that the expected excess return equals zero. However, the two above-mentioned theoretical relationships have proven to not hold empirically, as supported by several studies; the failure of these conditions is often referred to as “forward premium puzzle” in academic literature and it represents the empirical phenomenon that allows speculators to profit from carry trade activity.

The profitability of the strategy is one of the most investigated anomalies in FX markets: several academics has provided evidence of positive average excess returns, trying to find a possible justification in terms of compensation for the exposure to sources of risk; however, despite the various risk-based explanations proposed, an agreement on the source and the nature of the carry trade profitability has not yet been reached in literature.

The aim of this thesis is to analyze the carry trade strategy both from a theoretical and an empirical point of view: the research first focuses on the theoretical framework behind the investment strategy and then presents a literature review, providing evidence of positive excess returns and proposing different explanations for the observed profitability; finally, following the academic studies examined, an empirical analysis of the strategy is carried out, in order to directly assess the performance of carry trade and check whether it is consistent with a risk-based explanation. The thesis is structured in three chapters, organized as follows.

The first chapter is dedicated to the empirical anomaly that makes carry trade profitable, that is, the “forward premium puzzle”; the chapter starts with the description of three fundamental results in international finance, which establish the relationship between interest rates and spot and forward exchange rates, also known as “parity conditions”: the covered interest parity (CIP), the uncovered interest parity (UIP) and the forward rate unbiasedness (FRU). After the illustration of how these conditions are derived and what are the main assumptions and implications, the major findings in the related empirical literature are reported: while the first relationship is generally supported by data, several studies point out the failure of the other two, since the interest differential between a currency pair (or the forward premium) seems to predict exchange rate changes with the opposite sign with respect to what is prescribed by theory. Finally, the chapter reviews the principal explanations provided by researchers for the forward premium anomaly, which still remains largely unexplained, allowing investors to gain significant profits from speculations on exchange rate movements.

In the second chapter, the focus shifts to the main subject of this research, namely, the carry trade strategy; it is analyzed in detail, explaining its rationale, deriving the associated expected return and investigating the relationship between the latter and the forward premium puzzle. Further, different ways of implementing the strategy are described, starting from the basic trading rule involving just one currency pair to more complex investments in currency portfolios, and the risks associated with this speculative activity are illustrated. Then, the chapter presents empirical evidence of carry trade profitability, through the analysis of carry trade indices’ performance and the study of the strategies simulated by authors in academic literature; the reported evidence reveals statistically and economically significant average excess return, from 1980s to recent years. The last paragraph of the chapter, instead, focuses on the possible reasons behind carry trade profitability and, in particular, on the validity of a risk-based explanation: the researchers has studied the exposure of the strategy to different sources of risk, estimating several factor models, from the traditional ones to others specifically developed for the strategy, in order to check whether the excess returns delivered represent a compensation for bearing risk; furthermore, alternative explanations have been proposed, like, among others, the negative skewness of return and the presence of peso problems.

Finally, the third and last chapter presents a personal empirical analysis on carry trade, carried out to directly verify the profitability of the strategy during the last 20 years, from the point of view of an investor from the Eurozone. Data on interest rates and exchange rates are collected from Bloomberg and Refinitiv Workspace, in order to simulate different carry trade strategies involving the basket of G10 currencies, over the sample period from December 2001 to December 2021, with monthly frequency. The analysis first focuses on the computation of the excess returns, both for single currency positions and for two carry trade portfolios, built following different allocation criteria. Then, once assessed the performance of the simulated strategies, possible risk-based explanations for the profitability of carry trade are investigated, through the estimation of factor models, considering first conventional risk factors and then more specific ones; in particular, the monthly excess returns to the carry trade portfolios are regressed on the different factor considered, in order to study the strategies' exposure to the sources of risk involved and check whether the positive average excess returns represent a remuneration for risks borne by the investor.

CHAPTER 1 – THE FORWARD PREMIUM PUZZLE

1.1 Introduction

In order to understand how the currency carry trade operates and why it represents a profitable investment strategy, we first need to recall some basic results in international finance theory. Indeed, carry trade, like other speculative trading activities, is able to generate positive excess returns due to market inefficiencies.

The Efficient Market Hypothesis (EMH)[1] states that market efficiency depends on the degree to which information is incorporated into current security prices. Capital markets can be considered efficient when market prices reflect all the relevant information about the securities and are able to rapidly adjust to the arrival of new information; in this case, markets are also referred to as informationally efficient. If EMH holds, then there is no possibility for traders to consistently "beat the market", namely to obtain extraordinary profits, since any information available to an investor is already reflected into the price.

Efficiency in the foreign exchange market implies that some relationships between exchange rates, interest rates and prices should hold: these are the so-called "parity conditions", which represents the fundamentals of international finance. In particular, I will focus on three of these relationships, that are the most relevant for the analysis of carry trade:

1. The Covered Interest Parity (CIP), a non-arbitrage condition which links the forward premium, or forward discount, to the interest rate differential;
2. The Uncovered Interest Parity (UIP), a condition that establishes the relationship between interest rate differential and expected exchange rate depreciation, implying speculative efficiency in the foreign exchange market;
3. The Forward Rate Unbiasedness (FRU), an expression derived from the combination of the former two conditions, under the assumption of rational expectations, which states that forward exchange rates are unbiased predictor of future spot exchange rates.

[1] The Efficient Market Hypothesis is an economic theory usually related to Eugene Fama and his review of theory and empirical evidence (Fama, 1970).

This chapter is dedicated to the analysis of these relationships and the review of the related empirical literature, focusing in particular on the evidence about the failure of the UIP and FRU, also known as "forward premium puzzle", which is the phenomenon that allows speculators to obtain profits from carry trade. The following three paragraphs present the Covered Interest Parity (1.2), the Uncovered Interest Parity (1.3) and the Forward Rate Unbiasedness (1.4), describing how these are derived, what are the main assumptions behind them and the principal implications that follow. Paragraphs 1.5 and 1.6 illustrate the major findings from the empirical literature on these parity conditions, in particular, from the numerous studies that point out the empirical failure of the UIP and FRU. Finally, the last paragraph (1.7) examines also the primary explanations provided by researchers for the forward premium anomaly.

1.2 Covered Interest Parity

The Covered Interest Parity is a pure non-arbitrage condition: this means that when this relationship is violated, risk-free profit opportunities arise for investors. In the foreign exchange market, absence of arbitrage requires that an investment in a foreign currency and a comparable investment in the domestic currency must yield equal returns (expressed in the same currency), when the exchange rate risk is fully hedged[2]. If this is not the case, then investors will exploit the difference in the returns to obtain risk-free profits, until market equilibrium is restored.

This non-arbitrage principle can hold only in a fully integrated world with no market frictions, such that arbitrageurs can freely move funds among countries. This assumption is referred to as perfect capital mobility, which implies the absence of significant transaction costs, capital controls and, in general, any other restriction to capital movements.

To derive the Covered Interest Parity condition, consider an investor that has one unit of domestic currency and want to invest it for k periods; she/he can choose among two alternatives: investing in domestic or foreign bonds.

Following the first investment strategy, the gross return to the investor at the end of the investment period is:

[2] Therefore, the foreign investment is defined as "covered".

$$R_{t+k}^{D} = \left(1 + i_{t,k}\right)$$

where $i_{t,k}$ is the k-period interest rate at time t.

Alternatively, if the investor decides to invest in the foreign asset, she/he must follow three steps:

1. Exchange the domestic currency for the foreign currency: 1 unit of home currency yields $1/S_t$ units of the foreign one[3].
2. Invest foreign currency for k periods at the relevant foreign interest rate $i_{t,k}^{*}$.
3. Exchange back the foreign currency for the domestic one; to hedge the exchange rate risk, the investor can sell forward the foreign currency at the currency forward rate $F_{t,k}$[4].

Hence, investing in the foreign bond will generate a gross return (in domestic currency terms) equal to

$$R_{t+k}^{F} = \frac{F_{t,k}}{S_t}(1 + i_{t,k}^{*})$$

Both the domestic and the foreign investment are risk-free, since all the variables that make up the returns are known at time t; moreover, they both require the same initial investment, 1 unit of domestic currency. This implies that, in absence of arbitrage, they should yield the same return, $R_{t+k}^{D} = R_{t+k}^{F}$. Thus, equating the two expressions for the returns, we have

$$\left(1 + i_{t,k}\right) = \frac{F_{t,k}}{S_t}(1 + i_{t,k}^{*}) \qquad (1.1)$$

Equation (1.1) can be reformulated to derive the Covered Interest Parity condition:

$$\frac{F_{t,k}}{S_t} = \frac{(1 + i_{t,k})}{(1 + i_{t,k}^{*})} \qquad (1.2)$$

[3] S_t is the spot exchange rate defined as the price of the foreign currency in terms of the domestic one: in other words, the amount of domestic currency needed to buy 1 unit of foreign currency.
[4] The forward exchange rate is the exchange rate for the future exchange between two currencies, predetermined when a forward contract is stipulated. In this case, the forward rate $F_{t,k}$ is the price of the foreign currency (in domestic currency terms) established at time t for the exchange of currencies after k periods.

Further, taking a logarithmic approximation of the formula above, we obtain the logarithmic version of the CIP, that is the one generally used in empirical tests:

$$f_{t,k} - s_t = i_{t,k} - i^*_{t,k} \tag{1.3}$$

where s_t stands for the logarithm of the spot exchange rate, while $f_{t,k}$ is the logarithm of the forward exchange rate.

As we can see from the two equation, the CIP provides a linkage between spot and forward exchange rates and interest rate differential. In particular, the logarithmic version in equation (1.3) has a clear interpretation: the percentage forward premium/discount $(f_t - s_t)$, for any pair of currencies, should reflect exactly the interest rate differential between the two countries considered $(i_t - i^*_t)$. This implies that, considering two currencies, the one that yields the highest interest rate should trade at a forward discount, and vice versa.

1.3 Uncovered Interest Parity

The second relationship considered is the Uncovered Interest Parity (UIP), which links the interest rate differential to the expected exchange rate appreciation/depreciation. Analogously to CIP, this is a non-arbitrage condition; however, it involves uncertainty (due to exchange rate risk) and speculation, since the foreign investment in this case is not "covered".

UIP condition can be derived following an argument similar to the one used for the CIP. We consider again an investor with one unit of domestic currency and two investment alternatives, domestic and foreign bonds. The first alternative is unchanged: it is still a risk-free investment and yields the same k-period gross return, namely $R^D_{t+k} = (1 + i_{t,k})$.

The second strategy, instead, is not hedged against exchange rate risk in this case: it does not involve the forward sale of foreign currency, so the investor, at the end of the investment period, will change the proceeds to domestic currency at the future spot exchange rate S_{t+k}. Clearly, now the investment in foreign bond is not risk-free, so the return cannot be determined with certainty, but we can compute the expected gross return as

$$E_t[R^F_{t+k}] = \frac{E_t[S_{t+k}]}{S_t}(1 + i^*_{t,k})$$

where $E_t[S_{t+k}]$ is the expected value of the k-period ahead spot exchange rate conditional on the information available at time t.

In order to derive the UIP condition, it is necessary to consider an additional assumption: risk neutrality, the investors' attitude of indifference between various levels of risk. If the investor that is faced with the choice between the domestic and foreign investment opportunities is risk-neutral, she/he will be interested only in the expected returns delivered, without considering the volatility of the investments. In this setting of risk neutrality, the two investments should yield the same expected return, as they have the same cost (1 unit of domestic currency), according to the no-arbitrage principle. Thus, we can equate the expected returns for the domestic and the foreign bond:

$$\left(1 + i_{t,k}\right) = \frac{E_t[S_{t+k}]}{S_t}(1 + i_{t,k}^*) \tag{1.4}$$

Assuming that all investors are risk-neutral and, moreover, that they all have homogeneous expectations ($E_t[S_{t+k}]$), we can rearrange terms in equation (1.4) to derive the Uncovered Interest Parity condition as follows:

$$\frac{E_t[S_{t+k}]}{S_t} = \frac{(1 + i_{t,k})}{(1 + i_{t,k}^*)} \tag{1.5}$$

Again, applying the logarithmic transformation, we obtain the following logarithmic version of the UIP:

$$E_t[s_{t+k}] - s_t = i_{t,k} - i_{t,k}^* \tag{1.6}$$

Notice that, in equation (1.5) and (1.6), $E_t[s_{t+k}]$ is defined as the market's expectation about the future spot exchange rate, on the basis of time t information.

The Uncovered Interest Parity tells us that the expected exchange rate appreciation/depreciation must equal the interest rate differential, otherwise arbitrage opportunities arise for risk-neutral investors. Accordingly, if UIP holds, a (risk-neutral) investor cannot profit from speculation on high- and low-yielding currencies, since any gain deriving from the interest rate differential is completely offset by anticipated exchange rate changes.

However, the assumption of risk-neutrality poses some problem for the empirical validity of the UIP, since it is a strong assumption that does not hold in general, as investors are commonly risk-averse;

this suggests that a risk premium should be added to the foreign investment return, as will be discussed more in detail in the last paragraph of this chapter.

1.4 Forward Rate Unbiasedness

The last relationship analysed is the Forward Rate Unbiasedness (FRU) hypothesis, which argues that forward exchange rates are unbiased predictors of future spot exchange rates. This hypothesis is derived from the combination of the former two parity conditions, under the additional assumption of rational expectations. Therefore, in order for the FRU to hold, the following three main assumptions are needed:

- *Perfect capital mobility*, necessary for the validity of the Covered Interest Parity;
- *Risk neutrality*, which is required by the Uncovered Interest Parity;
- *Rational expectations*, the assumption added for the purpose of deriving the FRU; it is an economic theory about individuals' forecasts on economic variables. Rational expectations theory assumes that agents make decisions combining the information available in the market with their past experience and using human rationality. This kind of expectations is assumed to be the optimal forecast; this implies that individuals do not make systematic errors in formulating their expectations.

In this framework, both CIP and UIP hold; we can combine equations (1.3) and (1.6) to obtain the following relationship:

$$E_t[s_{t+k}] - s_t = f_{t,k} - s_t \tag{1.7}$$

Equation (1.7) tells us that the expected appreciation/depreciation should be equal to the forward premium/discount, when Covered and Uncovered Interest Parity hold.

Furthermore, applying rational expectations, the value of the k-period ahead spot exchange rate can be defined as

$$s_{t+k} = E_t[s_{t+k}] + u_{t+k} \tag{1.8}$$

where u_{t+k} is the forecast error: a random term with $E_t[u_{t+k}] = 0$.

Substituting the expression for the expectation from (1.8) into equation (1.7) yields

$$s_{t+k} - s_t = f_{t,k} - s_t + u_{t+k} \tag{1.9}$$

Thus, under rational expectations, the combination of the UIP and CIP shows that the forward premium/discount should predict the future change in the spot rate, except for a random error term.

In order to show that the forward rate is an unbiased predictor of the future spot rate, we first notice that (1.9) can be rewritten as

$$s_{t+k} = f_{t,k} + u_{t+k}$$

and then we compute the expected value:

$$E_t[s_{t+k}] = E_t[f_{t,k} + u_{t+k}] = E_t[f_{t,k}] + E_t[u_{t+k}] = f_{t,k},$$

where we can exploit the linearity of expectations, the fact that $f_{t,k}$ is not a stochastic variable (it is known at time t) and the property $E_t[u_{t+k}] = 0$. Once shown that

$$E_t[s_{t+k}] = f_{t,k} \tag{1.10}$$

we can conclude that the k-period forward rate is an unbiased predictor of the k-period ahead spot rate.

1.5 Empirical evidence on Covered Interest Parity

The empirical studies on Covered Interest Parity have generally agreed on the validity of the relationship, as the several tests performed show that there are not significant deviations from the parity condition, and so no profitable arbitrage opportunities, once accounted for transaction costs and other market frictions. Clearly, given its nature of non-arbitrage condition, the CIP has proven to hold in particular for industrial countries with free floating exchange rates and no restrictions to capital mobility.

It is possible to identify three main kinds of studies in the CIP empirical literature, according to the type of test they are based on:

- *Estimation of covered interest differentials*

Several tests have been performed through the computation of the covered interest differential, namely

$$\left(1+i_{t,k}\right)-(1+i_{t,k}^{*})\frac{F_{t,k}}{S_t} \qquad (1.11)$$

In order for the CIP to hold, this differential must equal 0, otherwise arbitrageurs will earn risk-free profits. Usually, researchers estimated the value of (1.11) and tested for the existence of profitable opportunities; most of these tests show that differentials are generally small, with some deviations that can be largely explained by higher transaction costs or market features. Examples of such research include Frenkel and Levich (1975,1977), Clinton (1988), Taylor (1987,1989) and Obstfeld and Taylor (2004).

- *Regression analysis*

In other studies, Covered Interest Parity has been tested carrying out regression analysis, on the basis of the logarithmic version in equation (1.3). In particular, such studies consist in testing the null hypothesis $H_0 : \alpha = 0,\ \beta = 1$ in the following regression:

$$f_{t,k}-s_t=\alpha+\beta\left(i_{t,k}-i_{t,k}^{*}\right)+\varepsilon_t \qquad (1.12)$$

Indeed, it is clear that the Covered Interest Parity holds when in (1.12) the intercept, α, is insignificantly different from 0 and the regression coefficient β does not significantly differ from 1. The results obtained from this analysis are also consistent with the validity of CIP: while the β is usually not significantly different from 1, in some tests the intercept tends to assume values that are different from 0; however, this does not represent evidence against CIP, as it is considered a consequence of transaction costs and other market frictions, like taxes and illiquidity. This line of empirical research includes, among others, Grubel (1966), Branson (1969) and Lang (1981).

- *Survey data*

The last segment of the empirical literature on CIP consists of studies performed with the use of survey data. An example is provided by Herring and Marston (1976) and Levich (1985) with their interviews to large bankers, which disclosed that they employed forward premium/discount to fix the spreads among foreign and domestic currency deposit rate applied to their clients. Further, surveys showed also that traders exploited the CIP to establish the forward rate offered to clients.

The early empirical literature on Covered Interest Parity includes the studies carried out by Frenkel and Levich, in 1975 and 1977. In their first research, they tested the validity of the CIP on a 3-month horizon for the major currency pairs, with both 3-month T-bill and euro-deposit rates; they used weekly data from January 1962 to November 1967. The results of this analysis support the CIP, after accounting for transaction costs: the few deviations found can be explained mainly by transaction costs (for about 85%) and also by other market features. In their later study (1977), Frenkel and Levich extended their previous analysis, expanding their sample and dividing it into three subperiods to analyse the impact of different exchange rate regimes; the results for all the periods were consistent with previous findings.

Further evidence in favour of CIP can be found in studies by Taylor (1987, 1989): he confirmed the findings of earlier research, using high-frequency data; moreover, he questioned studies showing evidence of deviations from the parity conditions, because these yielded results not compatible with a real trading situation, as they do not use simultaneous high-frequency data from currency and interest rate markets.

Although the above-mentioned empirical evidence has supported the validity of CIP for several years, some of the latest research show that the condition has been violated since the financial crises of 2008. In particular, Borio et al. (2016) and Du et al. (2018) observed systematic and persistent departures from the CIP, not explained by transaction costs, which imply significant arbitrage opportunities, even for the major currencies. According to these studies, deviations can be caused by the increasing limits to arbitrage deriving from banking regulation and shocks to assets' demand and supply resulting from unconventional policies of central banks. However, researchers are still analysing this phenomenon and searching for the reasons behind it.

1.6 Empirical evidence on Uncovered Interest Parity and Forward Rate Unbiasedness

While the CIP has generally proven to hold (with the exception of the last decade), literature on Uncovered Interest Parity and Forward Rate Unbiasedness has exhibited evidence for the failure of both the relationships; this anomaly is sometimes referred to as the "Forward Premium Puzzle". The two conditions have usually been tested jointly, since they are closely related: indeed, the FRU holds under the validity of both the CIP and UIP, in conjunction with the rational expectations' assumption;

consequently, once that CIP is verified, the Unbiasedness hypothesis differs from the UIP just for the additional assumption on expectations. Given the evidence in favor of CIP, researchers have assumed the latter to be valid and, therefore, have conducted studies on Forward Unbiasedness, which are also considered as indirect tests for the UIP. This was a consequence of the impossibility to test directly for the latter, since the relationship includes a variable that is not directly observable, namely the expected exchange rate appreciation/depreciation, $E_t[s_{t+k}]$; however, these tests involves assuming rational expectations, which may have implications on the results.

An attempt to direct test for UIP is represented by studies performed employing survey data on expectations; this method allows to remove the assumption of rational expectations. This part of empirical literature presents results that are more supportive of validity of the UIP; however, survey-based measures might create some problems, such as their availability, completeness or accuracy, as they may not mirror true expectations, have different horizons with respect to those of forecasters or be based on current forward premium/discount.

To clearly understand the forward premium anomaly, it is necessary to briefly review some of the empirical findings of both tests for the FRU and tests with survey data.

- *Tests for Forward Rate Unbiasedness Hypothesis*

Empirical literature testing for the Uncovered Interest Parity in conjunction with rational expectations assumption generally involves regression analysis, based on equation (1.9)

$$s_{t+k} - s_t = \alpha + \beta(f_{t,k} - s_t) + \varepsilon_{t+k} \tag{1.13}$$

or, alternatively, on equation (1.6) imposing rational expectations

$$s_{t+k} - s_t = \alpha + \beta(i_{t,k} - i^*_{t,k}) + \varepsilon_{t+k} \tag{1.14}$$

In both cases, the conditions are checked testing the null hypothesis $H_0\colon\ \alpha = 0,\ \beta = 1$. However, the intercept might differ from 0, due to the presence of a constant risk premium (because risk neutrality does not hold) or to approximation errors related with Jensen's inequality[5].

Most of the studies that estimated regressions (1.13) or (1.14) for horizons shorter or equal to one year found strong evidence for the rejection of UIP. One of the most notable examples in the early

[5] Jensen's inequality states that, given a convex function g, the expectation of the function is always greater than or equal to the function of the expectation: E[g(X)] ≥ g(E[X]). In our framework, this applies to the exchange rate, since the expectation of a ratio is different from the ratio of the expectation.

literature is Fama (1984), which estimated (1.13), also known as “Fama Regression”, and obtained negative values for the beta. Froot and Thaler (1990), with a similar analysis, found an average estimate of the slope coefficient of -0,88. These estimates show drastic deviations from UIP and FRU, since the forward premium/discount is able to forecast future exchange rate variation, but it points in the opposite direction: a positive forward premium is followed by a decrease in the spot rate, and vice versa, contrary to what theory suggests. The above-mentioned results are just some of the several findings that suggest rejection of the UIP and the FRU, showing that both the constant term and the coefficient of the regression tend to be negative.

However, some studies documented that the validity of the relationship is affected by the time horizon chosen: the UIP seems to hold better in the long run. Indeed, for short-term horizons the exchange rate path is better predicted by a random walk model rather than by interest rate differentials[6], while at longer horizons the latter outperform the former. An example of such findings is provided by Chinn and Meredith (2004), which estimated the regression for G7 currencies at 5- and 10-years horizons, finding greater support with respect to horizons shorter than one year, with positive coefficients close to the unity.

- *Tests with survey data*

The alternative method proposed by researchers in order to directly test the UIP, without imposing rational expectations, involves the usage of data on expected exchange rate movements collected through surveys. This implies that, in regression (1.13) and (1.14), the ex-post measure of the future spot rate, s_{t+k}, is replaced with the survey-based ex-ante measure $\hat{s}_{t+k}$. Tests of this types has provided results that support the UIP, thus suggesting that the rejection of the Unbiasedness hypothesis resulted from the other studies may be due to the assumption of rational expectations. This approach was proposed by Froot and Frankel (1989) and then supported also by Chinn and Frankel (1994, 2016), which first showed that rejection of UIP was more difficult using survey-based data and then confirmed their findings in their subsequent study, observing that similar results were still obtained when increasing the sample with data up to 2009. However, as already mentioned, tests with survey-based forecasts are quite challenging due to the nature of these data, which are not easily available and often may be incomplete or inaccurate.

One of the most recent studies in the UIP literature is “The New Fama Puzzle” by Bussiere et al. (2018), which revisited the forward puzzle, considering the developments of the last years, such as,

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[6] as shown by Cheung et al. (2005, 2017)

in particular, the lower level of short-term interest rates, that reached the zero-lower bound in some periods. The study tested both the UIP condition and the FRU hypothesis for eight currencies[7] against the US dollar, following the two different approach mentioned above, that is, running the regression (1.14) with both the ex-post and the ex-ante (survey-based) measures of the exchange rate variation. The period considered is January 2000 – February 2016: the test is carried out first for the full sample and then for two subperiods, to account for the break point given by the financial crisis of 2008[8]. The estimation of the Fama regression shows results that are consistent with earlier evidence: the unbiasedness hypothesis seems to be rejected by data; the table below (Figure 1.1) summarizes the estimates at the one-year horizon for the full sample and the two subperiods, pre- and post-crisis.

[7] Canadian Dollar, Swiss Franc, Danish Krone, Euro, Japanese Yen, Norwegian Krone, Swedish Krona and Pound Sterling.

[8] Bussiere et al. (2018) carried out a Chow test to find the break date and found that all the currencies analyzed exhibited a significant break around 2007-2008; however, no common date resulted from the test, so they chose to set it on August 2007.

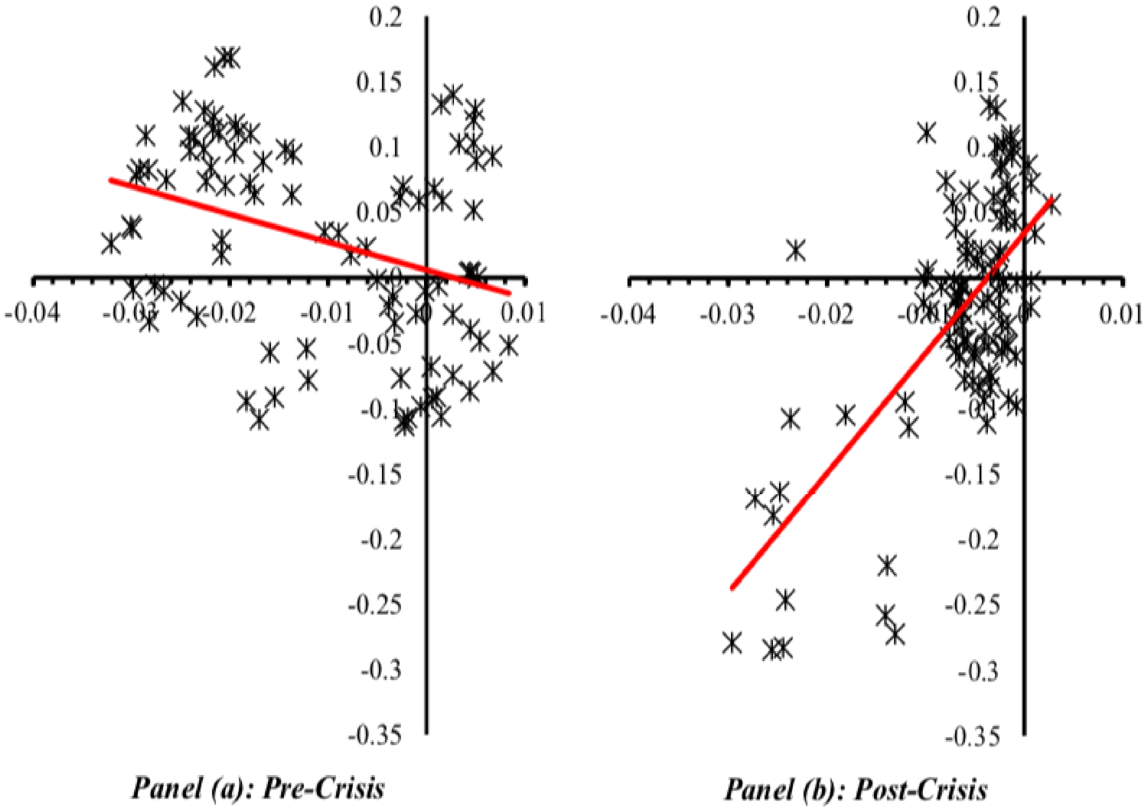
Figure 1.1 – *Fama regression results.*

	Canadian Dollar	Swiss Franc	Danish Krone	Euro	Japanese Yen	Norwegian Krone	Swedish Krona	Pound Sterling
Panel (A): Full Sample, 2000M1 – 2016M2								
Constant	0.013	0.049*	0.003	0.005	-0.007	-0.006	-0.002	-0.001
	(0.017)	(0.027)	(0.021)	(0.022)	(0.037)	(0.027)	(0.025)	(0.017)
Beta	1.838	-1.525*	-1.871	-1.500	0.117	-0.177	-0.953	0.351
	(2.274)	(1.332)	(1.876)	(1.887)	(1.134)	(1.448)	(1.709)	(2.290)
Adjusted R^2	0.020	0.035	0.035	0.021	-0.005	-0.005	0.007	-0.004
P-value of F-Statistic	0.026	0.005	0.005	0.024	0.758	0.748	0.121	0.599
N. observations	194	194	194	194	194	194	194	194
Panel (B): Pre-Crisis, 2000M1 – 2007M8								
Constant	0.035***	0.129***	0.048***	0.061***	0.085***	0.013	0.039*	0.003
	(0.012)	(0.023)	(0.016)	(0.016)	(0.027)	(0.023)	(0.021)	(0.027)
Beta	-3.631***	-4.85***	-5.065***	-5.107***	-2.564***	-2.000***	-4.034***	-2.089***
	(1.291)	(0.969)	(1.409)	(1.171)	(0.808)	(0.936)	(1.302)	(1.427)
Adjusted R^2	0.295	0.435	0.424	0.463	0.284	0.189	0.366	0.105
P-value of F-Statistic	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
N. observations	92	92	92	92	92	92	92	92
Panel (C): Post-Crisis, 2007M9 – 2016M2								
Constant	0.031	-0.007	-0.016	-0.013	-0.054	0.047	0.003	0.034**
	(0.021)	(0.027)	(0.025)	(0.023)	(0.036)	(0.040)	(0.030)	(0.016)
Beta	10.857***	4.239**	3.147	5.888**	4.387***	5.863***	5.145**	9.983***
	(1.975)	(1.505)	(2.875)	(2.166)	(1.244)	(1.782)	(1.777)	(2.325)
Adjusted R^2	0.379	0.115	0.055	0.168	0.253	0.166	0.150	0.473
P-value of F-Statistic	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000
N. observations	102	102	102	102	102	102	102	102

Note: the table reports the estimates of the Fama regression, at the 1-year horizon, for the Full sample and the Pre- and the Post-Crisis subsamples; the base currency is the US Dollar. Significance tests relate to the null hypothesis that the intercept is null and slope equal to one. * (**) [***] denotes significance at the 10% (5%) [1%] marginal significance level. The F-statistic refers to the joint null hypothesis that the intercept is null and slope equal to one.
Source: BUSSIERE M., CHINN M. D., FERRARA L., HEIPERTZ J. 2018. The new Fama puzzle. NBER Working Paper 24342.

As we can observe in Panel (A), the beta coefficients estimated for the full sample regression are almost all negative, in accordance with previous findings, and the same holds for the pre-crisis period, as reported in Panel (B); however, completely different values result from the regression over the post-crisis sample: the slope coefficients, shown in Panel (C), are all positive, but much larger than 1 (from 3.91 to 10.9) and the F-test rejects the null hypothesis of unity. This means that, for the period after the global financial crisis, the correlation among interest differentials and exchange rate variation presents the sign prescribed by the UIP, but the magnitude is not consistent with the arbitrage nature of the relationship. Moreover, this evidence suggests that the parity condition seems to hold better in periods of high risk, in contrast with the intuition that it should be verified in an environment in which investors do not give importance to risk (i.e. risk neutrality). The presence of a structural break between the two periods before and after the financial crisis can be observed also through the scatterplot of exchange rate changes and interest differentials (for the currency pair US Dollar – Pound Sterling) in Figure 1.2, which highlights how the slope of the linear fit changes from negative to positive between the two subsamples.

Figure 1.2 – *Linear fit of exchange rate variations on interest rate differentials.*



Note: the figure displays the linear fit of 1-year ex-post depreciation rate (1 year ahead) on 1-year Eurodeposit Rates Differential of US Dollar with respect to Pound Sterling, for the two subperiods, Pre- and Post-Crisis.
Source: BUSSIERE M., CHINN M. D., FERRARA L., HEIPERTZ J. 2018. The new Fama puzzle. NBER Working Paper 24342.

The tests performed using survey data, instead, provide quite different results; the regression analysis is performed substituting the ex-post measure of depreciation with the ex-ante survey-based measure, which is defined assuming classical measurement error

$$\hat{s}_{t+k} = E_t[s_{t+k}] - \eta_{t+k}.$$

Where $E_t[\eta_{t+k}] = 0$; this means that the survey-based measure is equal to the market expectations plus a measurement random error with zero mean. This test is carried out running the regression

$$\hat{s}_{t+k} - s_t = \alpha + \beta(i_{t,k} - i^*_{t,k}) + \varepsilon_{t+k}$$

Where the error ε_{t+k} embeds the forecasts error, which in this case is not guaranteed to be mean zero. In this case, UIP is tested without imposing rational expectations, since the assumption that the ex-ante (expected) depreciation is an unbiased measure of the ex-post depreciation is relaxed. The results obtained do not reject the condition, thus confirming prior empirical research based on this approach; the estimates are presented in the following table:

Figure 1.3 – *UIP Regression results using survey data for expectations on exchange rate.*

	Canadian Dollar	Swiss Franc	Danish Krone	Euro	Japanese Yen	Norwegian Krone	Swedish Krona	Pound Sterling
Panel (A): Full Sample, 2003M1 – 2016M2								
Constant	-0.007*	-0.061***	-0.013**	-0.014**	-0.058***	0.027***	0.023***	-0.006
	(0.004)	(0.008)	(0.006)	(0.006)	(0.009)	(0.004)	(0.006)	(0.006)
Beta	-0.327***	3.481***	1.388	1.699	3.167***	1.332	1.395	0.424
	(0.308)	(0.339)	(0.559)	(0.528)	(0.270)	(0.237)	(0.395)	(0.390)
Adjusted R^2	0.001	0.483	0.133	0.180	0.657	0.233	0.176	0.013
P-value of F-Statistic	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.092
N. observations	146	146	146	146	146	146	146	146
Panel (B): Pre-Crisis, 2003M1 – 2007M8								
Constant	-0.003	-0.008	0.012**	0.012**	-0.018	0.026***	0.045***	0.005
	(0.004)	(0.013)	(0.006)	(0.006)	(0.013)	(0.005)	(0.007)	(0.006)
Beta	-0.468***	1.839*	1.127	1.096	2.337***	1.151	0.689	0.458*
	(0.268)	(0.497)	(0.375)	(0.374)	(0.341)	(0.200)	(0.316)	(0.284)
Adjusted R^2	0.028	0.304	0.198	0.182	0.612	0.272	0.085	0.044
P-value of F-Statistic	0.144	0.000	0.001	0.002	0.000	0.000	0.031	0.093
N. observations	44	44	44	44	44	44	44	44
Panel (C): Post-Crisis, 2007M9 – 2016M2								
Constant	-0.009	-0.067***	-0.026***	-0.025***	-0.062***	0.033***	0.015***	-0.005
	(0.007)	(0.008)	(0.005)	(0.023)	(0.036)	(0.040)	(0.005)	(0.007)
Beta	-0.276*	3.247***	0.666	1.245	2.922***	1.685	1.527	1.097
	(1.975)	(0.454)	(0.639)	(0.620)	(0.363)	(0.451)	(0.467)	(0.536)
Adjusted R^2	-0.007	0.329	0.019	0.068	0.546	0.174	0.135	0.046
P-value of F-Statistic	0.598	0.000	0.091	0.005	0.000	0.000	0.000	0.017
N. observations	102	102	102	102	102	102	102	102

Note: the table reports the estimates obtained running the UIP regression with survey data for expected exchange rate variation, at the 1-year horizon, for the Full sample and the Pre- and the Post-Crisis subsamples; the base currency is the US Dollar. Significance tests relate to the null hypothesis that the intercept is null and slope equal to one. * (**) [***] denotes significance at the 10% (5%) [1%] marginal significance level. The F-statistic refers to the joint null hypothesis that the intercept is null and slope equal to one.
Source: BUSSIERE M., CHINN M. D., FERRARA L., HEIPERTZ J. 2018. The new Fama puzzle. NBER Working Paper 24342.

The slope coefficients are almost all positive in this case, so again this may indicate that evidence of failure of the UIP, when tested assuming rational expectations, depends on the assumption on market forecasts. Moreover, these data do not exhibit the same break observed in the previous estimates between the two subperiods, implying that this can depend on the nature of the forecasts error.

To summarize, the empirical literature overall reveals that the Uncovered Interest Parity and the Forward Rate Unbiasedness are not supported by data, since the interest differential (or the forward premium) seems to predict exchange rate changes with the opposite sign with respect to what is prescribed by theory. The forward premium puzzle (or Fama puzzle) is one of the most investigated empirical anomalies, but it is still largely unexplained.

1.7 Explanations for the forward premium puzzle

Since the anomaly of the forward biasedness has been supported by a great variety of studies, it is worth it to try to understand which phenomena may justify this empirical result. Several explanations have been proposed by researchers through years; the most frequently advocated theories are the presence of a time varying risk premium and the investors' irrationality. Both of them stem from the questioning of the two main assumption behind the unbiasedness hypothesis: risk-neutrality and rational expectations.

- *Risk Premia*

Uncovered Interest Parity and Forward Unbiasedness are both derived under the assumption that investors are risk-neutral, namely they are not concerned about the level of risk of an investment, so they make investment decisions considering just the expected return, not the associated volatility. However, in general, investors are not risk-neutral, but rather they tend to be risk-averse; this implies that they require a higher compensation to bear higher level of risk, that is, a risk premium. Since UIP involves uncertainty (specifically, exchange rate risk), investors' risk aversion and, consequently, the risk premium should be considered. The presence of these risk premia may be one of the phenomena responsible for departures from the UIP and FRU. Several studies have tried to check whether this theory is supported by data or not, using different methods, which includes CAPM; the resulting evidence is mixed. For instance, Lustig and Verdelhan (2005) used a CAPM framework, with interest rate differentials as explanatory variables, and obtained positive evidence; further, Fama (1984) observed that forward biasedness can be explain by the presence of a risk premium different from zero. On the other hand, Froot and Frankel (1989) found evidence against this theory and Frankel and Poonawala (2006) argued that risk premia are not a reasonable explanation of the bias, since the latter resulted to be larger for developed economy rather than emerging countries, where risk is typically higher.

- *Irrationality*

The extra assumption added to derive the Forward Rate Unbiasedness is that all investors have rational expectations. This means assuming that investors process correctly and efficiently all the available information and do not commit systematic error in their predictions, as defined in equation (1.8); hence, the market forecast is the best one that can be formulated on the basis of the available information. An implication is that the forecast error of market participants must be uncorrelated with all the variables known at time t. However, real-world investors can be irrational, or have limited rationality, and in this case their forecasts can be systematically biased; this fact clearly creates problem for the unbiasedness hypothesis and can explain its empirical failure. This is suggested also by the empirical evidence reviewed in the previous paragraph: while estimates of Fama regression generally presents strong evidence for the rejection of the FRU, the survey-based tests for the UIP without the assumption of rational expectations tend to favor the parity condition. Literature supporting the irrationality-based explanation of the forward premium puzzle usually resorts to survey data on expected depreciation, since this kind of measure allows to compute the forecast error u_{t+k} of (1.8) and then to verify if it is uncorrelated with all information available at time t; these empirical tests show a strong negative correlation among the error term and the forward premium, meaning that information is not efficiently processed by market participants, thus explaining the forward rate bias. Advocates of this theory are, among others, Froot and Frankel (1989) and Chinn and Frankel (1994), which argue that failure of the unbiasedness hypothesis is due to errors in market forecasts, rather than to risk premia.

In order to analyze more formally how deviations from the Forward Unbiasedness can be determined by risk premia and systematic forecast error, it can be useful to examine the decomposition of the forward premium bias proposed by Froot and Frankel (1989). The slope coefficient β of the Fama regression in equation (1.13) can be expressed as

$$\beta = \frac{Cov(\Delta s_{t+k}, f_{t,k} - s_t)}{Var(f_{t,k} - s_t)} \tag{1.15}$$

where $\Delta s_{t+k} = s_{t+k} - s_t$. According to rational expectations hypothesis, from equation (1.8), we can define $\Delta s_{t+k} = E_t[\Delta s_{t+k}] + u_{t+k}$ and substitute in (1.15), obtaining the following decomposition:

$$\beta = \frac{Cov(E_t[\Delta s_{t+k}], f_{t,k} - s_t) + Cov(u_{t+k}, f_{t,k} - s_t)}{Var(f_{t,k} - s_t)} \tag{1.16}$$

by bilinearity of the covariance.

Now we can define also the risk premium, which can be interpreted as a variable that creates a gap among forward and expected future spot exchange rate,

$$rp_t \equiv E_t[s_{t+k}] - f_t \tag{1.17}$$

This allows us to write the expected future spot rate change as the sum of the forward premium/discount and the risk premium,

$$E_t[\Delta s_{t+k}] = (f_t - s_t) + rp_t \tag{1.18}$$

Plugging (1.18) in (1.16), with a bit of algebra, yields

$$\beta = 1 + \frac{Cov(rp_t, f_{t,k} - s_t)}{Var(f_{t,k} - s_t)} + \frac{Cov(u_{t+k}, f_{t,k} - s_t)}{Var(f_{t,k} - s_t)}$$

Which, applying again (1.17) and covariance bilinearity, can be rewritten as

$$\beta = 1 - \frac{Var(rp_t) - Cov(rp_t, E_t[\Delta s_{t+k}])}{Var(f_{t,k} - s_t)} + \frac{Cov(u_{t+k}, f_{t,k} - s_t)}{Var(f_{t,k} - s_t)} \tag{1.19}$$

From the above formula, it is easily observable that the beta coefficient of the Fama regression may deviate from the theoretical value of unity because of these two covariance terms; the first one refers to the risk premium, while the second one is related to the forecast error. These two components are defined as

$$\beta_{rp} = \frac{Var(rp_t) - Cov(rp_t, E_t[\Delta s_{t+k}])}{Var(f_{t,k} - s_t)}$$

and

$$\beta_{re} = -\frac{Cov(u_{t+k}, f_{t,k} - s_t)}{Var(f_{t,k} - s_t)}$$

to rewrite the forward bias decomposition in a more compact way:

$$\beta = 1 - \beta_{rp} - \beta_{re} \tag{1.20}$$

β_{rp} depends on the variance of the risk premium and its covariance with expected depreciation; when there is a time-varying risk premium, i.e. the variance is different from zero, this component will be non-zero. β_{re} is determined by the covariance of the forecast error with the forward premium; since the latter falls within the information available on the market at time t, the forecast errors should be uncorrelated with it, according to rational expectations assumption. Thus, when agents do not have rational expectations, the β_{re} term will be different from zero. When both the assumptions of risk-neutrality and rational expectations do not hold empirically, the two components in (1.20) may differ from zero, thus giving rise to the bias.

Froot and Frankel (1989) estimated the components of the forward premium bias, with pooled data on different currencies, using survey data for the expectation on exchange rate movements; the results are summarized in the following table.

Figure 1.4 – *Components of the Forward Premium Bias.*

			Failure of rational expectations (1)	Existence of risk premium (2)	Implied regression coefficient 1-(1)-(2)
Data set	Approximate dates	N	b_{re}	b_{rp}	β
Economist data	6/81–12/85	525	1.49	0.08	−0.57
Econ 3-month	6/81–12/85	190	2.51	−0.30	−1.21
Econ 6-month	6/81–12/85	180	2.99	−0.00	−1.98
Econ 12-month	6/81–12/85	155	0.52	0.19	0.29
MMS 1-month	11/82–1/88	740	4.81	−2.07	−1.74
MMS 3-month	1/83–10/84	188	6.07	1.18	−6.25
AMEX data	1/76–7/85	97	3.25	−0.03	−2.21
AMEX 6-month	1/76–7/85	51	3.63	−0.22	−2.42
AMEX 12-month	1/76–7/84	46	3.11	0.03	−2.14

Note: estimates of the beta coefficients and the risk premium and the forecast error components, obtained with pooled data on different currencies. Data on expectations come from three different surveys: one by the American Express Banking Corporation of London between 1976 and 1985, another by The Economist's Financial Report during the period 1981-1985 and the last by Money Market Services (MMS) of Redwood City, California, from 1982 to 1988.
Source: Froot K.A., Frankel J.A. 1989. *Forward Discount Bias: Is it an Exchange Risk Premium?* The Quarterly Journal of Economics, Vol. 104, No. 1 (Feb. 1989), pp. 139-161.

The results show larger values for the rational expectations component, rather than the risk premium one; moreover, while the β_{re} values are always positive (thus contributing to deviations of the beta from the unity), the β_{rp} assumes also negative values in some cases, meaning that it drives the slope coefficient towards 1. Froot and Frankel concluded that risk premia have little power in explaining the forward premium puzzle, whereas forecasts errors seem to cause a large portion of the deviations from the theoretical relationship.

A similar analysis on the decomposition of the beta coefficients was carried out also in the study by Bussiere et al. (2018), examined in the former paragraph. They pointed out three components responsible for the bias: the two terms outlined before plus an additional one, which represents the covered interest differential. In this framework, the formula for the decomposition proposed is

$$\beta = 1 - \beta_{cip} - \beta_{rp} - \beta_{re} \tag{1.21}$$

Where the components are defined as

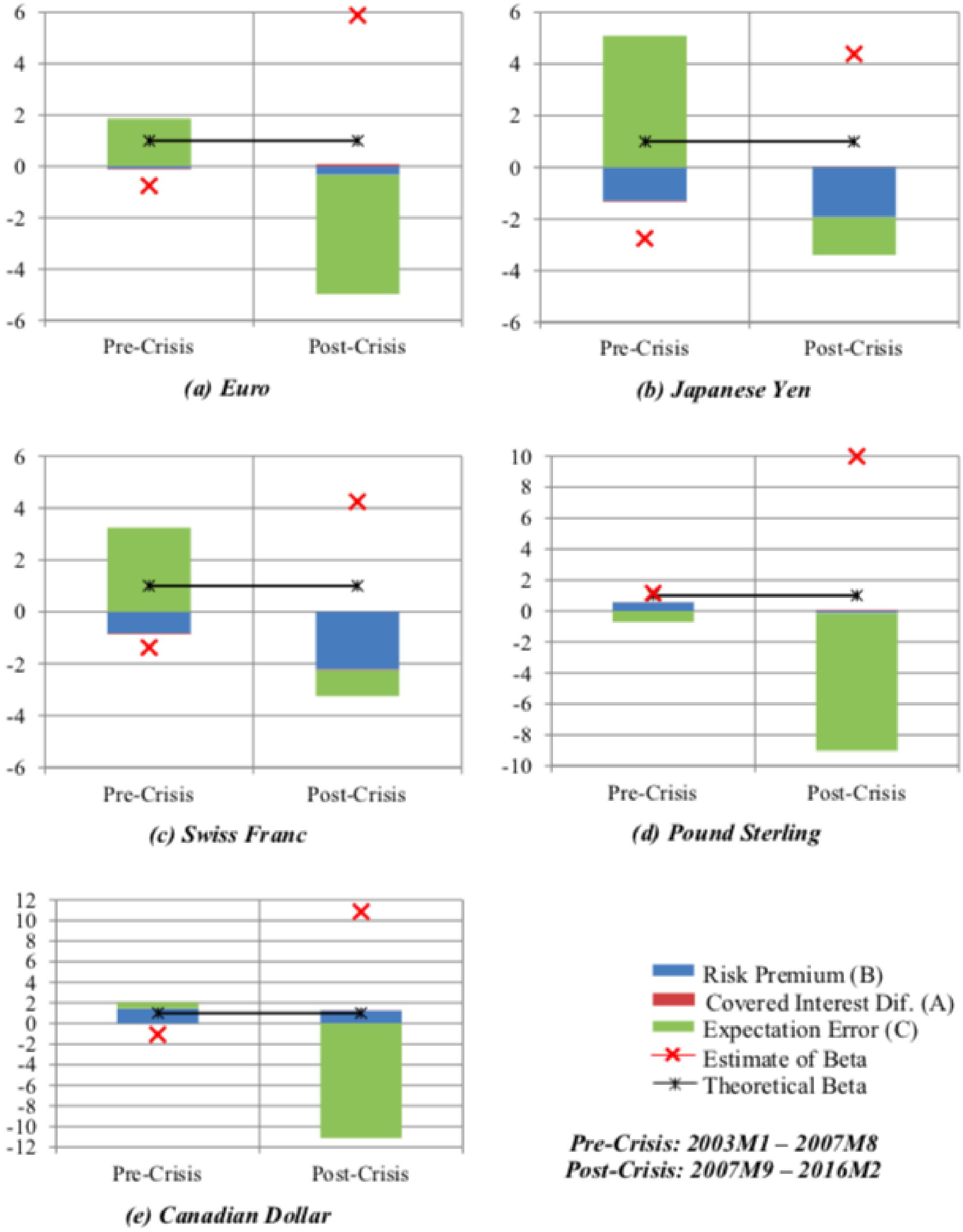
$$\beta_{cip} = \frac{Cov(i_{t,k} - i^*_{t,k}, \epsilon^{cip}_{t,k})}{Var(i_{t,k} - i^*_{t,k})}$$

$$\beta_{rp} = \frac{Cov(i_{t,k} - i^*_{t,k}, \epsilon^{rp}_{t,k})}{Var(i_{t,k} - i^*_{t,k})}$$

$$\beta_{re} = \frac{Cov(i_{t,k} - i^*_{t,k}, \epsilon^{re}_{t+k})}{Var(i_{t,k} - i^*_{t,k})}$$

The term β_{cip} equals zero when the covered interest differential is zero, that is, when the Covered Interest Parity holds; in general, several studies in literature assumed that $\beta_{cip} = 0$, according to the strong support of CIP founded during past years. However, Bussiere et al. do not impose this assumption, to account for the more recent evidence of departures from the Covered Parity. This implies that also the latter may contribute to the failure of the FRU, together with violations of risk-neutrality and rational expectations. The results of the estimation of these components are represented in Figure 1.5.

Figure 1.5 – *Decomposition of deviations from unity of beta estimates from 1-year horizon Fama regression w.r.t. US Dollar*.



Source: BUSSIERE M., CHINN M. D., FERRARA L., HEIPERTZ J. 2018. The new Fama puzzle. NBER Working Paper 24342.

The above figure shows clearly that departures from CIP have a very little impact on the overall deviations of the beta from unity, for all currencies. The risk premium component, instead, is able to explain a more significant part of the deviations in the post-crisis period, in particular for the Japanese yen (approximately half of the deviation) and the Swiss franc (roughly two thirds of the deviation); this means that, for the latter two currencies, which are the ones considered as “safe-haven”, most of the bias is determined by the negative correlation between the risk premium and the interest rate differentials. The component that has the major influence on beta's deviations is the one related to the forecast error, which seems also to be the main determinant in the switch of sign between the pre- and post-crisis periods; this is the result of changes in how the forecast error co-move with the interest rate differential: the correlation switches from positive in the pre-crisis period to negative in the post-crisis one.

Irrationality and risk premium are the two main reasons for the forward premium bias analyzed in literature; however, several other explanations have been proposed through years by researchers. Despite numerous studies have proved the influence of risk premia and forecast errors on the failure of the unbiasedness hypothesis, no consensus has been reached yet. In conclusion, the forward premium puzzle represents an empirical anomaly which remains still largely unexplained and allows investors to gain from speculative activities like carry trade.

CHAPTER 2 – THE CARRY TRADE STRATEGY

2.1 Introduction

The forward premium puzzle analyzed in the former chapter is the empirical anomaly exploited by traders that engage in the speculative activity of currency carry trade, that is one of the simplest and most widespread trading strategies in the foreign exchange market. The basic idea behind this strategy is to profit from the difference in the interest rates between currencies in a forex pair[9]: typically, the speculators borrow the currency associated with the lowest interest rate, the so-called "funding currency", to finance the investment in the currency with the highest yield, referred to as "investment currency". This implies that the investor will receive an interest rate from its investment that is higher than the interest paid on its debt, thus earning the differential; however, the strategy is not risk-free, since the return of the investment is affected by movements in the relevant exchange rate, thus leaving the investor exposed to exchange rate risk.

According to the theoretical framework provided by the Uncovered Interest Parity and the Forward Rate Unbiasedness, the carry trade, on average, should not be profitable: the high-yielding currency is expected to experience a depreciation that should exactly offset the gains deriving from the interest rate differential. Consequently, when UIP holds, the expected excess return of the strategy should be zero. However, as highlighted in the first chapter, there exists a vast literature supporting the empirical failure of the Uncovered Interest Parity; this anomaly allows investors to profit from carry trade activity.

Accordingly, several studies have addressed the profitability of carry trade, analyzing returns delivered from the strategy: the overall results point out significant positive excess returns. Consequently, a strand of the empirical literature has focused on the possible explanations for the observed returns, trying in particular to understand whether these can be justified by sources of risk involved in the activity. Numerous different risk-based explanations have been proposed by researchers through years, starting from traditional risk factors to more specific ones; however, an

[9] A forex pair, or currency pair, is the price quote of the exchange rate between two currencies traded in the foreign exchange market (Investopedia, https://www.investopedia.com/terms/c/currencypair.asp). The most commonly traded pairs for carry trade activity are AUD/JPY and NZD/JPY, where the Australian Dollar and New Zealand Dollar are used as investment currencies, while the Japanese Yen is the funding currencies, due to its features of "safe haven currency".

agreement on the source and the nature of the carry trade profitability has not yet been reached in literature.

This Chapter first provides an overview of the main characteristics of the carry trade strategy (paragraph 2.2), describing the rationale of this kind of trades, the expected return and its relationship with the forward premium puzzle, the different ways of implementing the strategy and, finally, the associated risks. Paragraph 2.3, instead, presents a literature review about the empirical evidence of carry trade profitability, whereas the last paragraph (2.4) analyses the different explanations provided by researchers for the observed returns associated with this speculative activity.

2.2 Basic features of carry trade

In finance, the term "carry" generally refers to the return obtained or the cost incurred by the investor when holding an asset; the asset will be referred to as a "positive carry asset" in the first case or a "negative carry asset" in the second one. The term "carry trade" instead refers to the currency carry trade strategy: as mentioned before, it is a speculative strategy in the foreign exchange market, which consists in borrowing a low-yielding currency and investing in a high-yielding currency, thus making profit from the interest rate differential among the currencies involved. This is a zero-investment strategy, in that it requires no initial investment, since funds borrowed at the lower interest rate are used to finance the investment in the currency with higher yield.

More specifically, the above-mentioned strategy is defined as "positive carry trade", in which speculators collect the interest rate differential, while betting that the exchange rate between the two currencies will remain the same or that the investment currency will appreciate. Despite this is the most common way of entering a carry trade, sometimes speculators undertake also the opposite strategy, the so-called "negative carry trade": in this case, the investor buys a currency characterized by a low interest rate and borrows a higher interest rate currency. Consequently, she/he will initially suffer a loss deriving from the difference between the interests paid and received, but there is the possibility of gains (that could even offset losses) if the high-yielding currency depreciates; hence, negative carry represents a speculation on the depreciation of the currency with the highest yield in a forex pair. However, this thesis focuses on the first type of carry trade, as it is the most commonly used by speculators and the most investigated in literature for the empirical evidence on its profitability.

2.2.1 Overview of the strategy

In order to describe how the carry trade works and derive its expected return, we should first consider the basic carry trading rule, usually implemented buying and selling short-term assets, with the same maturity. Suppose, for instance, that an investor observes a large interest rate differential between the domestic currency and a foreign one, in that the domestic interest rate (i_t) is significantly smaller than the foreign one (i_t^*). If the investor wants to enter a carry trade to exploit the difference among rates, she/he needs to take a long-foreign/short-domestic position. In particular, this can be accomplished with an investment in foreign bonds and the sale of domestic bonds.

Assume that the investor borrows one unit of domestic currency and uses this to fund a one-period investment in foreign bonds; since she/he needs to change the domestic currency into foreign one at the prevailing exchange rate S_t, the amount invested in foreign bonds will be equal to $1/S_t$. At the end of the investment period, the investor will change the proceeds of the investment back to domestic currency at the one-period ahead spot exchange rate S_{t+1}, since the investment is not covered. The realized gross return from the long foreign position is:

$$R_{t+1}^F = \frac{1}{S_t}(1 + i_t^*)\, S_{t+1} \tag{2.1}$$

while the gross return from shorting domestic bonds after one period is:

$$R_{t+1}^D = -(1 + i_t) \tag{2.2}$$

Combining the gross returns from the two positions, (2.1) and (2.2), we get the realized (ex-post) excess return from the carry trade:

$$X_{t+1} = (1 + i_t^*)\frac{S_{t+1}}{S_t} - (1 + i_t) \tag{2.3}$$

which, taking a logarithmic approximation, becomes

$$x_{t+1} = (i_t^* - i_t) + (s_{t+1} - s_t) \tag{2.4}$$

Equation (2.4) shows clearly that the realized excess return is made up of two components:

- the interest rate differential $(i_t^* - i_t)$, which by definition of carry trade is positive, since the currencies are chosen such that $i_t^* > i_t$.

- The ex-post appreciation/depreciation of the foreign currency with respect to the domestic one, $(s_{t+1} - s_t)$.

As opposed to the interest differential, which is known at time t, the second component can be observed only at the end of the investment period, so it is the element that makes the excess return of carry trade uncertain. This term will be positive when the foreign currency appreciates, increasing the return to carry trade, and negative instead when it depreciates; in the latter case, the depreciation, depending on its magnitude, can lower the investor's excess return, completely offset it or even cause potentially infinite losses when it exceeds the differential in yields. The depreciation component can also equal zero when the spot exchange rate at the end of the investment period remains at the same initial level.

To compute the expected (ex-ante) excess return to carry trade, we take expectations in (2.4):

$$E_t[x_{t+1}] = E_t[(i_t^* - i_t) + (s_{t+1} - s_t)] = (i_t^* - i_t) + (E_t[s_{t+1}] - s_t) \tag{2.5}$$

The expected excess return is equal to the interest rate differential plus the expected exchange rate variation; according to Uncovered Interest Parity, we have that the expected depreciation of the foreign currency is equal to the interest rate differential between the domestic and the foreign currency, namely

$$E_t[s_{t+1}] - s_t = (i_t - i_t^*) = -(i_t^* - i_t)$$

Thus, substituting the above expression for the expected depreciation in (2.5) yields

$$E_t[x_{t+1}] = (i_t^* - i_t) - (i_t^* - i_t) = 0$$

Which can be generalized for a k-period investment as

$$E_t[x_{t+k}] = 0 \tag{2.6}$$

The equation (2.6) states that, when UIP holds, the ex-ante (expected) excess return to carry trade should equal zero, meaning that the strategy should not be profitable on average. However, this is not what empirical evidence has suggested, since UIP is usually rejected by data and, as we will analyze more in detail in the following chapters, carry trade exhibits significant positive excess returns.

It is possible to examine the excess return of carry trade also from another point of view, that points out the linkage between the profitability of the strategy and the empirical failure of the Forward Rate

Unbiasedness hypothesis. Considering again the formula for the realized excess return in (2.4) and assuming the validity of Covered Interest Parity (1.3), we can rewrite

$$x_{t+1} = -(f_t - s_t) + (s_{t+1} - s_t) \tag{2.7}$$

And substituting from the Fama regression in (1.13), we have

$$x_{t+1} = \alpha + (\beta - 1)(f_t - s_t) + \varepsilon_{t+1} \tag{2.8}$$

Applying expectations, assuming that $E_t[\varepsilon_{t+1}] = 0$, the expected excess return to carry trade is:

$$E_t[x_{t+1}] = \alpha + (\beta - 1)(f_t - s_t) \tag{2.9}$$

From equation (2.9), we can clearly see that the forward premium anomaly implies positive expected return for carry trade: whenever the Fama regression provides a negative estimate for the beta coefficient, as usually found in empirical research, the strategy is on average profitable. In order to show this, we can consider, as before, a carry trade based on a long-foreign/short-domestic position; assuming foreign and domestic interest rates, respectively, at the 5% and 1% level, we obtain a differential $(i_t^* - i_t) = 4\%$. Under CIP, this means that the foreign currency trades at a forward discount of 4%, since the resulting forward premium is negative ($f_t - s_t = -(i_t^* - i_t) = -0.04$). Supposing that the Fama regression provides the estimates $\alpha = 0$ and $\beta = -1.5$, this results in a large expected return to the position (10%), as we can see substituting these values in (2.9):

$$E_t[x_{t+1}] = 0 + (-1.5 - 1)(-0.04) = 0.1$$

In this example, exploiting the decomposition of carry trade's realized excess return in (2.4), we can observe that the spread among foreign and domestic yields accounts for 40% of the expected return (=4%), whereas the remaining 60% (=6%) stems from the Forward Rate Biasedness: since the forward premium fails to predict the future spot rate, the high-yielding currency is expected to appreciate by 6% during the investment period. Thus, the expected excess return is given by the sum of the two components, that are both positive.

2.2.2 Implementation of the strategy

Carry trade can be implemented in several different ways, starting from the basic trading rule, which involves just one forex pair, to most complex strategies based on portfolios of currencies. Moreover, it can consist in a simple buy and hold strategy or rests on algorithms which determine when the position should be open or closed, in order to profit from high-frequency exchange rate fluctuations.

The simple trading rule described in the former paragraph is generally implemented in the spot foreign exchange market, using short-term asset which are held until maturity; however, also assets with longer maturities can be employed for the same purpose. Moreover, an equivalent strategy is obtained also investing in the forward market, observing which currencies are trading at a forward premium or discount. Indeed, when Covered Interest Parity holds, the interest rate differential is completely reflected in the forward premium/discount: in particular, the high-yielding currency trades at a forward discount, while the low-yielding one is at a forward premium. This implies that carry trade activity can be performed on the forward foreign exchange market by entering a long-foreign position when the foreign currency trades at a discount with respect to the home currency and, vice versa, shorting it when the forward premium is positive. Under the validity of CIP, that is, with perfect capital mobility, this strategy is totally equivalent to the one carried out in the spot market.

Beyond focusing on a specific bilateral exchange rate, carry trade can be also implemented through the construction of portfolios of currencies. Generally, currencies are collected into different portfolios depending on the related yield, thus the profit of the carry trade portfolio stems from cross-sectional differences in currencies' returns. In particular, given N currencies, these can be sorted in M portfolios observing their interest rates at time t; the ranking can be carried out according to the interest rate differential among each of the foreign currencies and the domestic one $(i_t^* - i_t)$[10], or considering just the yield for each currency. Despite the differences in the ranking, in both cases the first and the last one of the M portfolios will be P_{HIGH} and P_{LOW}, which are made up of currencies with, respectively, the highest and the lowest interest rate or interest rate differential. Each portfolio is equally weighted, meaning that the same weight is given to all the currencies included. Finally, the carry trade portfolio is created with a long position in P_{HIGH} and a short position P_{LOW}; the excess return to carry trade, in this case, is equal to the difference between the returns of the two portfolios considered, which are computed as the equally-weighted average of the excess returns to the individual currencies included.

Furthermore, there exist also several instruments that facilitate carry trade activity for retail investors; while in the past this speculative activity was mainly restricted to institutional investors, like in

[10] Alternatively, the sorting can be realized considering the forward premium $f_t - s_t$, when Covered Interest Parity holds.

particular hedge funds and commodity trading advisors[11], in the last decades it has acquired a growing popularity among retail investors, due to the positive performance observed through years[12]. As a consequence of the increased recognition in the financial sector, many indices have been created with the purpose of replicating a carry trade strategy based on a basket of currencies; accordingly, many investment vehicles are now available for investors to gain exposure to such carry trade indices, like Exchange Traded Funds (ETFs) or Exchange Traded Notes (ETNs)[13]. The above-mentioned indices will be described more in detail later, when analyzing empirical evidence on carry trade.

2.2.3 Risks connected with carry trade

Besides the average positive excess returns provided by the carry trade strategy, it is necessary to consider also the risk profile of this speculative activity. The trade is not hedged against the exchange rate risk, since the return depends on the future value of the spot exchange rate at the end of the investment period; thus, the major source of risk for carry trade is represented by exchange rate movements.

Furthermore, starting from the definition of the excess return to carry trade, it is possible to derive the variance of expected excess returns, finding that the latter can be much more volatile than the expected exchange rate variations. When CIP holds, we can consider the expression for the excess return in equation (2.7), generalizing for a k-period investment, to derive the following formula for the expected excess return:

$$E_t[x_{t+k}] = E_t[-(f_t - s_t) + (s_{t+k} - s_t)] = E_t[s_{t+k} - s_t] - (f_t - s_t) = E_t[\Delta s_{t+k}] - (f_t - s_t)$$

And from this we can compute the variance of the expected excess return as

$$Var(E_t[x_{t+k}]) = Var(E_t[\Delta s_{t+k}]) + Var(f_t - s_t) - 2Cov(E_t[\Delta s_{t+k}], f_t - s_t)$$

Combining the above formula with the expression for the Fama regression's β coefficient in (1.15) yields

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[11] A Commodity Trading Advisor (CTA) is a registered individual or company providing customized advice concerning commodities trading: the purchase or sale of futures contract, options on futures and certain foreign exchange contracts.
[12] GALATI G., HEATH A., MCGUIRE P. 2007. *Evidence of carry trade activity*. BIS Quarterly Review.
[13] ETFs and ETNs are both investment vehicles designed with the purpose of tracking an underlying asset, but they present some structural differences: while an ETF provides an investment into a fund that holds the assets tracked, the ETNs are more like bond, being structured products issued as senior debt notes.

$$Var(E_t[x_{t+k}]) = Var(E_t[\Delta s_{t+k}]) + (1 - 2\beta)Var(f_t - s_t) \quad (2.10)$$

Equation (2.10) shows that the variance of the expected excess return to carry trade is equal to the variance of the expected exchange rate change plus a term that can be either positive or negative; since the variance of the forward premium cannot be negative, the sign ultimately depends on the value of β. In particular, $\beta < 1/2$ implies that

$$Var(E_t[x_{t+k}]) > Var(E_t[\Delta s_{t+k}]).$$

Since empirical research on UIP and FRU has usually revealed negative values for the beta coefficient, we can conclude that, empirically, the expected excess returns associated to carry trade activity are more volatile than the expected variations of exchange rate.

Given the high risk associated with carry trade activity, the evaluation of the strategy should involve measures that consider also the volatility of the currency pairs involved. One of the most widespread indicators of the attractiveness of carry trade is the "carry-to-risk ratio", an ex-ante measure of the risk-adjusted profitability of carry trade; it is computed as the ratio of the interest rate differential among the currencies involved to the expected volatility of the relevant exchange rate, proxied by the volatility implied by foreign exchange options. The following chart (figure 2.1) displays the carry-to-risk ratios during the period 1999-2010 for three different carry trades: one based on a long-Australian Dollar and a short-US Dollar position and the other two with Japanese Yen as funding currency and, respectively, Australian Dollar and US Dollar as investment currency.

Figure 2.1 – *Carry-to-risk ratios.*

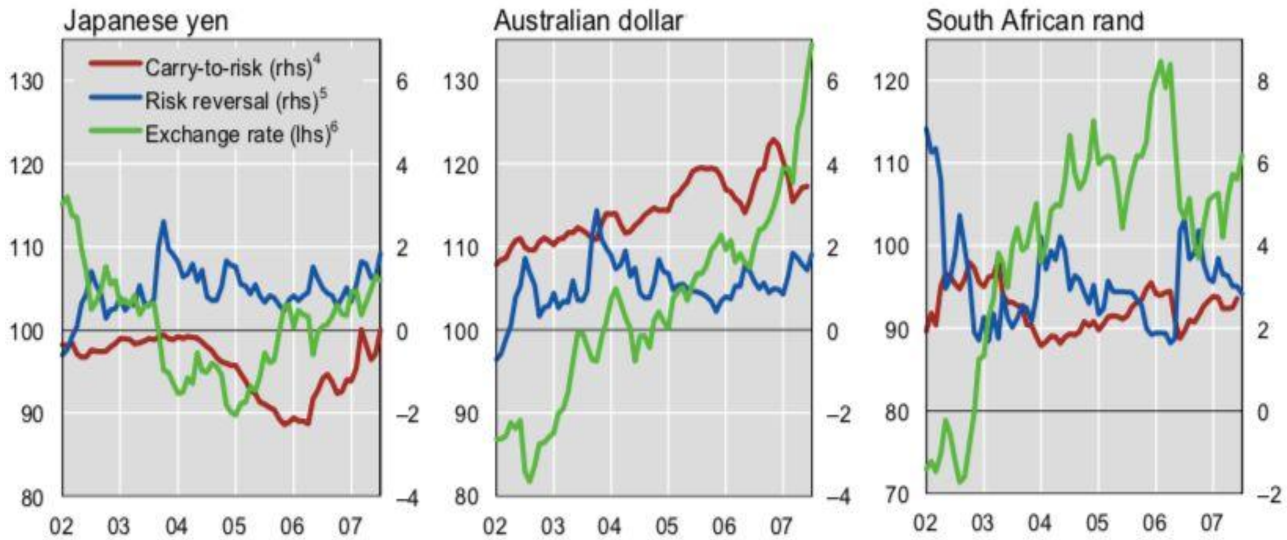
Note: the graph presents the patterns of the carry-to-risk ratios associated to three different carry trades: USD-AUD (blue line), JPY-AUD (red line) and JPY-USD (green line). The carry-to-risk for the JPY-USD is computed as the ratio of 3-month interest rate differential among US dollar and Japanese yen to the implied volatility of at-the-money JPY/USD exchange rate options with 3-month maturity; the other two measures are computed analogously.
Source: CURCURU S., VEGA C., HOEK J. 2011. Measuring Carry Trade Activity. IFC Bulletins chapters 34, pp. 436-453.

From the above graph we can see that the two strategies involving Japanese Yen, namely JPY-AUD (red line) and JPY-USD (green line), exhibited the highest values for the ratio during the period 2006-2007, reflecting the popularity of these trades on markets in that period. The carry-to-risk ratio for the USD-AUD (blue line), instead, started to increase in 2008, when US interest rates were lowered, thus making the carry trade more profitable. Finally, all three ratios experienced a sharp decline at the end of 2008, as a result of the increased implied volatility during the financial crisis.

Another commonly used measure of risk for carry trade activity is the so-called “risk reversal”, that is defined as the difference between the implied volatility of FX out-of-the-money call and put options. Hence, this measure represents the cost of a strategy that involves a long position in the FX call option funded by a short position in a put option with equal features; in other words, it is the cost of hedging against foreign currency appreciation while selling insurance against the depreciation of the same foreign currency. Risk reversal provides information about the risk-neutral implied skewness of exchange rate movements: if the underlying risk-neutral distribution of the exchange rate is symmetric, risk reversal equals zero, since prices of the call and the put exactly offset; when this measure differs from zero, instead, the distribution is positively or negatively skewed, depending on whether the value is, respectively, positive or negative. As a consequence, risk reversal is a more suitable measure when the attention is on directional risk, namely, the risk of losses, rather than general uncertainty about returns, which is captured by the carry-to-risk ratio.

The two above-mentioned risk measure are characterized by a strong correlation, as shown in the following graph (figure 2.2), where they are plotted, together with the exchange rate's pattern, for three carry trade strategies, namely, USD-JPY, JPY-AUD and JPY-ZAR, for the period 2002-2007.

Figure 2.2 – *Carry trade risk measures.*



Note: [4] Carry-to-risk is defined as the three-month interest rate differential divided by the implied volatility derived from three-month at-the-money exchange rate options; quintuple scale (e.g. the number 2 represents a ratio of 0.4).
[5] A positive value indicates a willingness to pay more to hedge against a yen appreciation. [6] 2002–06 = 100.
Source: GALATI G., HEATH A., MCGUIRE P. 2007. Evidence of carry trade activity. BIS Quarterly Review.

Beyond the risk measure for the excess returns described above, there are some other relevant risks connected to carry trade, which must be considered when entering such strategy. One of the major risks is represented by the possibility of large drawdowns connected with the collective unwinding of carry trade positions. Some research suggests that the significant excess return to carry trade may partly depend on the positive response to the buildup of large positions; indeed, the profitability may increase as a consequence of investors' activity, since significant carry trades produce a further strengthening of the high-yielding currency and a weakening of the low-yielding one. Clearly, the unwinding of a relevant portion of these positions will have the reverse effect: when large carry positions are liquidated simultaneously, exchange rate volatility may increase steeply, triggering the depreciation of investment currencies and the appreciation of funding currencies in a short span of time, thus causing large losses for investors that have not closed their positions yet.

Another relevant risk of carry trade is associated with the meltdown of the benefits of diversification. This is connected with the evidence of low correlation between carry trade and traditional asset classes, like, for instance, stocks and bonds, revealed by numerous studies; this has led several investors to include carry trades in their portfolio investments for diversification purposes. However, a research by Kohler (2007) showed that this correlation, though generally low, increase considerably in situations of financial distress. This implies that investors using carry trade in a portfolio context can observe diversification benefits from carry trade reducing significantly during periods of financial turmoil, thus deteriorating portfolio performances.

2.3 Empirical evidence on carry trade activity

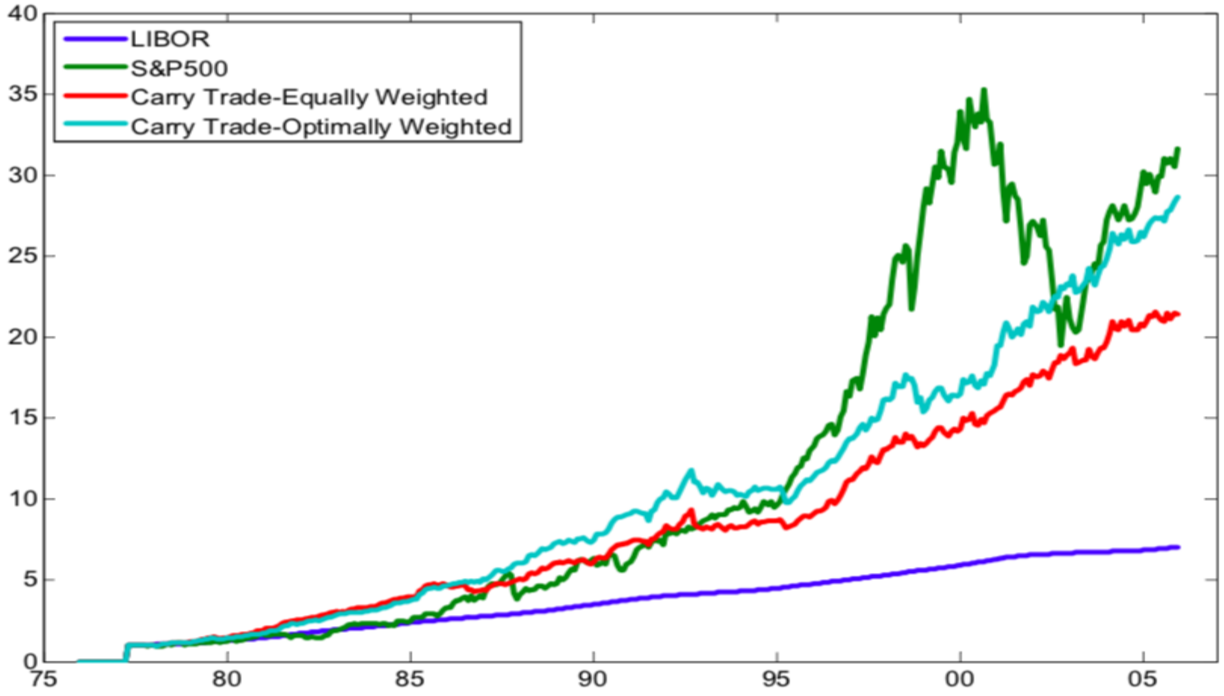
Since 1980s, empirical evidence on carry trade activity has revealed statistically and economically significant average excess return associated with the strategy. This profitability does not reconcile with UIP and FRU theory; however, empirical studies have pointed out the failure of these two relationships, since they are not supported by empirical data. This is the main reason behind the observed profitability of carry trade. Assessing the performance of carry trades is not straightforward, since data are not easily available; however, statistics about carry trade returns can be obtained from two major sources: the results of carry strategies simulated by researchers and the performance of carry trade indices.

2.3.1 Simulated strategies in empirical literature

Evidence on carry trade activity has been provided over the years by several researchers, who have attempted to simulate carry trade strategies in order to analyze statistics on the returns delivered, such as the average excess return, the volatility and the Sharpe ratio; in particular, the latter is an important indicator to consider when assessing investment strategies, since it represents a risk-adjusted measure of performance: it is computed as the ratio of the excess return of an investment to its volatility, thus expressing the amount of excess return earned per unit of risk borne. The majority of these studies reveals high mean excess returns to carry trades, associated with large values for the Sharpe Ratio, often substantially higher than the ones for equity markets.

For instance, Burnside et al. (2006) computed the mean, volatility and Sharpe ratio of monthly non-annualized payoffs to carry trades considering strategies based on individual currencies as well as carry portfolios. In particular, two different portfolios are built: an equally-weighted portfolio of currency and an optimally-weighted one, in which weights are selected in order to maximize the Sharpe ratio. Figure 2.3 displays the cumulative returns to the two alternative currency portfolio strategies, compared with cumulative returns for the S&P 500 index and the 1-month Libor, for the period 1977-2007.

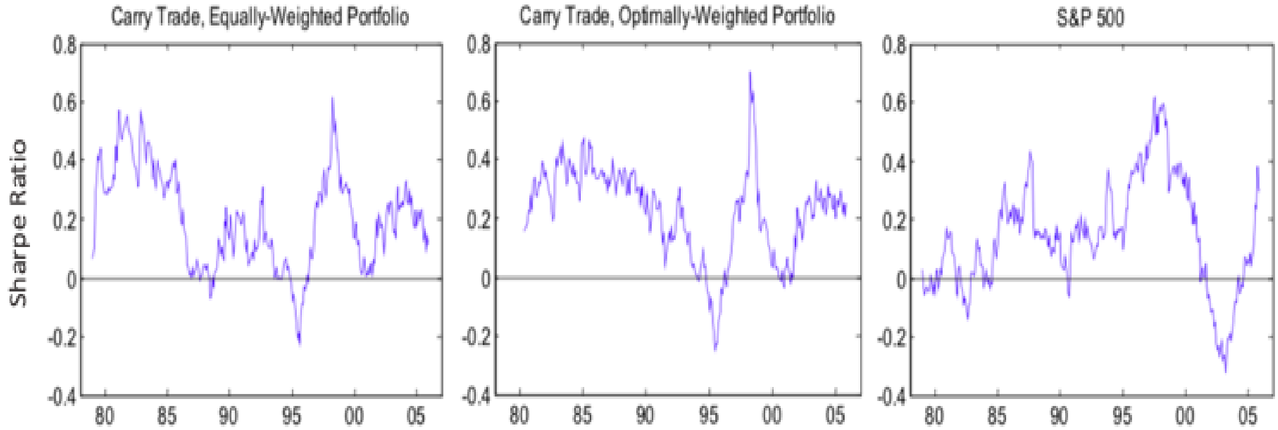
Figure 2.3 – *Cumulative Realized Nominal (USD) Returns to Currency Speculation*.



Note: *May 1977=1*.
Source: BURNSIDE C., EICHENBAUM M., KLESHCHELSKI I., REBELO S. 2006. *The Returns to Currency Speculation*. NBER Working Paper 12489.

As we can see from the above chart, both the carry strategies and the S&P 500 dominated the Libor; the optimally-weighted portfolio presents higher cumulative returns compared with the equally-weighted one and, moreover, it exhibits a total cumulative return that is very close to that of the S&P 500. An overview of the risk-adjusted performance of the two strategies, instead, is provided by the following figure, in which the three charts present the Sharpe ratio for, respectively, the equally-weighted carry portfolio, the optimally-weighted carry portfolio and the S&P 500 index.

Figure 2.4 – *Realized Sharpe Ratio for Nominal (USD) Excess Returns*.



Note: the charts present realized Sharpe ratio for US Dollar excess returns computed with a three-year rolling window. Source: BURNSIDE C., EICHENBAUM M., KLESHCHELSKI I., REBELO S. 2006. *The Returns to Currency Speculation*. NBER Working Paper 12489.

Both the carry trade strategies are characterized by high values for the Sharpe ratio during early 1980s, while the S&P 500 delivered negative returns in the same period. The two portfolios generally show higher values for the ratio compared with that of equity markets, with the optimally-weighted strategy outperforming the equally-weighted one over almost the entire sample, except for a short period around 1995, when carry trade strategies yielded negative excess returns.

Analogous results are reported by Lustig and Verdelhan (2007), who studied the risk-return trade-off associated with carry trades from the perspective of a US investor; they observe 3-month interest rates to sort currencies in eight portfolios, according to their interest rate differential with respect to the base currency (USD). Following this decision rule, portfolio 1 is made up of currencies with the lowest differentials, whereas portfolio 8 incudes the ones associated with highest differentials; these portfolios are rebalanced annually, in order to adapt to changes in yields. The researchers derived statistics on the US investor's excess return for each of the eight currency portfolios, considering two different samples: the first one covers the interval 1953-2002, while the second is a subperiod of the former, starting from 1971, that is, from the collapse of Bretton Woods. These statistics are summarized in the table below.

Figure 2.5 – *Summary statistics for currency portfolios' excess returns*.

Portfolio	1	2	3	4	5	6	7	8
				1953–2002				
mean	−2.34	−0.87	−0.75	0.33	−0.15	−0.21	2.99	2.03
SR	−0.36	−0.13	−0.11	0.04	−0.02	−0.03	0.37	0.16
				1971–2002				
mean	−2.99	−0.01	−0.83	1.14	−0.69	−0.00	3.94	1.48
SR	−0.38	−0.00	−0.10	0.11	−0.07	−0.00	0.39	0.10

Note: This table reports the mean of annual real excess returns (in percentage points) and the Sharpe ratio for a US investor, associated with the eight currency portfolios, annually rebalanced.
Source: LUSTIG H., VERDELHAN A. 2007. *The Cross Section of Foreign Currency Risk Premia and Consumption Growth Risk.* American Economic Review 97(1), pp. 89-117.

The table in figure 2.5 shows that the larger spread in returns is among portfolio 1 and portfolio 7: these data imply that a carry trade strategy based on a long position in portfolio 7 and a short position in portfolio 1 would have yielded an average annual excess return of 5.33% for the entire sample period and an even higher excess return in the subsample 1971-2002, equal to 6.93%. The mean returns reported are almost monotonically increasing in the interest rate differential; however, an exception is represented by the portfolio of highest yielding currencies (portfolio 8): the lower returns may be explained by the high inflationary nature of the currencies included, since Bansal and Dahlquist (2000) suggested that UIP tends to hold better with high levels of inflation. The resulting values for the Sharpe ratio of the excess return associated to carry trade are generally positive but not so large, reflecting the riskiness of the strategy.

Another relevant study providing evidence for carry trade activity is Brunnermeier et al. (2008), which in particular shows the negative skewness of the carry trade returns, pointing out that such trading activity is subject to crash risk. The authors collected data on a restricted pool of currencies, from the eight main developed countries[14], relating to the period 1986-2006: in particular, they used nominal exchange rates against the US Dollar (USD) and 3-month interbank interest rates. With such data, they built three different equally-weighted carry portfolios, which are rebalanced either weekly or quarterly: portfolios are made up of a long position in the k highest yielding currencies and the k

[14] Australia (AUD), Canada (CAD), Japan (JPY), New Zealand (NZD), Norway (NOK), Switzerland (CHF), Great Britain (GBP) and the Euro area (EUR).

lowest yielding ones, with $k = 1, 2, 3$. The following table (figure 2.6) gives an overview of resulting statistics:

Figure 2.6 – *Summary statistics for carry trade portfolio returns*.

	1 long, 1 short		2 long, 2 short		3 long, 3 short	
	Wkly	Qtrly	Wkly	Qtrly	Wkly	Qtrly
Average return	0.002	0.022	0.001	0.016	0.001	0.018
Standard deviation	0.017	0.068	0.013	0.051	0.011	0.045
Skewness	-0.717	-0.700	-0.537	-0.748	-0.695	-0.977
Kurtosis	2.851	0.674	1.534	0.661	2.597	1.968
Annualized Sharpe Ratio	0.704	0.654	0.592	0.638	0.747	0.784

Note: the table reports the mean return, standard deviation, skewness, kurtosis and Sharpe ratio for the three equally-weighted carry portfolios. The three portfolios are, respectively, long in the 1, 2 and 3 highest yielding currencies and short in the 1, 2 and 3 lowest yielding currencies. Currencies are sorted in the three portfolios according to the interest rates observed at the beginning of each week/quarter. Quarterly data are referred to the whole sample, 1986-2006, while the weekly data are from 1992-2006.
Source: BRUNNERMEIER M. K., NAGEL S., PEDERSEN L. H. 2008. Carry trades and currency crashes. NBER Working Paper 14473.

The data in the table support the average profitability of carry trade: both average return and Sharpe ratio are positive for all three portfolios, with values for the ratio even larger than the ones found by Lustig and Verdelhan (2007) in figure 2.5, since these data referred to a shorter sample corresponding to a particularly favorable period for carry trade. Moreover, results reveal that carry trade returns are characterized by negative skewness and positive kurtosis, thus suggesting that carry trade activity is exposed to crash risk and has fat tails[15].

Beyond the above-mentioned studies, several other researches have derived statistics on excess return to carry trade, simulating strategies based on different choices for currencies, samples, data and portfolio construction; despite the different methodologies, almost all the literature presents similar results, providing evidence of high average excess return and large values for the Sharpe ratio. The following table (figure 2.7) summarize the results reported by some of the most relevant studies in carry trade empirical literature.

[15] This means that the carry trade returns have a fat-tailed distribution, that implies a greater likelihood associated to extreme values.

Figure 2.7 – *Overview of some of the empirical literature on carry trade.*

Authors	Publication	Period	Interest	Currencies	Return	Volatility
Brunnermeier, Nagel and Pedersen	NBER 2008	1986-2006	3-month	9	6.4%	10.2%
Burnside, Eichenbaum and Rebelo	JEEA 2008	1976-2007	-	23	5.4%	6.5%
Burnside, Eichenbaum, Kleshchelski and Rebelo	RFS 2011	1976-2009	1-month	21	4.8%	5.3%
Christiansen, Ranaldo and Söderlind	JFQA 2011	1995-2008	1-day	10	4.6%	-
Darvas	JBF 2009	1976-2008	1-month	11	4.1%	4.6%
Della Corte, Riddiough and Sarno	WP 2012	1983-2011	1-month	60	5.4%	8.9%
Koijen, Moskowitz, Pedersen and Vrugt	WP 2012	1983-2012	1-month	20	5.3%	7.8%
Lustig, Roussanov and Verdelhan	RFS 2011	1983-2009	1-month	35	8.5%	9.0%
Barroso and Santa-Clara	JFQA 2013	1996-2011	1-month	27	21.4%	24.3%
Menkhoff, Sarno, Schmeling and Schrimpf	JF 2012a	1983-2009	1-month	48	7.2%	9.8%
Rafferty	WP 2011	1976-2011	1-month	37	7.0%	8.3%
Jurek	JFE 2013	1990-2012	1-month	10	4.5%	9.5%

Source: NORGES BANK INVESTMENT MANAGEMENT. 2014. *The Currency Carry Trade*. Discussion note. ISSN 1893-966X.

With respect to the data sample, most of the studies cover the time period from late 1970s or early 1980s, after the collapse of Bretton Woods fixed exchange rate system, to the global financial crisis; further, the most common choice for the interest rate is the one-month rate, with the exception of two studies using the three-month or one-day interest rate. The number of currencies considered in the strategy varies greatly: some of the surveys, such as Brunnermeier et al. (2008), focus on a restricted basket of currencies, that are generally those of developed countries, while others select a large pool of currencies, including also emerging markets, like for instance Menkhoff, Sarno, Schmeling and Schrimpf (2012a) with a sample of 48 currencies or Della Corte, Riddiough and Sarno (2012) with 60 currencies. However, the choice of the sample of currencies does not seem to have a significant impact on the resulting Sharpe ratios.

Furthermore, empirical studies differentiate also in the methodology adopted for the construction of carry trade portfolios. Some researchers, like Burnside et al. (2011), focus on the US dollar as the reference currency, thus replicating a carry trade strategy from the perspective of a US investor: this implies that the portfolio is long USD and short a basket of foreign currencies when the US interest rate is relatively high and vice versa, thus taking a non-diversified directional position on USD. Other studies prevent this sensitivity to the US dollar by choosing a different strategy: currencies are sorted into different portfolios according to their interest rate and the carry trade portfolio is built taking long positions in the highest yielding currencies while shorting the lowest yielding ones. This type of approach was followed, for instance, by Brunnermeier et al. (2008) and Lustig, Roussanov and Verdelhan (2011); this strategy does not take directional position on a specific currency, but it has the drawback of accounting for just currencies with extremely high/low interest rate, neglecting the ones associated with intermediate values for the yields. Koijen, Moskowitz, Pedersen and Vrugt (2013), instead, follow a further alternative approach, which consists in taking long/short position in all currencies, with magnitude determined on the basis of cross-sectional ranking of yields.

Notwithstanding the methodological differences, all the studies reported in the table present results that are overall consistent: all the average returns are positive and range from 4.1% to 8.5%, with the exception of an extremely high value of 21.4% in Barroso and Santa-Clara (2013), and values for Sharpe ratio are significantly large, from 4.6% to 10.2%, again with the same unique exception; these empirical findings show substantially positive risk-adjusted performances of carry strategies, thus confirming carry trade profitability.

2.3.2 Carry trade indices

As already mentioned, several indices replicating carry trade strategies entered the market during last decades, as a consequence of the increasing recognition of this trading activity in the financial sector. These market indices all provide exposure to carry trade, but they differ for the basket of currency involved and for the construction of the carry trade portfolios. Such indices allow investors to track carry trade performance, observing the path of the index level over the years. For example, Deutsche Bank has created several carry indices, like, among others, the *DB EUR Currency Harvest Balanced* and the *DB G10 Currency Future Harvest*.

The *Deutsche Bank EUR Currency Harvest Balanced Index* has the purpose of tracking the performance of a portfolio made up of a long position in a diversified basket of high-yielding currencies, funded by a short position in a diversified basket of low-yielding currencies. The eligible currencies that can be included are divided in four sets, according to their region, presented in the following table (figure 2.8).

Figure 2.8 – *Sets of eligible currencies for the DB Currency Harvest Balanced Index.*

G10	ASIA	LATIN AMERICA	EMERGING EUROPE AND AFRICA
▪ US Dollar (USD) ▪ Euro (EUR) ▪ Japanese Yen (JPY) ▪ Pound Sterling (GBP) ▪ Swiss Franc (CHF) ▪ Australian Dollar (AUD) ▪ New Zealand Dollar (NZD) ▪ Canadian Dollar (CAD) ▪ Norwegian Krone (NOK) ▪ Swedish Krona (SEK)	▪ Korean Won (KRW) ▪ Singapore Dollar (SGD) ▪ New Taiwan Dollar (TWD)	▪ Mexican Peso (MXN) ▪ Brazilian Real (BRL)	▪ Turkish Lira (TRY) ▪ Polish Zloty(PLN) ▪ Hungarian Forint (HUF) ▪ Czech Koruna (CZK) ▪ South Africa Rand (ZAR)

Source: DEUTSCHE BANK. 2007. *DB Currency Harvest.* http://www.cbs.db.com/new/docs/Harvest-Mar2008.pdf

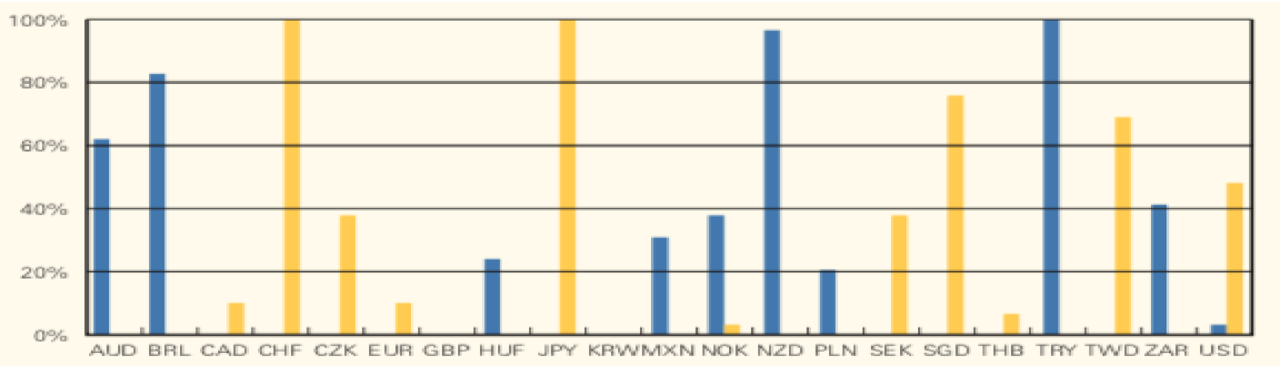
The term "balanced" refers to the constraint imposed to the carry strategy of this index: it must maintain a balanced exposure between developed and emerging markets. In particular, the investment strategy is the following:

- Long position: two highest yielding G10 currencies and three highest yielding currencies from the whole basket;
- Short position: two lowest yielding G10 currencies and three lowest yielding ones from the remaining currencies.

Currencies are ranked according to 3-month Libor rates and the portfolio is rebalanced quarterly; the index is quoted in terms of excess return, net of transaction costs, and in EUR notional.

The following bar chart, in figure 2.9, displays the historical composition of the index during the period September 2000 – October 2007: the predominant investment currencies are Turkish Lira (TRY), New Zealand Dollar (NZD), Brazilian Real (BRL) and Australian Dollar (AUD), while the core funding currencies include Japanese Yen (JPY), Swiss Franc (CHF) and Singapore Dollar (SGD) and New Taiwan Dollar (TWD).

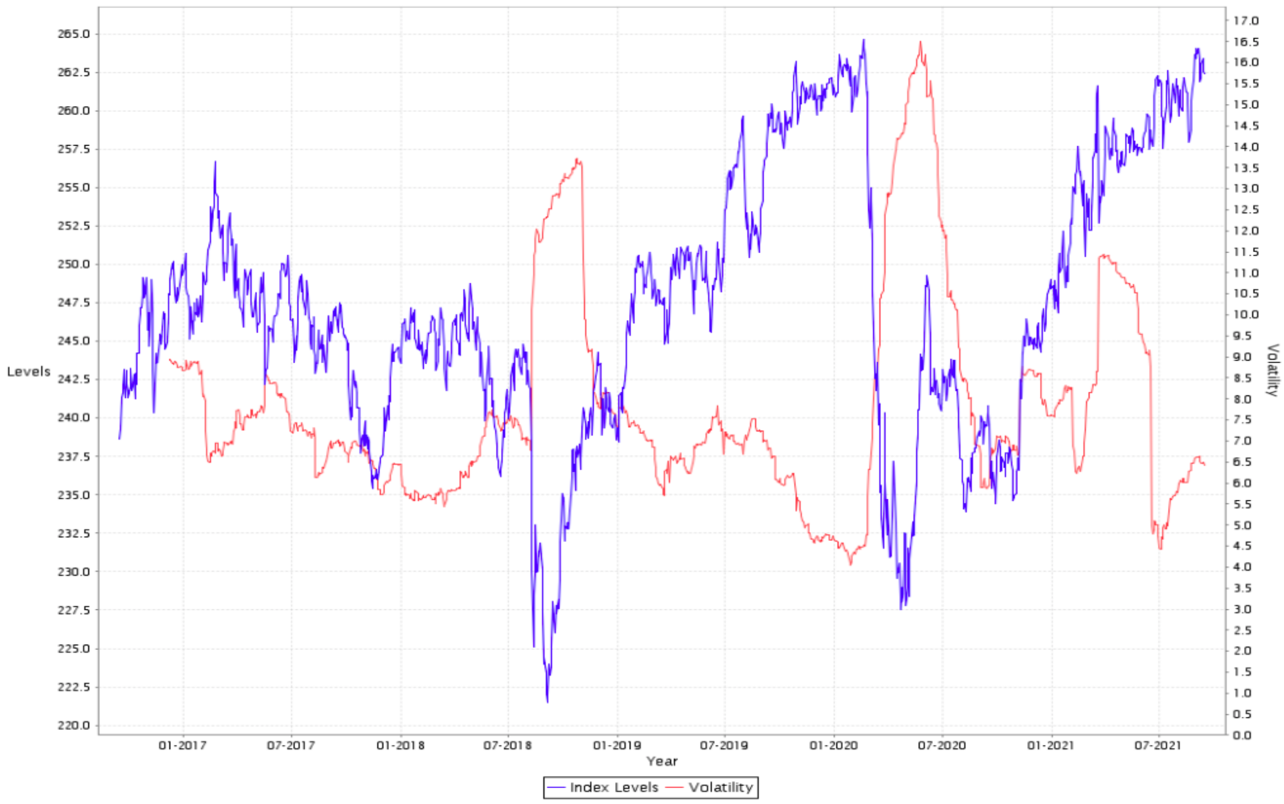
Figure 2.9 – *Historical composition of the DB Currency Harvest Balanced Index (September 2000 – October 2007).*



Note: for each currency, the yellow bar represents the percentage of times it was selected for the long position, while the blue bar instead outlines the percentage of times that it was shorted.
Source: DEUTSCHE BANK. 2007. *DB Currency Harvest.* http://www.cbs.db.com/new/docs/Harvest-Mar2008.pdf.

The performance of the Deutsche Bank EUR Currency Harvest Balanced Index in recent years provide empirical evidence to assess the carry trade strategy followed by the index portfolio: the following charts display the pattern of the index level, together with the related volatility, during the last 5 years (figure 2.10) and the annual returns of the index over the last 20 years (figure 2.11).

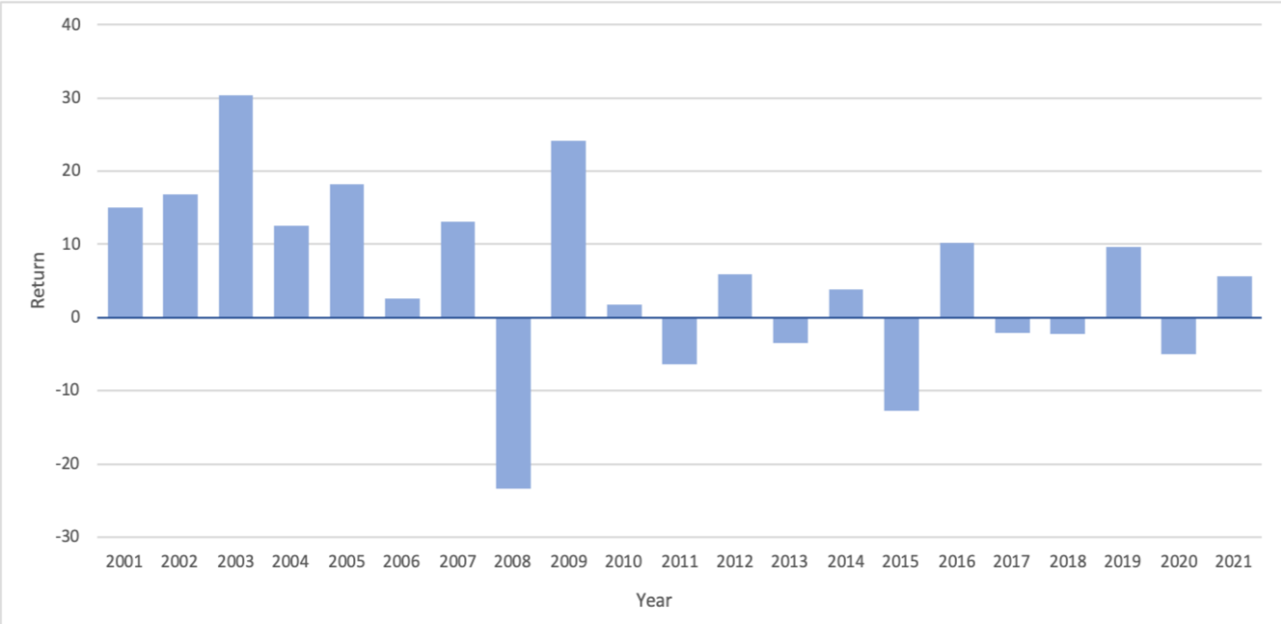
Figure 2.10 – *DB Currency Harvest Balanced Index level and volatility (September 2016 – September 2021).*



Note: data are referred to the period from September 15, 2016 to September 15, 2021.
Source: Deutsche Bank's website.

The current level of the index is 262.45; the maximum and minimum values assumed by the DB Currency Harvest Balanced during the sample period considered are, respectively, 264.63 in February 2020 and 221.51 in September 2018. The chart in figure 2.10 shows two major troughs in the path of the index value, associated with high levels of volatility: the first is represented by the above-mentioned minimum index level in September 2018, which corresponds to the cryptocurrency crash, while the second dates to April 2020, with index levels below 230, due to the recession caused by the Covid-19 pandemic. Starting from the end of 2020, the index exhibits a rising trend; the annualized return offered by the index portfolio during the last 5 years is equal to about 1.83%, associated with a volatility of approximately 8.16%, thus corresponding to a Sharpe ratio of 0.22.

Figure 2.11 – *Annual returns of the DB Currency Harvest Balanced Index (2001 – 2021).*



Note: data are referred to the period from September 15, 2001 to September 15, 2021.
Source: Deutsche Bank's website.

The bar chart in figure 2.11 presents the annual returns to the index portfolio from 2001 to 2021. As we can see, the returns are positive for most of the years considered: in particular, the index performance has been particularly positive for the years preceding the financial crisis of 2008, which is instead associated with a particularly negative return (-23,34%); further, in 2009 the DB Currency Harvest Balanced delivered a positive and large return. For the 20-year period considered (from September 2001 to September 2021), the annualized return amounts to almost 5%, with volatility equal to 10.42%, which implies a value for the Sharpe ratio of 0.48.

The table below (figure 2.12) provides a summary of the statistics for the DB Currency Harvest Balanced Index described above, over the two samples considered:

Figure 2.12 - *Summary statistics for the DB Currency Harvest Balanced Index.*

	Annualized Return	Volatility	Sharpe Ratio
2016 – 2021	1.83 %	8.16 %	0.22
2001 – 2021	4.97 %	10.42 %	0.48

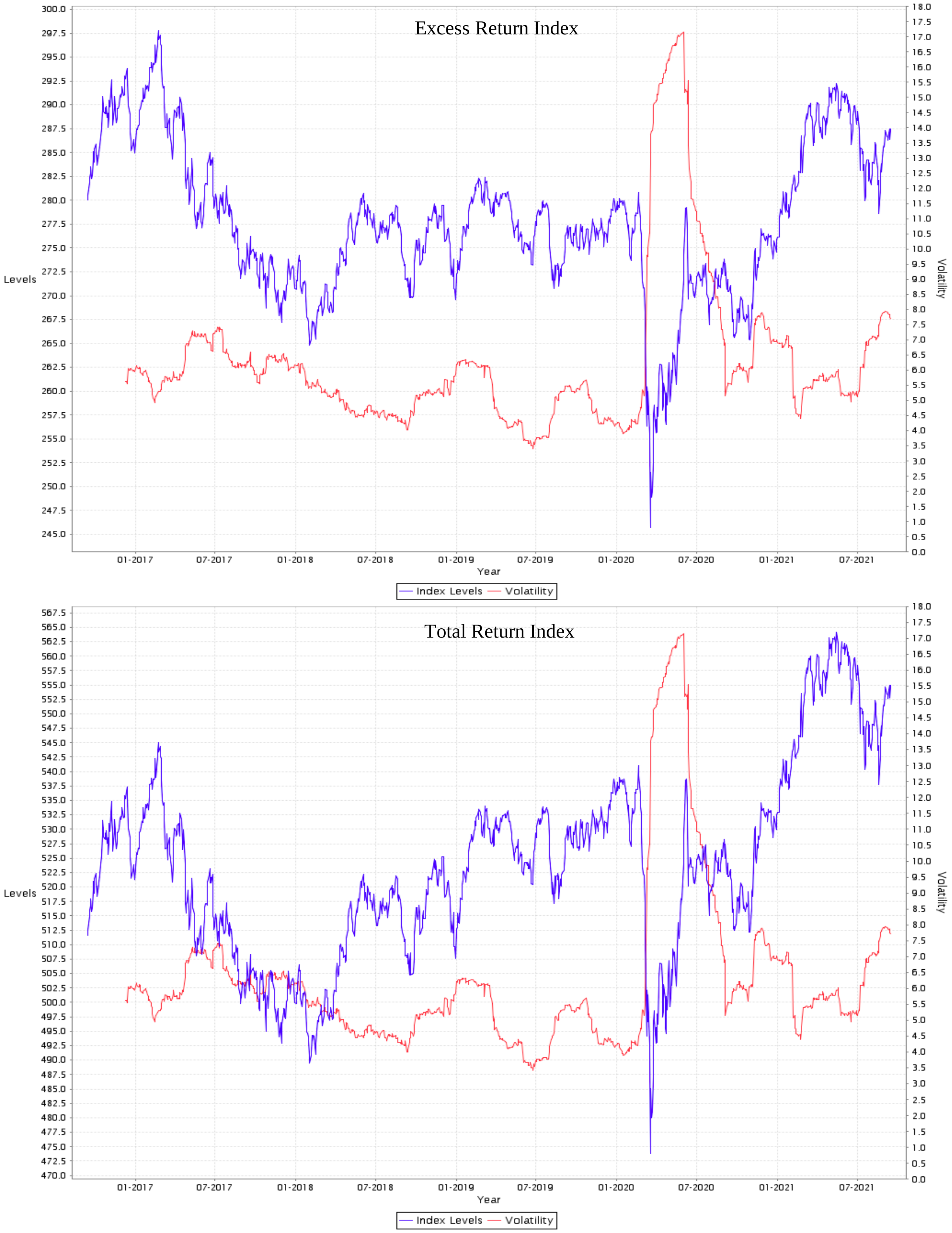
Source: Deutsche Bank's website.

The *Deutsche Bank G10 Currency Future Harvest Index*, instead, replicates a carry trade strategy implemented investing in currency futures: it consists in a long position in futures for currencies associated with high yields and a short futures position in currencies with low interest rates. The index portfolio is built with FX futures[16] on G10 currencies against USD; this means that all the G10 currencies are eligible for index selection, except for the US Dollar. Again, the currencies in the eligible pool are ranked according to their interest rates and the index invests in the three highest yield currencies, while shorting the three lowest yielding ones. In particular, the index is currently long on Canadian Dollar (CAD), New Zealand Dollar (NZD) and Norwegian Krone (NOK), whereas the funding currency are Japanese Yen (JPY), Swiss Franc (CHF) and Euro (EUR)[17].

Both the excess return and the total return indices are calculated: the former stands for the return from currency futures, while the latter is defined as the currency futures return plus the return from holding 3-month T-bills. The following two charts in figure 2.13 present variations in the level of, respectively, the excess return index and the total return index over the last 5 years, displayed with the corresponding volatilities.

[16] In particular, the Chicago Mercantile Exchange FX Futures are used for the calculation of the index.
[17] Index composition on September 2021. Source: Deutsche Bank's website.

Figure 2.13 – *DB G10 Currency Future Harvest Excess Return and Total Return Indices level and volatility (September 2016 – September 2021).*

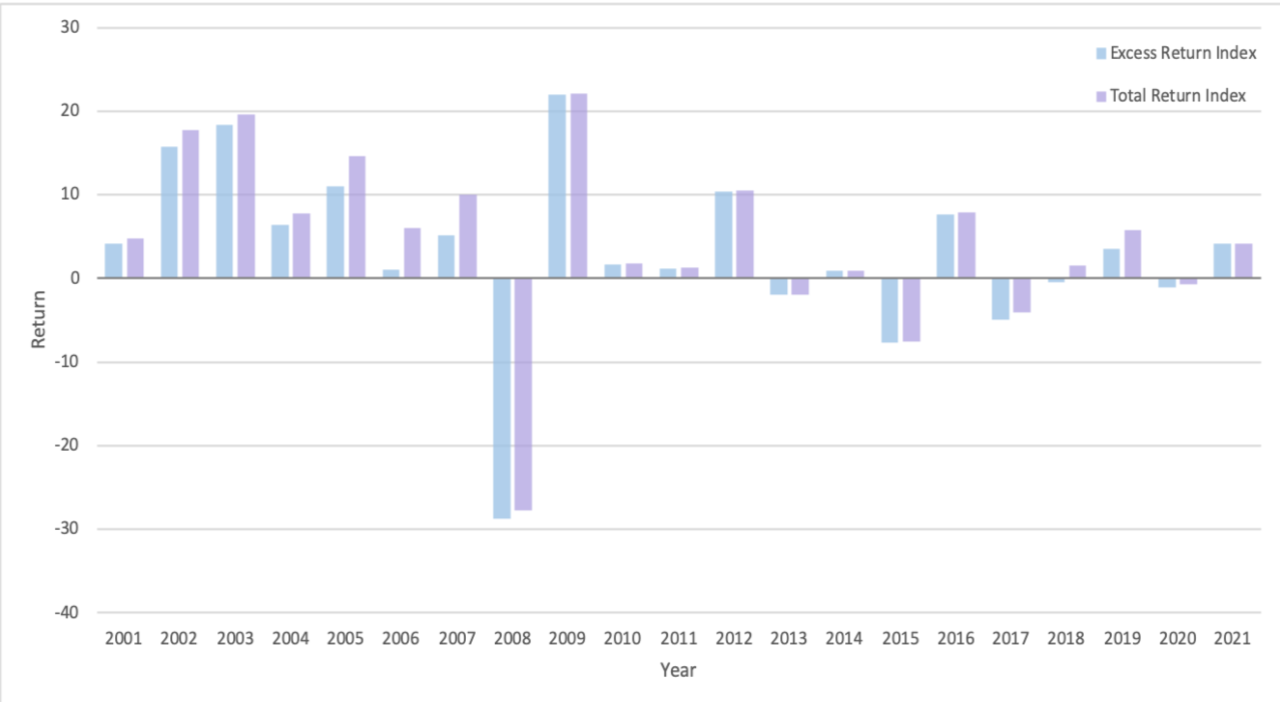


Note: data are referred to the period from September 15, 2016 to September 15, 2021.
Source: Deutsche Bank's website.

Clearly, the two indices follow an analogous path, with the only difference being in the values assumed: the current levels are, respectively, 287.47 for the excess return index and 554.95 for the total return index. Both are characterized by a decreasing trend from March 2017 to February 2018, followed by a general increasing trend, which lasts until March 2020. Differently from the former index, the DB G10 Currency Future Harvest does not present a sharp decline in September 2018; however, the two charts display again a trough related to the Covid-19 crisis, even if in this case the fall in the index value is already detectable after mid-March 2020. In particular, in that period the two indices reached their minimum level over the considered horizon: approximately 245.74 and 473.85, respectively, for the excess return and total return indices, both on March 18, 2020. The maximum values over the 5 last years, instead, date to different periods for the two indices: 297.76 in February 2021 for the excess return index and 564.11 during May 2021 for the total return index.

The following figure, instead, provides an overview of the annual returns associated with both the excess return and the total return indices, during the last 20 years.

Figure 2.14 - *Annual returns of the DB G10 Currency Future Harvest Excess return and Total Return Indices (2001-2021).*



Note: data are referred to the period from September 15, 2001 to September 15, 2021.
Source: Deutsche Bank's website.

The bar chart in figure 2.14 displays a comparison among the annual returns delivered by the excess and total return G10 Currency Future Harvest index: for almost all the years, the total return index exhibits slightly larger returns, exceeding the return to the other index by more or less 1% throughout the sample; however, there are some significant discrepancies, in particular for the years 2006 and 2007, when the difference widens up to almost 5%. Despite these differences, the performances of the two indices are analogous: returns are positive over most of the sample, with just few exceptions, like, in particular, the large and negative values assumed in 2008.

The following table, in figure 2.15, summarizes statistics for both the excess return and the total return indices over the two periods considered:

Figure 2.15 – *Summary statistics for the DB G10 Currency Future Harvest Index.*

	Annualized Return	Risk Free Rate	Volatility	Sharpe Ratio
	2016 – 2021			
DB G10 Currency Future Harvest ER	0.53 %		6.79 %	0.08
DB G10 Currency Future Harvest TR	1.64 %	1.11 %	6.79 %	0.08
	2001 – 2021			
DB G10 Currency Future Harvest ER	2.83 %		10.17 %	0.28
DB G10 Currency Future Harvest TR	4.11 %	1.33 %	10.17 %	0.27

Source: Deutsche Bank’s website.

The two indices present positive annualized returns and Sharpe ratios, even if not particularly large, especially over the shorter sample. Moreover, these values are substantially smaller than the ones observed for the DB Currency Harvest Balanced Index, which thus exhibit a better risk-adjusted performance; however, these data still provide support for the positive profitability of carry trade activity.

2.4 Explanations for the carry trade profitability

The positive performance of carry trade observed through years has led many researchers to investigate the possible reasons for the existence of these significant positive excess returns; in particular, the main focus of the empirical literature is on the validity of a risk-based explanation for the carry trade profitability: does it represent a compensation for investors' risk exposure?

In order to answer this question, several academics carried out empirical studies aimed at detecting the potential risk factors connected with carry trading and checking whether these are able to explain the positive average payoff observed. This kind of analysis has been generally performed using multifactor models: these are models that try to define the return on an asset in terms of its exposure to a specified set of risk factors, which represent priced risks[18]. In general, the estimation of a multifactor model involves choosing a set of factors that may affect the return on the considered asset (or portfolio of assets) and then running the following regression:

$$R_i = \alpha + \beta_{i,1} f_1 + \beta_{i,2} f_2 + \cdots + \beta_{i,k} f_k + \varepsilon_i$$

where R_i is the return on the asset (or portfolio) i over a specified time horizon, $f_1, \dots, f_k$ are the factors selected for the estimation of the model and the β terms represents the asset's sensitivities to each factor, namely the reactions in the return on the asset to changes in the risk factors.

The above-mentioned factor models have been largely employed in the empirical literature on carry trade in order to find risk-based explanations for the profitability of the strategy; the analysis usually performed by researchers is based on the regression of the excess returns delivered by carry trade over time, X_t, on a set of risk factors, $f_1, \dots, f_k$, to estimate the relevant exposures[19]:

$$X_t = \alpha + \beta_1 f_{1,t} + \beta_2 f_{2,t} + \cdots + \beta_k f_{k,t} + \varepsilon_t \tag{2.11}$$

The aim of this factor model is to show that the excess returns to carry trade are just compensation for the exposure to the sources of risk represented by the factors considered in the model; accordingly, after correcting for these exposures, the remaining excess returns (the alphas of the regression) should no longer be statistically different from 0.

Several academics performed this analysis in their studies, considering risk factors of different kinds, starting from the traditional ones, like, in particular, those connected with the business cycle, to more specific ones, related to the nature of the strategy. However, the different factor models proposed by researchers do not result in a general risk-based explanation for the profitability of carry trade, since

[18] This means that investors require an additional return (risk premium) to bear these risks.
[19] Or, alternatively, on the regression of the logarithm of the excess return, x_t, on the risk factors.

there is no agreement on which factors are able to explain the excess returns. Consequently, different kind of studies have been performed with the aim of finding alternative explanations to the phenomenon: return skewness and peso problems can be mentioned as the most acknowledged ones in literature.

2.4.1 Traditional risk factors

A natural starting point for the investigation on the nature of the carry trade profitability is checking whether payoffs are consistent with a traditional risk-based explanation. Generally speaking, an investment should compensate investors for bearing risk if it follows trends in the business cycle: it delivers low returns during bad states of the economy and, vice versa, high returns during periods of expansion. In this case, the payoffs of the assets are more volatile and, thus, returns must embed a risk premium to compensate investors for their risk exposure.

Therefore, in order to check if the returns to carry trade can be explained by the presence of risk premia, many studies have computed the covariance among the payoffs to the strategy and different variables connected with the business cycle; however, most of the factor models estimated have pointed out that these covariances are generally low.

Empirical evidence of the correlation between carry trade payoffs and traditional risk factors is presented in the already-mentioned study by Burnside et al. (2006), which focuses on two carry trade portfolios, the equally-weighted and the optimally-weighted one. The authors analyzed the exposures of the two carry trade strategies to several risk factors connected with the economic cycle, estimating eight different models that regress the accumulated quarterly real excess returns to the two portfolios on a variety of independent variables: the returns to the S&P 500, the CAPM factor[20], the three Fama-French factors[21], the per-capita consumption growth, the luxury retail sales growth, the growth rate of per-capita consumption of durables, the industrial production and the Yogo factors[22]. The following table shows the results obtained from the time-series regressions for the two carry trade

[20] The CAPM single factor is the market excess return ($R_m - R_f$).
[21] The three factors used by Fama and French are: the CAPM factor, the SMB (small minus big) factor, that represents the size premium due to the outperformance of small-cap companies with respect to large-cap ones, and the HML (high minus low), which corresponds to the value premium, that is, the excess returns of value stocks (high book-to-price ratio) over growth stocks (low book-to-price ratio).
[22] The Yogo factors are the CAPM factor, the growth rate of per-capita consumption of nondurables and services and the growth rate of the per-capita consumption of durables.

portfolios considering U.S. risk factors; the estimated coefficients show clearly that there is no significant correlation between the real returns and the traditional risk factors considered and, therefore, the latter are not able to explain the observed profitability of the two carry trade strategies.

Figure 2.16 – *Quarterly real excess returns to carry trade and U.S. risk factors*.

	Equally-Weighted Portfolio					Optimally-Weighted Portfolio				
	Intercept	Slope Coefficients			R^2	Intercept	Slope Coefficients			R^2
S&P 500	0.010	-0.007			0.000	0.013	-0.017			0.001
	(0.003)	(0.039)				(0.004)	(0.049)			
CAPM	0.010	-0.006			0.000	0.013	-0.019			0.002
	(0.003)	(0.038)				(0.004)	(0.046)			
Fama-French factors	0.010	-0.008	-0.019	-0.019	0.002	0.010	0.047	-0.024	0.150	0.045
	(0.003)	(0.051)	(0.075)	(0.069)		(0.004)	(0.057)	(0.093)	(0.071)	
Per-capita consumption growth	0.012	-0.548			0.005	0.015	-0.545			0.004
	(0.004)	(0.673)				(0.005)	(0.746)			
Luxury retail sales growth	0.008	0.009			0.001	0.012	-0.010			0.001
	(0.007)	(0.045)				(0.008)	(0.052)			
Per-capita durables services growth	0.014	-0.463			0.004	0.014	-0.096			0.000
	(0.007)	(0.664)				(0.009)	(0.772)			
Yogo factors	0.015	-0.004	-0.412	-0.341	0.007	0.015	-0.016	-0.533	0.061	0.005
	(0.007)	(0.036)	(0.747)	(0.732)		(0.009)	(0.048)	(0.847)	(0.847)	
Industrial production	0.009	0.150			0.003	0.013	-0.062			0.000
	(0.003)	(0.203)				(0.004)	(0.234)			

Note: the table contains the intercepts and the slope coefficients estimated from the time-series regressions of the quarterly real excess returns to the equally- and the optimal-weighted portfolios on different U.S. risk factors, together with the respective standard errors, in parentheses, and the R^2 of the models.
Source: BURNSIDE C., EICHENBAUM M., KLESHCHELSKI I., REBELO S. 2006. *The Returns to Currency Speculation*. NBER Working Paper 12489.

These results were confirmed by a subsequent study by Burnside et al. (2011), which employs data on 20 main currencies, over the sample period from 1976 to 2010, to build an equally-weighted carry trade portfolio[23]. The research uses monthly data on the payoffs to the strategy, which are regressed on several conventional risk factors, estimating six different models, namely, the CAPM, the Fama-

[23] The equally-weighted portfolio is built by investing $1/n_t$ US dollars in each individual currency carry trade, where n_t is the number of currencies included in the sample at time t, so that the total value of the bet is normalized to 1 US dollar.

French model and other extensions of the CAPM; the corresponding findings are displayed in the following table.

Figure 2.17 – *Factor betas of the carry trade portfolio (1976-2010).*

	Betas			R^2
CAPM	0.029 (0.017)			0.01
Fama-French	0.045* (0.018)	-0.034 (0.030)	0.042 (0.029)	0.02
Quadratic CAPM	0.033 (0.019)	0.286 (0.343)		0.01
CAPM-Volatility	-0.004 (0.026)	-0.010 (0.231)	2.093 (1.627)	0.02
C-CAPM	0.006 (0.733)			0.00
Extended C-CAPM	-0.314 (0.824)	0.671 (0.572)	0.013 (0.031)	0.01

Note: the table reports the slope coefficients estimated from a regression of the portfolio payoffs (monthly nominal excess returns) on a constant and the indicated risk factors, together with the R^2 of the model, for the sample period 1976-2010. The betas that are statistically significant at the 5% level are denoted by * and the heteroskedasticity consistent standard errors are in parentheses. The Quadratic CAPM uses the market excess return $(R_m - R_f)$, that is the excess return on the value-weighted US stock market, and $1/2\ (R_m - R_f)^2$ as factors; the CAPM-Volatility uses the market excess return, the stock volatility (the standard deviation of daily excess returns, measured monthly) and their interaction as factors; the C-CAPM uses the log growth rate of real consumption of nondurables and services, and is estimated with quarterly real excess returns (1976Q2-2010Q1); the Extended C-CAPM uses the C-CAPM factor, the log growth rate of the service flow of durables (assumed to be proportional to the real stock of consumer durables) and the market excess return as factors.
Source: BURNSIDE C., EICHENBAUM M. S., REBELO S. 2011. Carry trade and momentum in currency markets. NBER Working Paper 16942.

The conclusions that can be drawn from these results are similar to the ones derived from the previous study: none of the traditional risk factors considered in the models employed is able to explain the return to the carry trade strategy. In particular, the slope coefficients estimated are not statistically significant, except for the one related to the market excess return in the Fama-French model, which is, however, economically small, thus it cannot justify the high return to the strategy[24].

[24] In Burnside et al. (2011), the annual return computed from the data sample is 4.6%, while the expected return implied by the estimates of the Fama-French model is just 0.3%.

2.4.2 Specific risk factors

The poor results obtained from the analysis of the correlation between carry trade returns and traditional risk factors has led some academics to focus on the detection of different risk factors, more specific to currency markets and to the nature of the strategy, which may provide a risk-based explanation for carry trade profitability. Two relevant examples of such kind of research can be found in Lustig et al. (2009) and Menkhoff et al. (2012), which both postulate two-factor models that are able to account for a large portion of the cross-sectional variation in excess returns among high and low interest rate currencies.

Lustig et al. (2009) analyzed currency markets data from the end of 1983 to the beginning of 2008, ranking currencies by their forward discount at the end of every month to create six different portfolios, where the first is made up of low-yielding currencies, while the last contains the high-yielding ones. Then, monthly excess returns are computed for each portfolio, as the average of the excess returns to currencies included. In order to identify common risk factors that may explain the excess return to a carry trade strategy, the authors carried out a principal component analysis[25] on currency portfolios, which showed that more than 80 percent of the variation in returns can be attributed to the first two principal components, as displayed in the following table.

[25] Principal Component Analysis is a statistical technique that has the purpose of detecting a smaller group of uncorrelated variables, the so-called principal components, from a larger set of data; in particular, this tool is employed to highlight variation and identify strong pattern in datasets.

Figure 2.18 – *Principal Components*.

Panel I: All Countries						
Portfolio	1	2	3	4	5	6
1	0.43	0.41	−0.18	0.31	0.72	0.03
2	0.39	0.26	−0.14	−0.02	−0.44	0.75
3	0.39	0.26	−0.46	−0.38	−0.31	−0.57
4	0.38	0.05	0.72	−0.56	0.16	−0.01
5	0.42	−0.11	0.38	0.66	−0.37	−0.31
6	0.43	−0.82	−0.28	−0.10	0.18	0.11
% Var.	70.07	12.25	6.18	4.51	3.76	3.23
Panel II: Developed Countries						
Portfolio	1	2	3	4	5	
1	0.48	0.56	0.60	0.23	0.20	
2	0.47	0.29	−0.66	−0.32	0.40	
3	0.46	0.05	−0.30	0.36	−0.76	
4	0.42	−0.34	0.34	−0.72	−0.25	
5	0.41	−0.69	0.02	0.44	0.40	
% Var	79.06	9.33	4.73	3.58	3.30	

Note: the table presents the loadings of the currency portfolios on each of the principal components, for the entire sample (Panel I) and for the subsample of developed countries (Panel II). In each panel, the last row displays the portion (in %) of the total variance that is explained by each factor. The data used have monthly frequency and belong to the sample period 11/1983-03/2008.
Source: LUSTIG H., ROUSSANOV N., VERDELHAN A. 2009. Common risk factors in currency markets. SSRN Paper 1139447.

The results of the principal component analysis are similar for both the samples of currencies considered: the share of the total variance of portfolio returns explained by the first component is 70 percent for the whole sample and 79 percent for the subsample of developed countries' currencies, while the portion attributed to the second component is 12 percent for the entire sample and 9 percent for the subsample. Furthermore, the principal component analysis reveals that all the portfolios have roughly equal loadings on the first component, which therefore can be interpreted as a level factor, whereas the second one can be considered as a slope factor, since the corresponding coefficients increase monotonically from the first to the last portfolio. From the analysis of these two principal components the authors derived two currency risk factors for their model:

- the level factor, named as Dollar risk factor (RX), which is the average return to all the currency portfolios and can be interpreted as the average return for a U.S. investor that buys all the foreign currencies in the forward market;
- the slope factor, referred to as Carry Trade risk factor (HML_{FX}), that is defined as the difference between the returns on the last portfolio and the first one, thus interpreted as the

return on a zero-cost strategy involving a long position in the high interest rate currencies portfolio and a short position in the portfolio of low-yielding currencies.

According to Lustig et al. (2009), the exposure of a currency to these two risk factors affects the associated excess return, since it determines the required risk premium, made up of the dollar risk premium, which is equal for all the currencies, and a carry trade risk premium, that varies according to the currency interest rate. The two-factor model is estimated through both a cross-sectional and a time-series regression; in particular, the authors followed two different procedures for the estimation of the factor prices and the portfolio betas: the application of the Generalized Method of Moments (GMM) to linear factor models and the Fama-MacBeth (FMB) two-stage OLS estimation[26]. The results of the two methods are summarized in the following table, for both the whole sample of currencies and the subsample of developed countries.

[26] The FMB procedure involves two steps: the first one consists in running a time series regression for each portfolio, regressing the returns on the factors, in order to estimate the exposures (betas) of each portfolio to risk factors; the second stage, instead, is a cross-sectional regression of all portfolio returns on the previously estimated betas to determine the price (risk premium) of each factor.

Figure 2.19 – *Estimation of the two-factor model for currency returns (RX and HML_{FX} risk factors).*

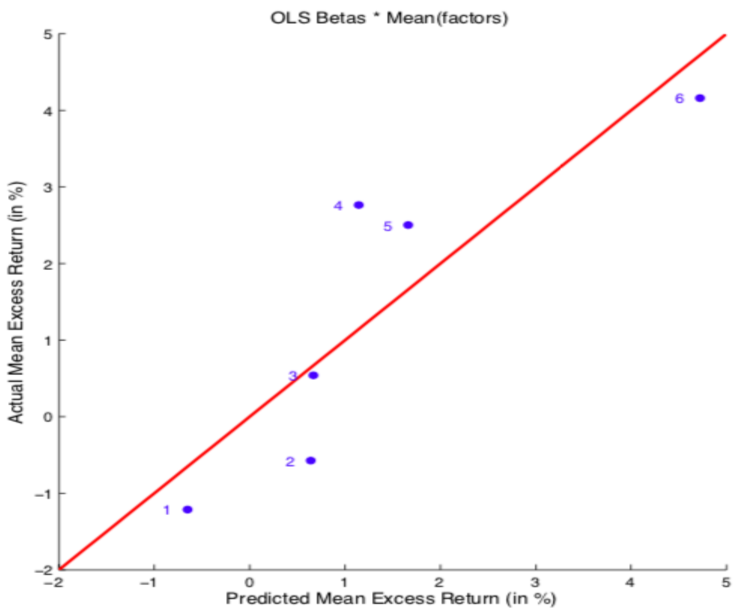
Panel I: Risk Prices														
	All Countries							Developed Countries						
	$\lambda_{HML_{FX}}$	λ_{RX}	$b_{HML_{FX}}$	b_{RX}	R^2	RMSE	χ^2	$\lambda_{HML_{FX}}$	λ_{RX}	$b_{HML_{FX}}$	b_{RX}	R^2	RMSE	χ^2
GMM_1	5.46	1.35	0.59	0.26	69.28	0.95		3.56	2.24	0.43	0.32	71.06	0.61	
	[2.34]	[1.68]	[0.25]	[0.32]			13.83	[2.19]	[2.02]	[0.24]	[0.24]			41.06
GMM_2	4.88	0.58	0.52	0.12	47.89	1.24		3.78	3.03	0.46	0.42	20.41	1.00	
	[2.23]	[1.63]	[0.24]	[0.31]			15.42	[2.14]	[1.95]	[0.23]	[0.23]			44.36
FMB	5.46	1.35	0.58	0.26	69.28	0.95		3.56	2.24	0.42	0.32	71.06	0.61	
	[1.82]	[1.34]	[0.19]	[0.25]			13.02	[1.80]	[1.71]	[0.20]	[0.20]			41.34
	(1.83)	(1.34)	(0.20)	(0.25)			14.32	(1.80)	(1.71)	(0.20)	(0.20)			42.35
Mean	5.37	1.36						3.44	2.24					

Panel II: Factor Betas												
	All Countries						Developed Countries					
Portfolio	α^j	$\beta^j_{HML_{FX}}$	β^j_{RX}	R^2	$\chi^2(\alpha)$	*p-value*	α^j	$\beta^j_{HML_{FX}}$	β^j_{RX}	R^2	$\chi^2(\alpha)$	*p-value*
1	-0.56	-0.39	1.06	91.36			0.00	-0.50	1.00	94.95		
	[0.52]	[0.02]	[0.03]				[0.48]	[0.02]	[0.02]			
2	-1.21	-0.13	0.97	78.54			-0.90	-0.11	1.02	82.38		
	[0.76]	[0.03]	[0.05]				[0.81]	[0.04]	[0.04]			
3	-0.13	-0.12	0.95	73.73			1.01	-0.02	1.02	85.22		
	[0.82]	[0.03]	[0.04]				[0.83]	[0.03]	[0.03]			
4	1.62	-0.02	0.93	68.86			-0.12	0.13	0.97	81.43		
	[0.86]	[0.04]	[0.06]				[0.85]	[0.04]	[0.04]			
5	0.84	0.05	1.03	76.37			0.00	0.50	1.00	93.87		
	[0.80]	[0.04]	[0.05]				[0.48]	[0.02]	[0.02]			
6	-0.56	0.61	1.06	93.03								
	[0.52]	[0.02]	[0.03]									
All					10.11	0.12					2.61	0.76

Note: Panel I reports the estimates obtained from the GMM and FMB procedures for the market prices of risk factors λ, the vectors of factor loadings b, the adjusted R^2, the square root of mean-squared errors RMSE and the p-values of the χ^2 tests on pricing errors. Excess returns used as test assets and risk factors take into account bid-ask spreads and are all annualized (multiplied times 12). Shanken (1992)-corrected standard errors are reported in parentheses. In the second stage of the FMB procedure, the cross-sectional regression does not include a constant, since the dollar risk factor acts like a constant in this context. Panel II, instead, displays OLS estimates of the factor betas, the alphas of the regression (annualized), the R^2, the p-values and the χ^2 test statistic for the null hypothesis that all the intercepts are jointly zero. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). Data are monthly, from Barclays and Reuters in Datastream, and the sample period is from 11/1983 to 03/2008.
Source: LUSTIG H., ROUSSANOV N., VERDELHAN A. 2009. Common risk factors in currency markets. SSRN Paper 1139447.

Panel I of the above table displays the results of the two procedures used for the cross-sectional analysis, which aims at estimating the market prices λ of the two risk factors. Focusing on the findings derived from the whole sample of currencies, the value for the carry trade risk factor price, $\lambda_{HML_{FX}}$, equals 546 basis point per annum, implying that the return to an asset or portfolio with a beta coefficient of one should include a carry trade risk premium of 5.46 percent per annum; moreover, in both the GMM and FMB procedures, this risk price is highly statistically significant. The market price estimated for the dollar risk factors, instead, is 135 basis points per annum. The beta coefficients of the six portfolios, representing the exposures to the risk factors, are computed through time series regression of returns for each portfolio on a constant and the risk factors; these slope coefficients are listed in Panel II of the table, together with the estimates of the constant α, which are almost all small and insignificantly different from zero. The betas associated with the HML_{FX} factor follow a monotonically increasing path from the first to the last portfolio, with values ranging from -0.39 to 0.61; in particular, the first four portfolios have negative betas, while the last two have positive coefficients, and all are significantly different from zero. This means that the exposure of a portfolio to the HML_{FX} factor depends on the interest rate level of the currencies included: it is negative for portfolios of low-yielding currencies and positive for the high-yielding ones. The slope coefficients estimated for the dollar risk factor RX, on the other hand, are all approximately equal to one, implying that all portfolio has the same exposure to this factor, regardless of the currency interest rates. Therefore, the carry trade risk factor accounts for the cross-sectional differences in currency portfolio returns, whereas the dollar risk factor does not, but it has the function of a level factor that is helpful in explaining the average level of excess returns. The results just described are robust, since they hold also in the smaller sample of developed countries. Figure 2.20 displays the plot of the model's predicted excess returns against the realized excess returns for the six portfolios, showing that the two-factor model provide a quite good fit.

Figure 2.20 - *Fit of the two-factor model (RX and HML_{FX} risk factors).*



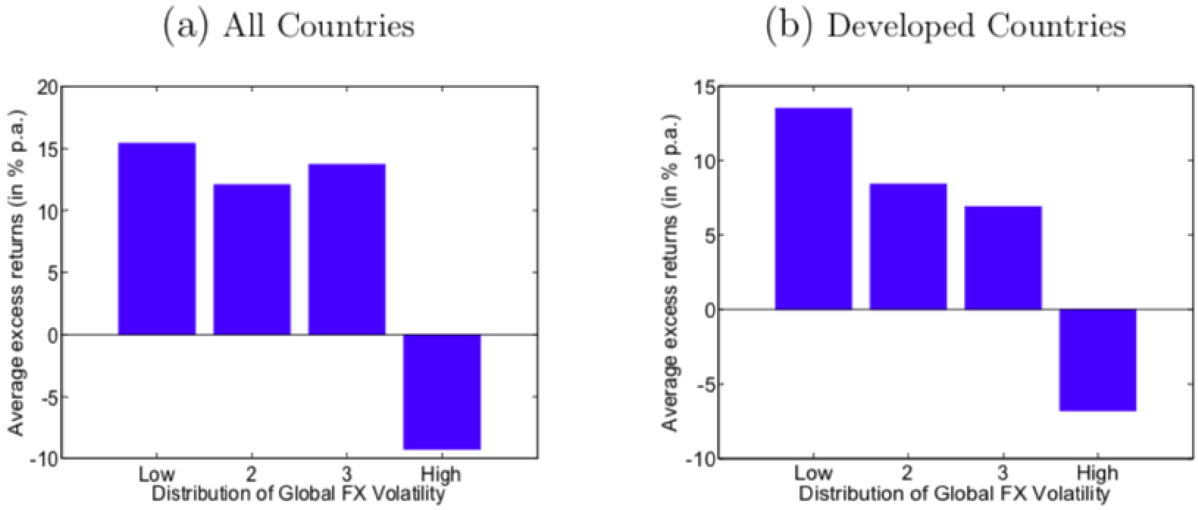
Note: This figure plots realized average excess returns on the vertical axis against predicted average excess returns on the horizontal axis. Each predicted excess return is obtained using the OLS estimate of β times the sample mean of the factors. All returns are annualized. The data are monthly, from the sample period 11/1983-03/2008.
Source: LUSTIG H., ROUSSANOV N., VERDELHAN A. 2009. Common risk factors in currency markets. SSRN Paper 1139447.

To summarize, Lustig et al. (2009) derived a two-factor model, which provides a risk-based explanation for carry trade excess returns; the risk premium of a currency is determined by two currency risk factors, namely, the dollar and the carry trade risk factors. While the dollar risk premium represents a compensation for home country risk, the carry trade risk premium compensates the investor for global risk. Therefore, the latter determines differences among currency excess returns: high interest rate currencies increase the investor's exposure to HML_{FX} risk, whereas low interest rate currencies provide insurance against it; this implies that the former require a higher risk premium to compensate investors for bearing this risk. Consequently, this model claims that a carry trade strategy, which invests in high-yielding currencies and borrows low-yielding ones, loads up on global risk, thus supporting a risk-based explanation for carry trade profitability.

The second relevant study in the strand of literature that investigates empirically the risk-return profile of carry trade through the detection of specific risk factors is Menkhoff et al. (2012). Following Lustig et al. (2009), they developed a two-factor model, proposing a different slope factor: they retained the dollar risk factor defined in the former study, which represents the average level of currency excess returns, and replaced the carry trade factor, HML_{FX}, with the global FX volatility risk factor, that is a proxy for unexpected changes (innovations) in the FX market volatility. Menkhoff et al. (2012) analyzed the relationship between global FX volatility risk and the cross-section of currency excess returns, in order to show that carry trade returns can be viewed as compensation for exposure to this source of risk. According to financial theory, risk-averse agents are concerned about unexpected increases in FX volatility and thus they wish to hedge their investment against this kind of risk. Assets characterized by a positive covariance with volatility innovations represent a good hedge for investors, since they perform well during periods of unexpectedly high volatility, and, consequently, they are expected to earn lower returns; this suggests that FX volatility risk must be negatively priced in the market, so that a positive exposure would imply lower expected returns and vice versa. This intuition is confirmed by empirical data in the analysis of Menkhoff et al. (2012).

The authors collected monthly data from the period 11/1983-08/2009 for a total sample of 48 currencies, which are sorted according to their forward discount in order to build five currency portfolios, rebalanced on a monthly basis, like in Lustig et al. (2009): the interest rate increases when moving from currencies in portfolio 1 to the ones in portfolio 5. Then, they derived descriptive statistics for the five portfolios, together with the excess return to a carry trade strategy, defined as the difference between the returns to the last and the first portfolios (long-short portfolio H/L). Before the estimation of the model, a graphical analysis of the relationship between FX volatility innovations and carry trade excess returns is carried out; the results, for the entire sample and for a smaller one of 15 developed countries, are displayed in figure 2.21, represented through bar charts.

Figure 2.21 – *Carry trade excess returns and global FX volatility.*



Note: The figure shows mean excess returns for carry trade portfolios (long-short portfolio H/L) conditional on global FX volatility innovations being within the lowest to highest quartile of its sample distribution (four categories from "lowest" to "highest" shown on the x-axis of each panel). Panel (a) shows results for all countries, while Panel (b) shows results for developed countries. The sample period is 11/1983 – 08/2009.
Source: MENKHOFF L., SARNO L., SCHMELING M., SCHRIMPF A. 2012. Carry trades and global foreign exchange volatility. The Journal of Finance 67, pp. 681-718.

The graph shows that, moving from low to high volatility, the mean excess returns to the carry trade portfolio follow a decreasing pattern; in particular, the returns decrease monotonically for the subsample of developed currencies and almost monotonically for the whole sample. This graphical representation highlights an inverse relationship among carry trade returns and innovations in FX volatility: carry trade is profitable in low volatility states, while performing poorly in periods of extremely high volatility. This implies that in times of unexpectedly high FX volatility funding currencies (low interest rates) perform well with respect to investment currencies (high interest rates) and thus the former represents a hedge against volatility risk.

The findings just illustrated through the graphical analysis are confirmed by the results obtained from the estimation the two-factor model; the following table (figure 2.22) reports the market prices λ of the risk factors and the beta coefficients of the portfolios, which are estimated following the same two procedures as in Lustig et al. (2009), namely the GMM and the FMB two-stage regression.

Figure 2.22 - *Estimation of the two-factor model for currency returns (DOL and VOL risk factors).*

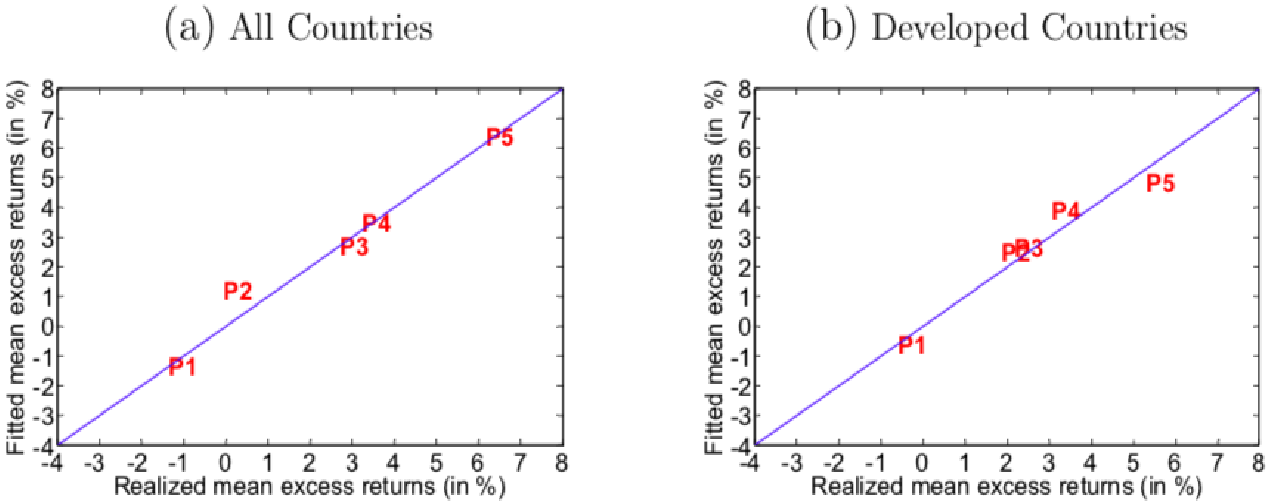
Panel A: Factor Prices									
All countries (with b-a)					Developed countries (with b-a)				
GMM	DOL	VOL	R^2	HJ-dist	GMM	DOL	VOL	R^2	HJ-dist
b	0.00	-7.15	0.97	0.08	b	0.02	-4.38	0.94	0.06
s.e.	(0.05)	(2.96)		(0.79)	s.e.	(0.03)	(2.73)		(0.89)
λ	0.21	-0.07			λ	0.22	-0.06		
s.e.	(0.25)	(0.03)			s.e.	(0.22)	(0.04)		
FMB	DOL	VOL	χ^2_{SH}	χ^2_{NW}	FMB	DOL	VOL	χ^2_{SH}	χ^2_{NW}
λ	0.21	-0.07	1.35	0.94	λ	0.22	-0.06	0.95	0.83
(Sh)	(0.15)	(0.02)	(0.72)	(0.82)	(Sh)	(0.16)	(0.02)	(0.81)	(0.84)
(NW)	(0.13)	(0.03)			(NW)	(0.15)	(0.03)		

Panel B: Factor Betas									
All countries (with b-a)					Developed countries (with b-a)				
PF	α	DOL	VOL	R^2	PF	α	DOL	VOL	R^2
1	-0.29	1.01	4.34	0.76	1	-0.23	0.94	4.52	0.71
	(0.08)	(0.04)	(0.70)			(0.09)	(0.05)	(1.42)	
2	-0.15	0.84	1.00	0.74	2	-0.05	1.05	0.43	0.82
	(0.06)	(0.04)	(0.59)			(0.07)	(0.04)	(0.89)	
3	0.05	0.97	-0.30	0.79	3	-0.02	1.01	0.01	0.88
	(0.06)	(0.04)	(0.63)			(0.05)	(0.03)	(0.64)	
4	0.09	1.02	-1.06	0.83	4	0.07	0.96	-1.94	0.82
	(0.06)	(0.04)	(0.71)			(0.07)	(0.03)	(0.97)	
5	0.30	1.15	-3.98	0.67	5	0.24	1.04	-3.02	0.73
	(0.11)	(0.06)	(1.20)			(0.10)	(0.05)	(1.09)	

Note: the table reports cross-sectional pricing results for the linear two-factor model based on the dollar risk factor (DOL) and the global FX volatility innovations risk factor (VOL), both for the full sample of currencies and the smaller one of developed countries. Panel A shows estimates of the factor loadings b and the factor prices λ resulting from first-stage GMM and FMB cross-sectional regression; the regressions in the second step of FMB do not include a constant. Standard errors (s.e.) of coefficient estimates are reported in parentheses. The table also reports the cross-sectional R^2 and the Hansen-Jagannathan distance (HJ-dist) along with the (simulation-based) p-value for the test whether the HJ-distance is equal to zero. The reported FMB standard errors and χ^2 test statistics (with p-values in parentheses) are based on both the Shanken (1992) adjustment (Sh) or the Newey-West approach with optimal lag selection (NW). Panel B reports the beta coefficients estimated regressing the time series of portfolio excess returns on a constant (α) and the two risk factors; HAC standard errors are reported in parentheses. The data used are monthly transaction-cost adjusted returns from the sample period 12/1983-08/2009.
Source: MENKHOFF L., SARNO L., SCHMELING M., SCHRIMPF A. 2012. Carry trades and global foreign exchange volatility. The Journal of Finance 67, pp. 681-718.

The table reports a positive price for the dollar factor and a negative one for global FX volatility innovations, as expected from financial theory; in particular, the volatility price, λ_{VOL}, equals -0.07 for the full sample and -0.06 for the subsample of developed countries. As a consequence, assets that are positively correlated with volatility innovations deliver lower returns compared to assets presenting a negative correlation, which require a higher risk premium since they do not provide a hedge against unexpected increase in FX volatility. The estimates for the portfolio beta coefficients listed in Panel B are consistent with the results of the graphical analysis: the slope coefficient β_{VOL} monotonically decreases across portfolios, from 4.34 for portfolio 1 to -3.98 for portfolio 5 in the full sample and from 4.52 to -3.02 in the developed countries sample. This implies that high-yielding currencies are negatively correlated to volatility innovations, while low-yielding ones are positively correlated to the risk factor, thus acting as volatility hedges. The estimates obtained for the dollar risk factor, instead, are comparable to the ones reported by Lustig et al. (2009): all the portfolios present a similar exposure, with beta coefficients roughly equal to 1, as expected from the definition of the factor. Again, the comparability among the estimates for the two different samples verifies the robustness of the results. A graphical representation of the mean excess returns implied by the model plotted against the realized mean excess returns is presented below (figure 2.23), in order to illustrate the fit of the model, which turns out to be quite successful in predicting the excess returns for the five portfolios, in both the samples of currencies considered.

Figure 2.23 – *Fit of the two-factor model (DOL and VOL risk factors).*



Note: the plot shows the realized mean excess returns along the horizontal axis and the fitted mean excess returns along the vertical axis, both for the whole sample and the developed countries subsample. The sample period is 11/1983-08/2009.
Source: MENKHOFF L., SARNO L., SCHMELING M., SCHRIMPF A. 2012. Carry trades and global foreign exchange volatility. The Journal of Finance 67, pp. 681-718.

In conclusion, the two-factor model proposed by Menkhoff et al. (2012) supports the idea that excess returns to carry trade are due to the high exposure of the strategy to specific sources of risk: according to this model, the risk of innovations in global FX volatility. This factor is able to explain the cross-sectional variations in currency excess returns, whereas the dollar risk factor is a level factor representing the average return to all currency portfolios. The estimates of the volatility factor price and the portfolios' beta coefficients imply large excess returns to a carry trade strategy, determined by its exposure to FX volatility innovations risk: indeed, the strategy involves investing in high interest rate currencies, which require higher volatility risk premium, and shorting low-yielding currencies, which include lower risk premium due to the insurance against volatility innovations provided. In other words, carry trade performs particularly poorly during periods of market turmoil and, consequently, delivers large payoffs to investors as compensation for higher risk-exposure.

2.4.3 Alternative explanations

Besides the development of multifactor models that try to rationalize excess returns to carry trade, empirical literature has proposed also alternative explanations to the observed profitability, analyzing the phenomenon from different perspectives: some instances of this line of research are, among others, return skewness and peso problems.

As already mentioned in paragraph 2.3, the negative skewness of returns to carry trade was pointed out by Brunnermeier et al. (2008): the study empirically shows that these returns are positive on average, but negatively skewed, since their distribution presents a fat left tail, implying that the strategy is subject to crash risk. The authors analyzed daily data for eight major currencies, with the U.S. Dollar as base currency, over the sample period from 1986 to 2006; in particular, they collected time-series daily data on exchange rate between each of these currencies and the U.S. Dollar and computed the skewness of exchange rate movements within quarterly intervals, as reported in the following table.

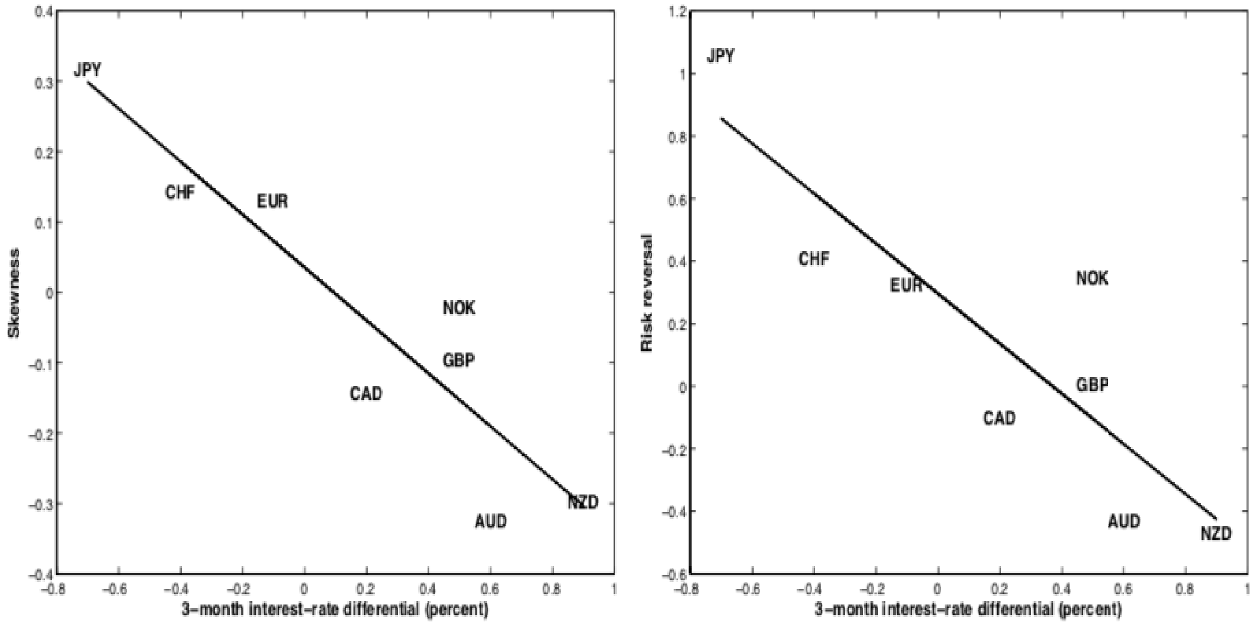
Figure 2.24 – *Summary statistics for eight major currencies against the U.S. dollar.*

	AUD	CAD	JPY	NZD	NOK	CHF	GBP	EUR
Panel A: Means								
Δs_t	-0.003	-0.002	-0.003	-0.005	-0.002	-0.004	-0.004	-0.004
z_t	0.009	0.004	-0.004	0.013	0.007	-0.001	0.009	0.003
$i^*_{t-1} - i_{t-1}$	0.006	0.002	-0.007	0.009	0.005	-0.004	0.005	-0.001
Futures positions	-	0.059	-0.097	-	-	-0.067	0.052	0.031
Skewness	-0.322	-0.143	0.318	-0.297	-0.019	0.144	-0.094	0.131
Risk reversals	-0.426	-0.099	1.059	-0.467	0.350	0.409	0.009	0.329

Note: quarterly data for the sample period 1986-2006 (1998-2006 for risk reversal). Δ_{s_t} is the quarterly change in the foreign exchange rates (units of foreign currency per U.S. dollar), z_t is the return from investing in a long position in the foreign currency financed by borrowing in the domestic currency, “Futures positions” refers to the net long position in foreign currency futures of non-commercial traders. Risk reversal is the implied volatility difference between 1-month foreign currency call and put options.
Source: BRUNNERMEIER M. K., NAGEL S., PEDERSEN L. H. 2008. Carry trades and currency crashes. NBER Working Paper 14473.

The table shows the average value of both the realized skewness, in the fifth row, and the risk-neutral skewness (i.e. the one implied from risk reversal), in the last row. In the cross-section, both the measures are negatively related to the average interest rate differential: they assume negative values for high interest rate currencies, like the New Zealand Dollar and the Australian Dollar, increasing to positive values for low-yielding currencies, such as the Japanese Yen and the Swiss Franc. This result is graphically represented in figure 2.25, which displays that the relationship among interest rate differential and skewness of exchange rates is well approximated by a downward sloping line.

Figure 2.25 – *Cross-sectional relationship between skewness of exchange rates and interest rate differential.*



Note: the figure displays the cross-section of empirical skewness (left-hand panel) and of risk reversal (right-hand panel), reflecting implied (risk-neutral) skewness, for different quarterly interest rate differentials.
Source: BRUNNERMEIER M. K., NAGEL S., PEDERSEN L. H. 2008. Carry trades and currency crashes. NBER Working Paper 14473.

This negative correlation in the cross section of currencies implies that carry trade returns are negatively skewed: a long position in an investment currency like the Australian Dollar, financed by a short position in the U.S. dollar, during the sample period considered, would have gained an excess return of 0.9% (i.e. 0.6% from the interest differential plus 0.3% from the AUD appreciation relative to the USD), but, at the same time, would have been exposed to a negative skewness of -0.322. The authors carried out the analysis also from a portfolio perspective, building long-short portfolios which differ for the number of currencies included, as already described in subparagraph 2.3.1; the results reveal that returns to these carry trades are characterized by negative skewness, as reported in the table in figure 2.6.

The second alternative explanation to carry trade profitability is provided by Burnside et al. (2011), which argued that the large positive average returns are due to the presence of a peso problem. This term refers to the problem arising when the risk of low-probability events (i.e. peso-events) is priced by the market. This phenomenon is clearly relevant for studies on the profitability of investment strategies: when the analysis is carried out on a data sample that does not include these rare events, the results will not consider the impact of the latter on the performance of the strategy. In the case of carry trade, a peso event can be represented, for instance, by a significant appreciation of the funding currency, assuming that it occurs with small probability. Since this event will cause large losses, the carry trader must receive a compensation for the potential negative payoffs associated with the peso state; this implies that the average risk-adjusted excess return to the strategy is positive in non-peso states of the world. Consequently, carry trade payoffs can be viewed as a compensation for peso-event risk; however, it is not easy to include the effect of these infrequent events in the results of empirical analyses, since they are not observed in the data sample used.

Burnside et al. (2011) studied the impact of peso problems on carry trade profitability in order to check whether this phenomenon can explain the returns to these trades. They analyzed the payoff to a hedged version of the carry trade, which involves the purchase of currency options, such that the strategy does not deliver large negative payoffs in a peso state; in particular, a forward sale of a foreign currency is covered buying a call option on that currency, while a long forward position in a foreign currency is combined with a currency put option. The following table compare the summary statics derived for the hedged and the unhedged version of an equally-weighted carry trade portfolio; as showed, the average payoff to the hedged strategy is lower with respect to the unhedged version, supporting the idea that the positive carry trade returns reflect the presence of a peso problem.

Figure 2.26 – *Annualized payoffs to hedged and unhedged carry trade strategies.*

	Mean	Standard Deviation	Sharpe Ratio	Skewness	Excess Kurtosis
Unhedged carry trade	0.0296	0.062	0.476	-0.708	1.47
	(0.0136)	(0.005)	(0.234)	(0.154)	(0.44)
Hedged carry trade	0.0158	0.035	0.449	0.722	1.14
	(0.0078)	(0.002)	(0.212)	(0.248)	(0.63)

Note: the sample period is February 1987 – April 2009 and the base currency is the U.S. Dollar. The payoffs are measured in U.S. Dollar. The carry trade portfolio is built as the equally-weighted average of up to six individual currency carry trades against the U.S. Dollar; the individual currencies are the Australian Dollar, the Canadian Dollar, the Japanese Yen, the Swiss Franc, the British Pound and the Euro. The hedged carry trade portfolio combines the forward market positions with an option contract that insures against losses from the forward position. Standard errors are in parentheses.
Source: BURNSIDE C., EICHENBAUM M. S., REBELO S. 2011. Carry trade and momentum in currency markets. NBER Working Paper 16942.

CHAPTER 3 – EMPIRICAL ANALYSIS ON THE PROFITABILITY OF CARRY TRADE

3.1 Introduction

After the examination of the theoretical framework for carry trade and the literature review on the profitability of the strategy and the possible explanations, this chapter focuses on a personal empirical analysis of the investment strategy. The analysis is carried out from the perspective of an investor from the Eurozone, which enters long (short) positions in foreign currencies while shorting (investing in) the domestic one, i.e. the euro; the research focuses on a relatively small basket of currencies, namely the G10 currencies: the Euro (EUR), the US dollar (USD), the Pound sterling (GBP), the Swiss franc (CHF), the Japanese yen (JPY), the Australian dollar (AUD), the New Zealand dollar (NZD), the Norwegian krone (NOK), the Swedish krona (SEK) and the Canadian dollar (CAD). Further, the analysis starts after the introduction of the euro and covers a period of 20 years, from December 2001 to December 2021; it is carried out with a monthly frequency, considering end-of-month observations for the data involved, which are all collected from Refinitiv Workspace and Bloomberg.

The chapter starts with a description of the data collected for the analysis and the methodology used to analyze carry trade profitability (paragraph 3.2): first, I focus on currency excess returns, namely the returns to an investment in a foreign currency, funded by shorting the domestic currency; after the study of the excess return to each of the foreign currencies in my sample, I move on to the definition of two different carry trade strategies, building two portfolios which combine different currency positions selected according to specific criteria. Paragraph 3.3 presents and describes the first results of the analysis, which concern the estimation of the excess returns to the currency positions and to the carry trade portfolios built, together with the related statistics, as, in particular, the average return, standard deviation, skewness and Sharpe ratio. Finally, paragraph 3.4 focuses on the investigation of the possible explanations for the profitability of carry trade in terms of compensation for the exposure to sources of risk: following the studies performed by academics, I estimate different factor models, considering first conventional risk factors and then more specific ones; in particular, the monthly excess returns to the carry trade portfolios are regressed on the different factor considered, in order to estimate the beta coefficients, which represent the exposure to the sources of risk involved.

3.2 Data and methodology

The starting point for an empirical analysis on the profitability of carry trades is the choice of the data set that will be considered for the simulation of the strategy, in particular, the currencies involved, the time-period covered and the frequency of the observations analyzed. I restrict my analysis to a small basket of currencies from developed countries, the G10 currencies, which are considered the most traded and liquid currencies in the world. The reasons behind this choice relate to the characteristics of these currencies: given their popularity on the FX market, data for these currencies are easily available, and their liquidity implies lower transaction costs; moreover, since they all belong to developed countries, these currencies are associated with low default risk and are less exposed to certain regulatory or political issues which characterize instead emerging markets, like, among others, political instability and capital controls. My analysis covers a time period of 20 years, starting after the introduction of the euro: more precisely, the sample period goes from December 2001 to December 2021, a choice dictated also by the availability of data. I start by collecting monthly data for the sample of currencies during the time interval considered, since this is the frequency usually chosen by authors in the empirical literature; these data are used first to analyze currency excess returns and, then, to build carry trade portfolios, as will be described in this paragraph.

3.2.1 Currency excess returns

The first step of my research is the analysis of the currency excess returns, defined as the excess returns earned by an investor who take a long position in the foreign currency, financed by a short position in the domestic currency. Since the perspective adopted in this study is the one of a Eurozone investor, I consider the euro as the domestic currency and compute the excess returns for the remining nine currencies in the sample. For ease of exposition and computation, the analysis is carried out with logarithms; hence, I use the logarithmic approximation in equation (2.4) to compute the log excess return to currency k as

$$x_{t+1}^{k} = \left(i_t^{*,k} - i_t\right) + \left(s_{t+1}^{k} - s_t^{k}\right) \tag{3.1}$$

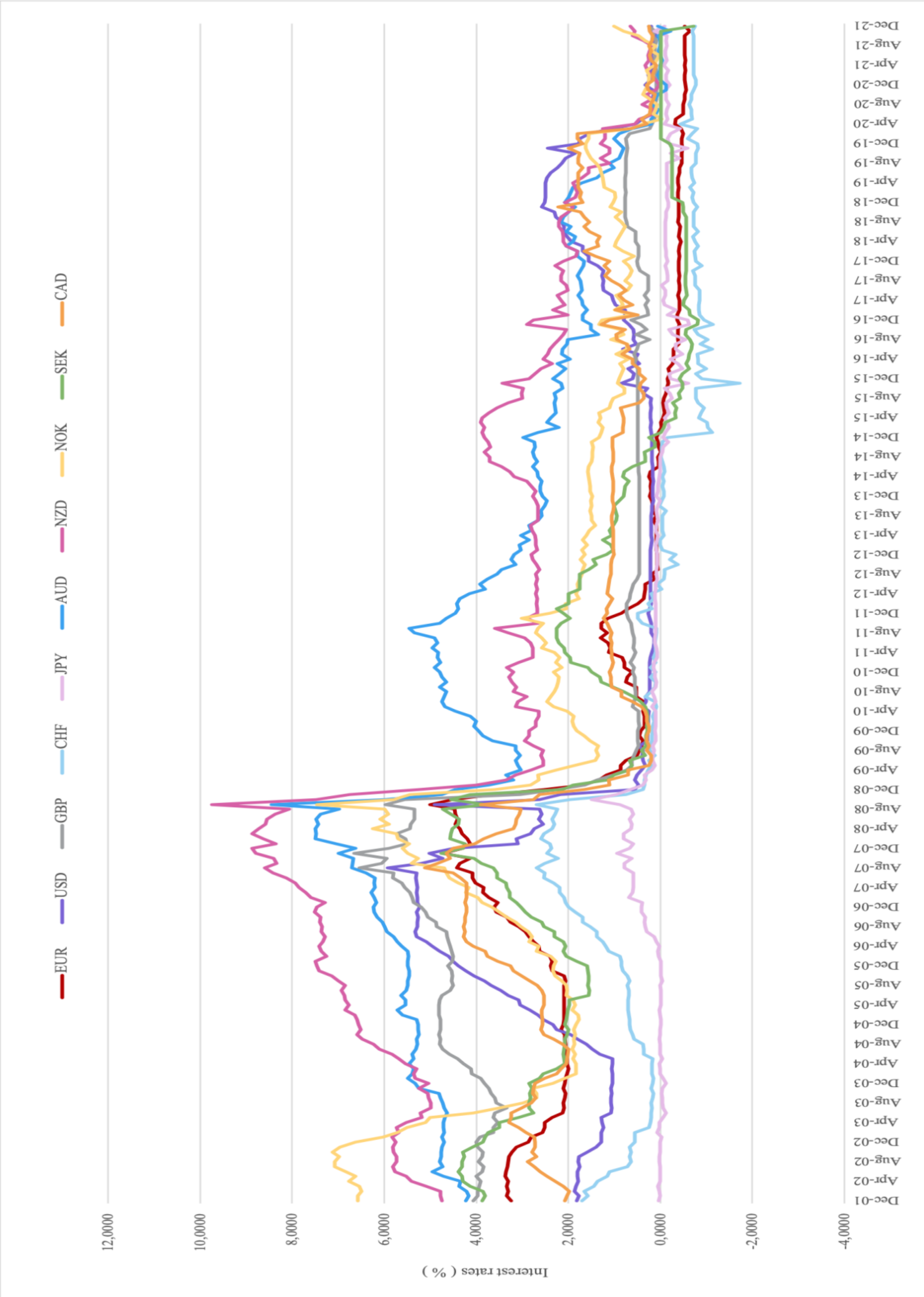
As shown by the above formula, for each of the foreign currencies in the sample, the excess return delivered by the investment from t to $t + 1$ is given by two components: the variation in the log spot exchange rate against the domestic currency in the time interval and the interest rate differentials with the home country at time t.

The time-series data for the spot exchange rates, defined as the amount of domestic currency needed to buy one unit of the foreign one, are collected from Refinitiv Workspace; in particular, the sample is made up of monthly data on the spot exchange rates against the euro for the nine foreign currencies in the G10 basket, from 31 December 2001 to 31 December 2021, for a total of 241 observations. I use this dataset to derive the log spot exchange rates and, then, to compute the appreciation/depreciation of the foreign currencies at the end of each month in the sample.

The second component of the excess returns is the interest rate differential, namely, the difference among the foreign and the domestic interest rates; most of the empirical studies carried out by academics choose T-bill yields or interbank rates as reference interest rates for the different currencies. Since my analysis is performed with a monthly horizon, I need to use one-month interest rates for the computation of the differentials between the euro and the nine foreign currencies; considering the readiness of these data for my sample of currencies and for the time interval, I decide to take deposit rates as reference interest rates, since they are the only data available for all the G10 currencies and for the whole period. Monthly observations on one-month deposit rates[27] for the basket of currencies, collected from Bloomberg, are displayed by the following chart (figure 3.1).

[27] A deposit rate is the interest rate paid by a bank or financial institutions on cash deposits.

Figure 3.1 – *One-month deposit rates for the G10 currencies.*



Note: the chart displays monthly observations on one-month deposit rates (in percentage) for the sample of G10 currencies, from the December 2001 to December 2021.
Source: Bloomberg.

As shown by the above graph, the general level of deposit rates has changed since the great financial crisis; after a steep decline during the last months of 2008, all the interest rates exhibit lower levels than the pre-crisis ones. Further, from the end of 2011, almost all the rates have followed a decreasing path, reaching the lowest levels in recent years; in particular, the EUR, CHF, JPY and SEK exhibit negative values for the last six years. Focusing on the differences between the currencies' interest rates, the Australian dollar and the New Zealand dollar are associated with the highest rates throughout the whole sample period, while the rates for the Swiss franc and the Japanese yen assume the lowest value; indeed, the AUD and NZD are considered as the most popular investment currencies for carry trade strategies, while the CHF and the JPY are typically used as funding currencies. It is possible to observe graphically that these currencies present the largest interest rate differential with the euro for the entire period considered, even if these spreads have narrowed since 2020; the average differentials are -1.03% for the JPY, -0.91% for the CHF, 2.49% for the AUD and 2.82% for the NZD.

3.2.2 Carry trade portfolios

After considering the excess return delivered by investments in each single foreign currency, funded by short positions in the domestic currency, my analysis focuses on the examination of the profitability of carry trade strategies that combine positions in different currencies. In particular, I built two different euro-based carry trade portfolios, both monthly rebalanced:

- Portfolio 1, which is made up of a long position in the three currencies associated with the highest interest rate differentials and a short position in the three currencies with the lowest differentials;
- Portfolio 2, that invests instead in all the nine foreign currencies, taking long or short positions according to the sign of the yield-spread with the euro.

In order to build Portfolio 1, at the end of each month t, I sort the foreign currencies according to their yield differentials with the domestic currency to select which currencies should be bought or shorted for the following one-month investment period. Then, on the basis of this ranking, the portfolio takes a long position in the three currencies with the highest interest differentials, borrowing the domestic currency, and a short position in the three currencies with the lowest yield spreads, while investing in the home currency. The return to the portfolio, from t to $t+1$, is computed as the average of the excess returns to the currencies involved during the considered time period, where the return to the short position in a given currency is calculated as the opposite of (3.1).

The following figure gives an idea of the composition of the portfolio throughout the time interval considered, showing how many times each of the foreign currencies falls within the long or short position of the strategy.

Figure 3.2 – *Composition of Portfolio 1 over the sample period.*

Note: the bar chart displays how many times each of the currencies in the sample is included in the portfolio, as part of the short position (red) or long position (green). The total number of observations is 240, since the portfolio is rebalanced at the end of each month from December 2001 to November 2021 (one month before the end of the sample considered). Source: Bloomberg, personal computation.

The bar chart shows that the composition of the portfolio varies over the sample period, including all the currencies in the sample; some of them, like the USD, belong to the short position in some period and to the long position in others, while some currencies are always shorted, as the CHF and the JPY, or always bought, like the NZD. As expected, the most shorted currencies are the Swiss franc and the Japanese yen, given their low interest rate levels, while the currencies that appear more frequently in the long side of the portfolio are the New Zealand dollar, the Australia dollar and Norwegian krone.

Portfolio 2, instead, follows a more diversified strategy, since it does not consider just extreme values as Portfolio 1, but involves all the currencies in the sample; at the end of each month t, the allocation of the portfolio is realized according to the sign of the interest rate differential with respect to the euro: the strategy goes long in currencies with positive differential and short in those with negative differential. Again, the return to the portfolio is defined as the average of the excess returns to the different currency positions involved in the strategy. The following bar chart (figure 3.3) reflects the composition of the portfolio, pointing out the number of times each currency is bought or shorted.

Figure 3.3 – *Composition of Portfolio 2 over the sample period.*

Note: the bar chart displays how many times each of the currencies in the sample is included in the portfolio, as part of the short position (red) or long position (green). The total number of observations is 240, since the portfolio is rebalanced at the end of each month from December 2001 to November 2021 (one month before the end of the sample considered). Source: Bloomberg, personal computation.

3.2.3 Transaction costs

In order to derive the actual excess returns earned by an investor that enters the above-described strategies, I collect also bid-ask quotes for spot exchange rates and interest rates for my sample and compute the log currency excess returns adjusted for bid-ask spreads, to assess the impact of transaction costs.

Since the relevant exchange rate in the analyzed strategies is defined as the price of the foreign currency in terms of the domestic one, the bid quote is the price received when selling one unit of the foreign currency, while the ask price is the cost of buying one unit of the same currency. The bid interest rate, instead, is the yield received when investing in a currency, whereas the ask interest rate is the yield paid when borrowing a currency. This means that, in a long foreign position funded by a short domestic one, the investor pays the ask price S_t^a to purchase the foreign currency at time t and, then, sells that currency in $t+1$, receiving the bid price S_{t+1}^{b}. Further, the interest differential collected by the investor is given by the difference between the foreign bid interest rate, $i_t^{*,b}$, and the domestic ask rate, i_t^{a}, since the agent is lending the foreign currency and borrowing the domestic one.

Consequently, the log currency excess return net of transaction costs for a long position in the foreign currency is defined as

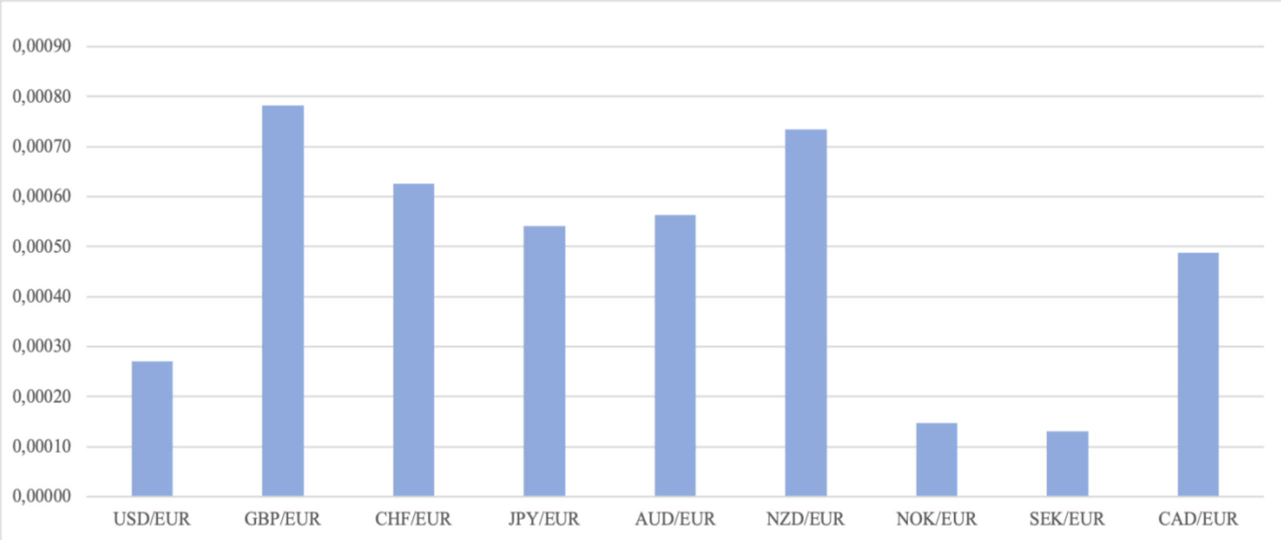
$$x_{t+1}^{L} = \left(i_t^{*,b} - i_t^{a}\right) + \left(s_{t+1}^{b} - s_t^{a}\right) \qquad (3.2)$$

A short position in the foreign currency, instead, consists exactly in the opposite of the investment just described: the investor shorts the foreign currency in t at the bid spot exchange rate and then sells it $t+1$ at the ask quote, paying the foreign ask interest rate for borrowing the currency, while receiving the domestic bid interest rate for the investment in the home money market. Thus, the net log excess return to a short foreign currency position, combined with a long position in the domestic currency, is computed as

$$x_{t+1}^{S} = \left(i_t^{b} - i_t^{*,a}\right) + \left(s_t^{b} - s_{t+1}^{a}\right) = -\left[\left(i_t^{*,a} - i_t^{b}\right) + \left(s_{t+1}^{a} - s_t^{b}\right)\right] \qquad (3.3)$$

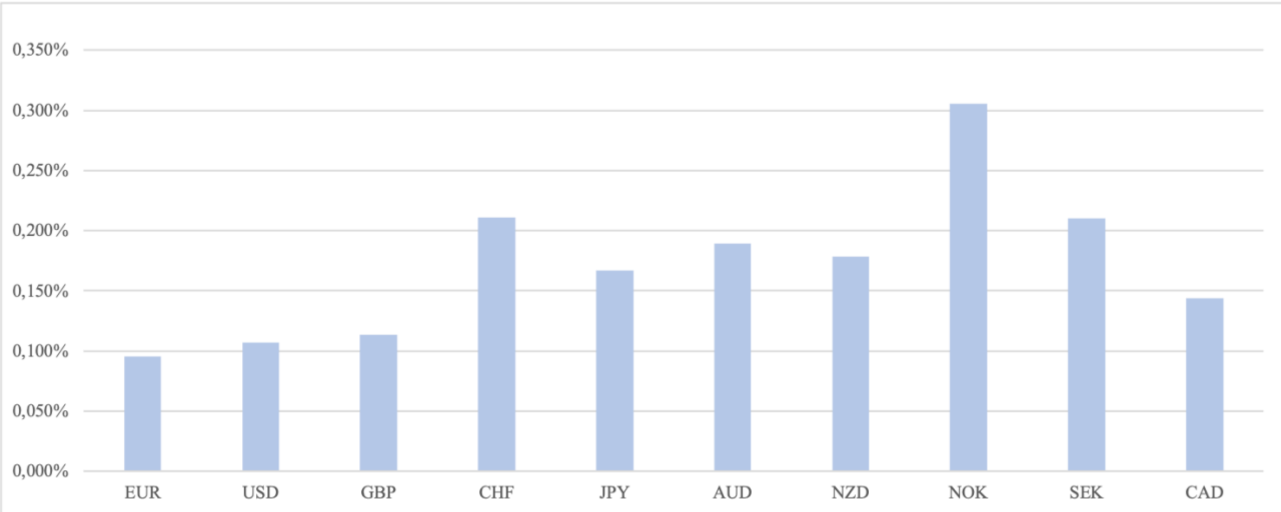
Equations (3.2) and (3.3) suggest that including bid-ask quotes in the computation will clearly result in lower excess returns compared to those derived with last prices (i.e. the ones derived using equation (3.1)), since ask prices are generally higher than bid ones: the interest rate collected when investing in a currency (bid) is lower than the rate due for borrowing the same currency (ask), while the exchange rate received when selling a currency (bid) is lower with respect to the one paid when purchasing the same currency (ask). The impact of transaction costs on the strategies' profitability depends on the entity of bid-ask spreads; the following bar charts displays the average bid-ask spreads for monthly spot exchange rates (figure 3.4) and for one-month deposit rates (figure 3.5), computed for the G10 currencies over the whole sample period.

Figure 3.4 – *Average bid-ask spreads for spot exchange rates.*



Note: the bar chart displays the average bid-ask spreads for monthly spot exchange rates versus the euro for the nine foreign currencies in the sample, over the time interval December 2001 – December 2021.
Source: Refinitiv Workspace, personal computation.

Figure 3.5 – *Average bid-ask spreads for interest rates.*



Note: the bar chart displays the average bid-ask spreads for one-month deposit rates (in percentage) for the basket of G10 currencies, over the sample period December 2001 – December 2021.
Source: Bloomberg, personal computation.

The first graph (figure 3.4) shows that transaction costs in the spot FX market are fairly low, as expected for the popularity and the liquidity of G10 currencies, ranging from a minimum of 0.00013 for the SEK/EUR exchange rate to a maximum of 0.00078 for GBP/EUR: the lowest bid-ask spreads are associated with the SEK/EUR, NOK/EUR and USD/EUR spot exchange rates, whereas the highest values correspond to the GBP/EUR, NZD/EUR and CHF/EUR forex pairs. The bid-ask spreads for the one-month deposit rates, displayed by the second bar chart (figure 3.5), are instead relatively higher, ranging from 0.095% for the euro to 0.306% for the Norwegian krone: the latter, together with the Swiss franc and the Swedish krona, exhibits the highest values, while the euro, the US dollar and the British pound present the lowest ones.

3.3 Summary statistics on carry trade excess returns

This section presents summary statistics on the excess returns estimated following the methodology highlighted in the previous paragraph, both from the currency-by-currency perspective and for the two carry trade portfolios. In both cases, the statistics are first derived without considering transaction costs, using last prices for exchange and interest rates; then, the computations are repeated with bid-ask quotes, to evaluate the effect of bid-ask spreads on the payoff to the strategies. The results obtained from this analysis support the average profitability of carry trade, showing large mean excess returns for high interest rate currencies and for the two carry portfolios, also when adjusted for risk, as measured by the values estimated for the Sharpe ratio.

3.3.1 Currency-by-currency perspective

The table in figure 3.6 summarizes statistics on monthly log currency excess returns (i.e. the payoffs to a Eurozone investor who borrows the domestic currency to invest in the foreign one) for the nine foreign currencies in the G10 basket, sorted according to their average interest rate differential with the euro, from the lowest to the highest. The table reports the mean, standard deviation, Sharpe ratio and skewness for these monthly excess returns over the period December 2001 – December 2021, with and without transaction costs.

Figure 3.6 – *Summary statistics on currency excess returns.*

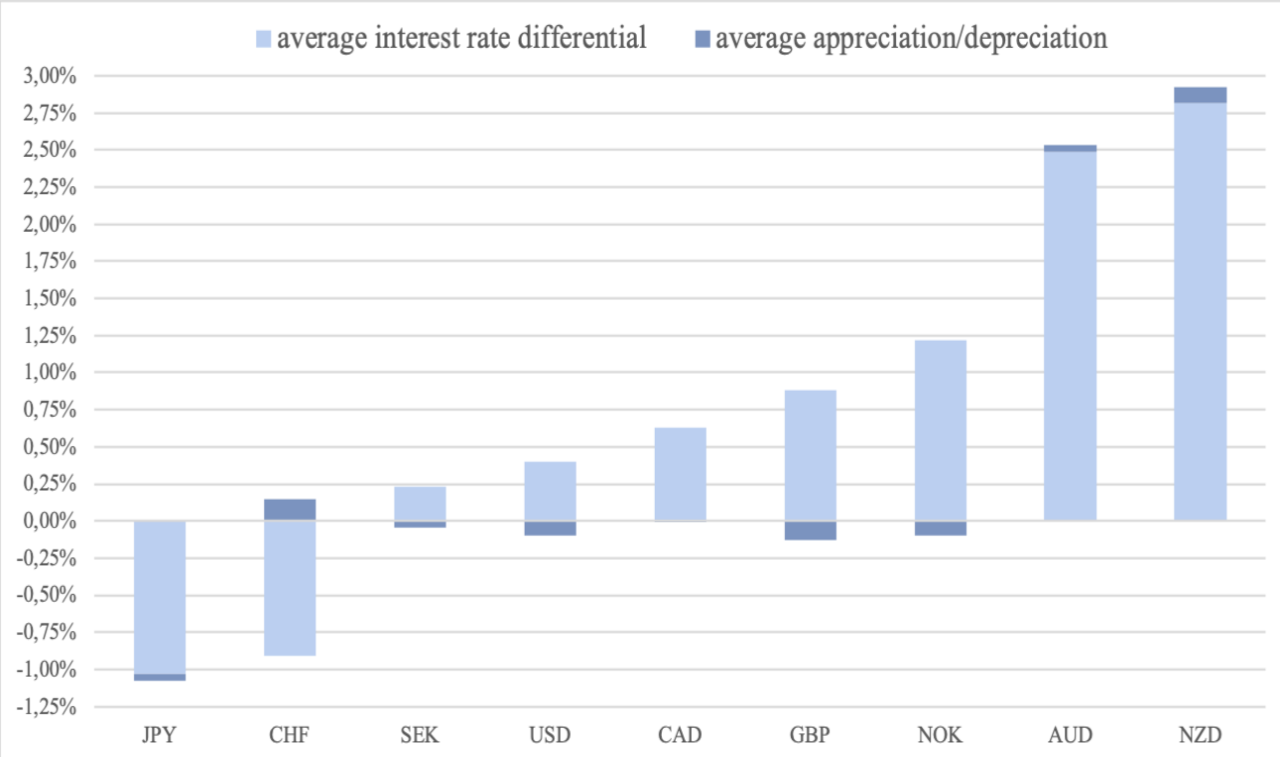
Currencies	JPY	CHF	SEK	USD	CAD	GBP	NOK	AUD	NZD
Panel I: *without Bid-Ask spreads*									
Average interest rate differential	-1.03%	-0.91%	0.23%	0.40%	0.63%	0.88%	1.22%	2.49%	2.82%
Average exchange rate variation	-0.05%	0.15%	-0.04%	-0.10%	-0.01%	-0.13%	-0.10%	0.05%	0.10%
Average excess return	-1.08%	-0.76%	0.19%	0.30%	0.64%	0.75%	1.12%	2.54%	2.92%
Standard deviation	3.44%	2.05%	1.68%	3.04%	2.64%	2.38%	2.28%	2.72%	2.82%
Sharpe ratio	-0.631	-0.905	-0.536	-0.261	-0.176	-0.144	0.012	0.531	0.648
Skewness	0.646	2.047	-0.151	-0.276	-0.500	-1.586	-0.235	-0.168	-0.066
Panel II: *with Bid-Ask spreads*									
Average interest rate differential	-1.16%	-1.06%	0.08%	0.30%	0.52%	0.78%	1.02%	2.35%	2.68%
Average exchange rate variation	-0.12%	0.07%	-0.16%	-0.13%	-0.08%	-0.19%	-0.22%	-0.04%	-0.03%
Average excess return	-1.28%	-0.99%	-0.08%	0.17%	0.44%	0.59%	0.80%	2.31%	2.65%
Standard deviation	3.42%	2.03%	1.68%	3.03%	2.65%	2.40%	2.28%	2.73%	2.83%
Sharpe ratio	-0.693	-1.030	-0.700	-0.306	-0.247	-0.211	-0.130	0.444	0.548
Skewness	0.655	2.068	-0.197	-0.323	-0.517	-1.634	-0.260	-0.175	-0.080

Note: the table reports summary statistics for the monthly log currency excess returns over the sample period December 2001 – December 2021, without considering transaction costs in Panel I and including bid-ask spreads in Panel II. The Sharpe ratio is computed as the average monthly return to the investment in excess to the risk- free rate (i.e. the Euribor) divided by the standard deviation of monthly log returns.
Source: Bloomberg and Refinitiv Workspace, personal computation.

Panel I shows the statistics derived without including transaction costs, computing interest rate differentials, exchange rate variation and log excess returns with last price data. The first two rows of the table display the average values for, respectively, one-month interest rate differentials and monthly changes in spot exchange rate, which represent the two components of the log currency excess returns. These first results point out the failure of the UIP, which prescribes that currencies with a positive interest rate differential are expected to experience a depreciation that offsets the interest gain, and vice versa. Indeed, the data in the table shows that this is not verified in the sample considered: some high-yielding currencies, like the NOK, depreciate just by a small percentage (-10%), while others, as the AUD and NZD, appreciate; on the other hand, low-yielding currencies depreciate instead of appreciating, like the JPY, or experience a modest appreciation that does not compensate the negative spread in interest rates, as in the case of the CHF.

As a consequence, the average log currencies excess returns estimated are negative for currencies associated with a negative average interest rate differential (JPY and CHF) and positive for currencies that have positive average differentials. The third row of the table highlights that the mean log currency excess return increases monotonically as the average interest differential rises, reaching considerably large values for high-yielding currencies as the Australian dollar (2.54%) and the New Zealand dollar (2.92%). As can be observed comparing values in the first three rows of the table, currency excess returns are mainly determined by the spread in interest rates, since this component is significantly larger than the appreciation/depreciation one; this is graphically represented by the following bar chart (figure 3.7), which displays the decomposition of the excess returns in the average interest rate differential and the average appreciation/depreciation components.

Figure 3.7 – *Decomposition of log currency excess returns.*



Note: the bar chart displays the average values for the interest rate differential and the average depreciation, to show how much of the excess returns are determined by each of the two components, since log excess returns are given by the sum of the latter.
Source: Bloomberg and Refinitiv Workspace, personal computation.

Going back to the results reported in the table, the fourth row displays the standard deviation for the monthly log excess returns, which range from 1.68% for the SEK to 3.04% for the USD, while the fifth row lists the estimated values for the Sharpe ratio, computed as the ratio between the average excess return over the risk-free rate (i.e. the Euribor) and the standard deviation of returns: the index exhibits negative values for most of the currencies in the sample, except for the three highest yielding currencies, namely the Norwegian krone, the Australian dollar and the New Zealand dollar; in particular, the last two currencies are associated with positive and fairly high values for the ratio, i.e. 0.531 and 0.648, respectively (corresponding to 1.84 and 2.25 when annualized[28]) .

Finally, the last row of Panel I contains estimates for the skewness of returns, which turns out to be positive for funding currencies and negative for investment currencies. These results are consistent with the explanation for carry trade profitability proposed by Brunnermeier et al. (2008): carry trade returns are negatively skewed and, therefore, subject to crash risk.

The second panel of the table reports the same statistics derived including bid-ask spreads, namely repeating the analysis with bid-ask quotes for interest rates and exchange rates. As expected, the results show that transaction costs reduce the average excess returns: indeed, the use of bid-ask prices in the simulation of the currency positions lowers both the average interest rate differentials and the mean exchange rate variations, thus implying a decrease in the log excess returns. However, transaction costs do not affect significantly the profitability of carry trade, since the average currency excess returns for investment currencies like the AUD and the NZD are still large (i.e. 2.31% and 2.65%, respectively).

3.3.2 Portfolio perspective

After analyzing the payoffs to the investments in the foreign currencies financed shorting the euro, I compute monthly log excess returns for the two carry trade portfolios built combining different currency positions, as described in the subparagraph 3.1.2. As already highlighted, Portfolio 1 invests in positions associated with extreme values for the interest rate differentials, namely, going long in the three currencies with the highest yield spread and short in three ones with the lowest differential. Portfolio 2, instead, takes positions in all the foreign currencies in the sample, based on the sign of the interest differential: the portfolio is long in a currency when the spread is positive and short when it is negative. For each month, the log excess returns to the portfolios are computed as the average of the excess returns to the currencies involved; the following table reports summary statistics derived for the two portfolios, again computed with and without bid-ask spreads.

[28] The annualized Sharpe ratio is defined as the ratio between the annualized average excess return, computed multiplying the monthly average excess rate (over the Euribor) times 12, and the annualized standard deviation, equal to the monthly standard deviation times $\sqrt{12}$.

Figure 3.8 – *Summary statistics on carry trade portfolio excess returns.*

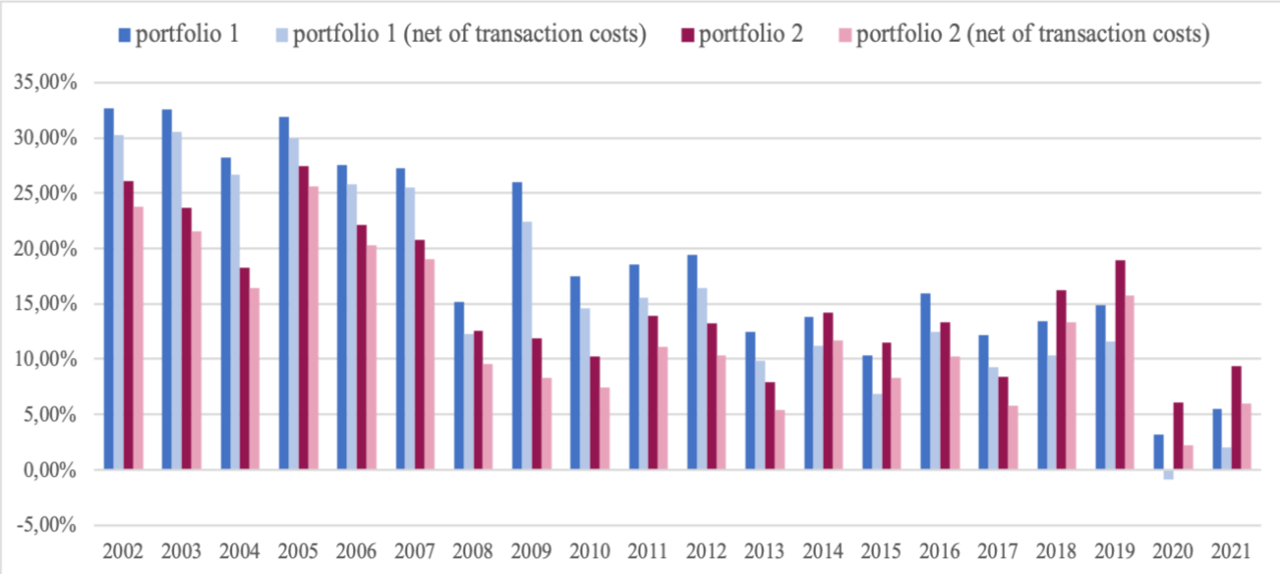
	Portfolio 1	*Portfolio 2*
Panel I: *without Bid-Ask spreads*		
Average excess return	1.58%	1.28%
Standard deviation	1.36%	1.12%
Sharpe ratio	0.355	0.162
Skewness	-0.210	-0.460
Panel II: *with Bid-Ask spreads*		
Average excess return	1.34%	1.05%
Standard deviation	1.39%	1.14%
Sharpe ratio	0.180	-0.039
Skewness	-0.215	-0.483

Note: the table reports summary statistics for the monthly log excess returns to the two carry trade portfolios, over the sample period December 2001 – December 2021, without considering transaction costs in Panel I and including bid-ask spreads in Panel II. The Sharpe ratio is computed as the average monthly return to the investment in excess to the risk-free rate (i.e. the Euribor) divided by the standard deviation of monthly log returns.
Source: Bloomberg and Refinitiv Workspace, personal computation.

Again, the results support the profitability of carry trade, since both the strategies deliver significantly positive excess returns. The first two rows of the table show, respectively, the mean and the standard deviation of monthly log excess returns: on average, Portfolio 1 offers higher returns than Portfolio 2, but it is associated with a slightly higher volatility; the lower average return and standard deviation of Portfolio 2 are due to a greater diversification, since it invests in all the currencies in the sample, while Portfolio 1 takes just extreme positions. The fourth row report the Sharpe ratio for the two portfolios, defined as the return in excess to a risk-free investment: both the strategies present positive values for the index, but Portfolio 1 is associated with a higher ratio compared to Portfolio 2: 0.35 for the former and 0.16 for the latter, equal to 1.24 and 0.58, respectively, in annualized terms. For both the portfolios, excess returns are characterized by negative skewness, which is lower for Portfolio 2; this suggests that the two strategies are subject to crash risk and, therefore, the large profitability may be a compensation for bearing this risk.

The second panel of the table displays estimates obtained with bid-ask quotes, which lower the average returns by 15% and 18% for Portfolio 1 and 2, respectively; however, the strategies remain still profitable after considering transaction costs. Bid-ask spreads clearly reduce the estimate for the Sharpe ratio too, which becomes negative for Portfolio 2. The following chart (figure 3.9) represents graphically the payoffs to the two carry trade strategies, displaying annualized log excess returns over the 20 years covered by the sample, with and without bid-ask spreads.

Figure 3.9 – *Annualized log excess returns for the carry trade portfolios.*



Note: the bar chart displays annualized log excess returns for the two carry trade portfolios, with and without considering transaction costs. The annualized returns are computed from the monthly ones, as the average of the latter over the year, multiplied times 12.
Source: Bloomberg and Refinitiv Workspace, personal computation.

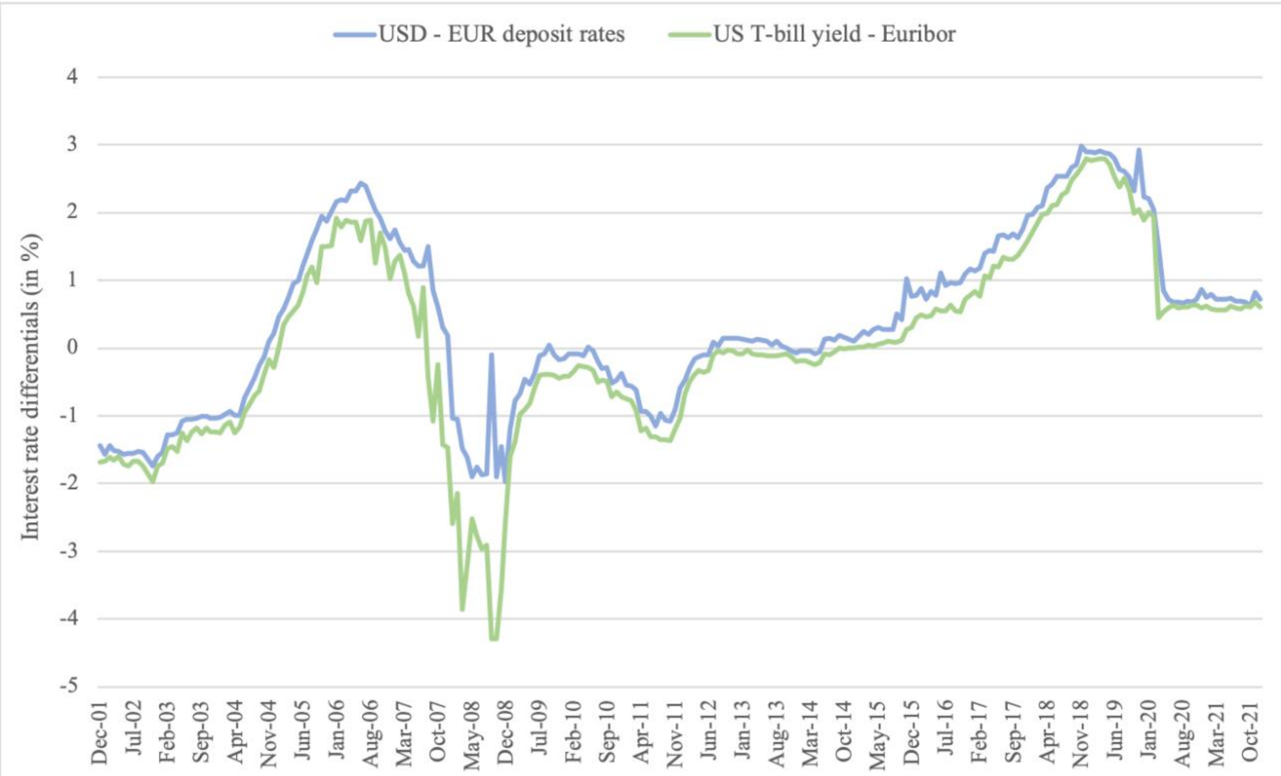
The graph shows significantly positive returns over the whole sample, for both the portfolios; average returns are higher for the pre-crisis period, with incredibly high values for Portfolio 1 (more than 30%), and tend to reduce throughout the sample, reaching lower values during the last two years, associated with the Covid-19 crisis. For almost the entire period considered, Portfolio 1 dominates Portfolio 2, except for years 2014-2015 and the last four years of the sample; the only negative value observed is the average return for Portfolio 1, net of transaction costs, in 2020, equal to -0.83%.

3.3.3 Robustness check

The estimated excess returns to positions in high-yielding currencies, as the Australian dollar and the New Zealand dollar, and to the two carry trade portfolios exhibit considerably high values, which are larger than returns reported in most of the study in academic literature. A possible explanation for this discrepancy in the results relates to the choice of the interest rates used in the simulation of the strategies: while the majority of researchers focuses on T-bill or interbank interest rates, I cannot use these rates due to issues in the availability of data at monthly frequency over my sample period for all the currencies in the basket, as already highlighted. Thus, I choose to build the carry trade strategies with deposit rates, which are probably slightly higher than sovereign bond rates in some countries; this may lead to larger interest rate differentials than those reported in other studies and, therefore, to higher excess returns for carry trades.

As a robustness check, I collect from Bloomberg the available rates, namely, the US 1-month T-bill yield and the 1-month Euribor, and then replicate the strategy for the euro and the US dollar, in order to compare the new results on excess returns with the ones already derived. The following figure presents a plot of the interest rate differential among the USD and the EUR computed using the different rates: the spread between the US 1-month T-bill rate and the Euribor is represented by the green line, while the spread between the USD and the EUR 1-month deposit rates corresponds to the blue line.

Figure 3.10 – *Comparison between interest rate differentials computed with deposit rates and with US T-bill rate – Euribor.*



Note: the figure plots the interest rate differential between the US dollar and the Euro computed with deposit rates (blue line) and with the US 1-month T-bill and the 1-month Euribor (green line), over the sample period December 2001 – December 2021.
Source: Bloomberg.

The chart clearly shows that the blue line stays above the green one over the whole sample period, with a significant divergence in 2008; this means that the interest rate differential between the two currency is clearly lower when the T-bill yield and the Euribor are considered as reference rates, implying also lower excess returns. The following table (figure 3.11) present a comparison between the statistics on log excess returns computed with the US T-bill – Euribor and with deposit rates.

Figure 3.11 – *Comparison of results with the US T-bill – Euribor and with deposit rates.*

Long USD – Short EUR	US T-bill – Euribor	Deposit rates
Average interest rate differential	0.04%	0.40%
Average exchange rate variation	-0.10%	-0.10%
Average excess return	-0.06%	0.30%
Standard deviation	3.07%	3.04%
Sharpe ratio	-0.38	-0.26
Skewness	-0.461	-0.276

Note: the table compares summary statistics on log excess return to a strategy that is long in the foreign currency (USD) and short in the domestic one (EUR) derived using different interest rates for the currencies involved: in the first column the reference rates are the US 1-month T-bill and the 1-month Euribor, while in the second one the deposit rates.
Source: Bloomberg and Refinitiv Workspace, personal computation.

As already highlighted by the chart in figure 3.10, the table shows that the average interest rate differential between the US dollar and the euro is considerably lower when computed using the US T-bill and the Euribor compared to the one derived with deposit rates: it declines by 90%, from 0.4% to 0.04%. Clearly, the average excess return to the currency position decreases accordingly, from 0.3% to -0.06%; also, the Sharpe ratio and the skewness exhibit lower values when using the sovereign bond rates in the strategy.

As expected, this robustness test points out that the excess returns to the strategies simulated may be overstated because deposit rates are higher compared to the T-bill yields for some of the currencies in the sample; however, the overall results are still consistent with other studies in academic literature that support the profitability of carry trade and, thus, are suitable to illustrate the mechanism of the strategy and to study the possible risk-based explanations.

3.4 Risk-based explanations for carry trade profitability

The final step of my analysis is dedicated to the research of possible explanations for the observed profitability of the carry trade strategies examined, in terms of compensation for the exposure to sources of risk. As discussed in paragraph 2.4, there exist several studies in academic literature that try to find a justification for the large positive returns to carry trade, estimating different factor models, from the most traditional ones to others specifically designed for the nature of the strategy.

In this paragraph, I use the excess return estimated for the two carry trade portfolios to replicate a similar risk-based analysis[29]; in particular, I run time-series regressions of the portfolio monthly log excess returns on different risk factors, in order to check whether the returns may be considered as a compensation for risk exposure. I start by estimating factor models that are conventionally used to explain return to different assets and, then, I focus on the more specific models proposed by researchers.

3.4.1 Traditional factor models

In order to examine carry trade exposure to traditional risk factors, I estimate three different model: two widespread factor models in asset pricing theory, the Capital Asset Pricing model (CAPM) and the Fama-French model, and a consumption growth model.

The first is a one-factor model, which links the asset return to the return of the market portfolio, defined as an ideal portfolio containing all risky assets on the market; according to the model, the return to the asset is determined by its covariance with the market and, specifically, by its systematic risk, as measured by the beta coefficient, which is the only kind of risk for which the investor should be remunerated. In order to estimate the beta for the two carry trade portfolios, the monthly log excess returns are regressed on the monthly excess return to the FTSEurofirst 300 Eurozone index[30], used as proxy for the market portfolio, over the risk-free rate, represented by the Euribor; the beta coefficients, reflecting the exposure of the two strategy to market risk, are OLS estimates resulting from the following time-series regression:

$$x_t = \alpha + \beta z_{M,t} + \varepsilon_t$$

[29] The analysis focuses on the return for the two portfolios net of transaction costs.
[30] The FTSEurofirst 300 Eurozone index is one of the sub-indexes of the FTSEurofirst 300 index, which comprises the 300 largest companies ranked by market capitalisation in the FTSE Developed Europe Index.

Where x_t is the log excess return to the portfolio for month t, and $z_{M,t}$ is the market log excess return, $(r_{M,t} - r_{f,t})$, defined as the log return to the FTSEurofirst 300 Eurozone index in excess to the log risk-free rates, proxied by the Euribor.

The second model is the one formulated by Fama and French, a three-factor model, which extends the CAPM adding the "small minus big" (SMB) and the "high minus low" (HML) factors: the first reflects the size premium and is defined as the excess return to a portfolio of small-capitalization stocks over a portfolio of big-capitalization stocks, while the second is the value premium, reflecting the outperformance of value stocks (high book-to-price ratio) with respect to growth stocks (low book-to-price ratio). The time-series regression of the returns to carry trade portfolios on these factors provide the estimates of three slope coefficients, which capture the portfolio exposures to the market risk and risks associated with the firm size and book-value to market-value ratio, respectively; the regression estimated is

$$x_t = \alpha + \beta_1 z_{M,t} + \beta_2 SMB_t + \beta_3 HML_t + \varepsilon_t$$

Where SMB_t is proxied by the difference between the log monthly returns to, respectively, the MSCI EMU Small Cap index and the EURO STOXX 50 index, whereas HML_t is computed as the monthly log excess return of MSCI EMU Value index over the MSCI EMU Growth index[31].

The last model studies the relationship among the carry trade returns and the real consumption growth in the Eurozone, I order to analyze the correlation between the returns and the state of the economy and, thus, to check whether these investments can be considered cyclical or not. The real consumption growth is computed starting from quarterly data on the Eurozone final consumption expenditure, collected from Refinitiv Workspace: I adjust these data for inflation, through the Eurozone CPI (i.e. consumer price index), and, then, I compute the percentage variation of real consumption. Since the data on consumption expenditure are available only at a quarterly frequency, the rates computed represent the quarterly real consumption growth; therefore, the model is estimated for three-month

[31] The MSCI EMU Small Cap Index captures small cap representation across the 10 Developed Markets countries in the EMU (European Economic and Monetary Union); with 473 constituents, the index covers approximately 14% of the free float-adjusted market capitalization of the EMU. The EURO STOXX 50 Index is a market capitalization-weighted stock index of 50 large, blue-chip European companies operating within eurozone nations, whose components are selected from the EURO STOXX Index. The MSCI EMU Value Index captures large- and mid-cap securities exhibiting overall value style characteristics across the 10 Developed Markets countries in the EMU. The MSCI EMU Growth Index captures large- and mid-cap securities exhibiting overall growth style characteristics across the 10 Developed Markets countries in the EMU.

intervals, regressing the quarterly log excess return to the two portfolios on the real consumption growth rate:

$$x_t = \alpha + \beta g_t + \varepsilon_t$$

Where g_t is the quarterly real consumption growth rate and x_t is the quarterly log portfolio excess return; in this case, the β reflects the exposure of the strategy to business cycle risk.

The three models are estimated for the two carry trade portfolios and the corresponding results are reported in the following table, in figure 3.12. For each model, the table presents the estimates for the intercept and the slope coefficients, the R^2 of the model, which represents a measure of the goodness of fit, and the p-value associated with the F-test of the overall significance of the regression model, that tests whether the specified model fits significantly better than a degenerate model with no predictors (i.e. intercept-only model). For the coefficient estimates, I report the standard errors in square brackets and the p-value for the t-test in round brackets, testing the null hypothesis that the corresponding coefficient is equal to zero.

Figure 3.12 – *Traditional factor models for carry trade portfolios.*

Factor Model	*Portfolio 1*						*Portfolio 2*					
	Intercept	Slope coefficients			R^2	p-value	Intercept	Slope coefficients			R^2	p-value
CAPM	0.014 [0.0009] ($6.29e^{-39}$)	0.061 [0.0156] (0.0001)			0.061	0.0001	0.011 [0.0007] ($8.35e^{-37}$)	0.054 [0.0127] ($2.91e^{-5}$)			0.071	$2.91\ e^{-5}$
Fama-French	0.014 [0.0009] ($1.44e^{-39}$)	0.031 [0.0175] (0.0877)	0.039 [0.0333] (0.2406)	0.146 [0.0382] (0.0002)	0.119	$1.54\ e^{-6}$	0.011 [0.0007] ($7.05e^{-36}$)	0.044 [0.0147] (0.0028)	0.023 [0.0280] (0.4075)	0.049 [0.0321] (0.1268)	0.082	0.0001
Consumption growth	0.014 [0.0015] ($3.54e^{-14}$)	0.089 [0.0619] (0.1525)			0.027	0.152	0.011 [0.0012] ($2.13e^{-13}$)	0.106 [0.0509] (0.0403)			0.054	0.040

Note: the models are estimated running time-series regression of log excess returns to portfolio 1 and 2 on the corresponding risk factors, over the sample period December 2001 – December 2021; the first two model consider monthly excess returns, while the last uses quarterly excess returns, due to availability of data for consumption. The R^2 of the model is a measure of goodness of fit, which represents the proportion of the variance of the dependent variable that is explained by the independent variables in the regression. The p-value of the model is associated with the F-test of the overall significance of the model, which compares the fit of the specified model to the fit of an only-intercept model, that is, a model with only the constant term; the null hypothesis is that the two fit are equal, thus a small p-value implies the rejection of the null, supporting the significance of the model considered. For each of the coefficients estimated, standard errors and p-values for the t-statistic are reported in square and round brackets, respectively. The standard error represents the standard deviation of the estimated coefficients and represents the precision of the estimate: the smaller the standard error, the more precise the estimate; if a coefficient is large compared to the standard error, it is probably different from zero. The t-statistic is computed dividing the coefficient by its standard error and is used to test the null hypothesis that the coefficient is equal to zero; thus, small p-values for the t-test (behind a determined significance level) lead to reject the null, implying that the coefficient is significantly different from zero.
Source: Bloomberg and Refinitiv Workspace, personal computation.

Observing the estimates reported in the table and the corresponding statistics, it is possible to conclude that none of the model is able to explain carry trade returns as compensation for exposure to traditional risk factors. All the coefficients estimated are positive and small, meaning that the two carry trade portfolios have a low exposure to these sources of risk. As shown by the p-value for the t-statistic, some of the coefficients are statistically different from zero, with different significance levels: the market beta in the CAPM for both portfolios, the HML beta in Fama-French for Portfolio 1 and the market beta in Fama-French for Portfolio 2 are significant at the 1% level, the consumption growth beta for Portfolio 2 at the 5% level and the Portfolio 1 market beta in Fama-French at the 10% level; however, the corresponding factors do not have much explanatory power for the portfolio returns. The poor performance of the three factor models is confirmed by the low values for the associated R^2, which ranges from 2,7% for the consumption growth model for Portfolio 1 to 11,9% for Portfolio 1 Fama-French model. Finally, the low p-values for the F-statistic on the CAPM and Fama-French model support the overall significance of the models for both portfolios, while p-values for the consumption growth model are higher, suggesting that the model is not significant and a degenerate model with only the intercept has a better fit.

The results derived are overall consistent with other studies in academic literature: the conventional risk factors are not able to justify the large average excess returns to carry trade, since the strategy turns out to have a low exposure to these sources of risk and, thus, investors are not remunerated for bearing these risks.

3.4.2 Specific factor models

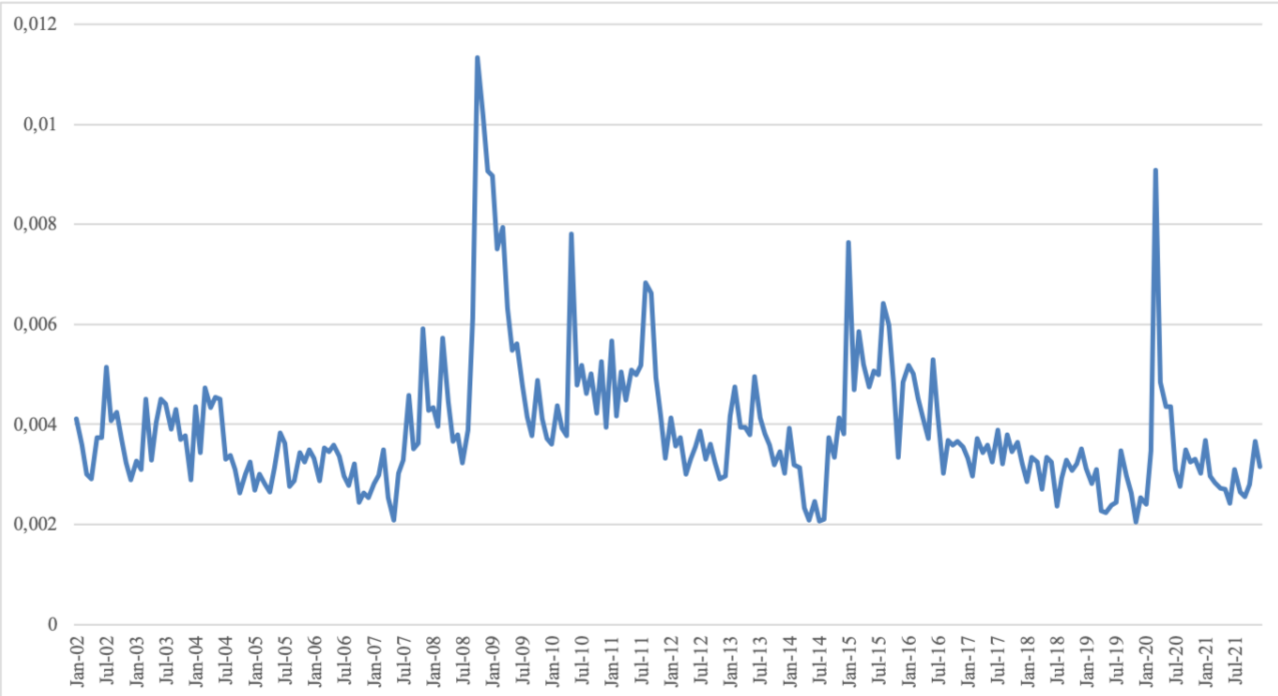
Since models with traditional risk factors do not provide an explanation for carry trade excess returns, I move on to the estimation of models involving factors which are more specific to the strategy. I take two of the factor models proposed in academic literature, which have proven to be quite successful: the FX volatility factor model by Menkhoff et al. (2012) and the currency factor model by Lustig et al. (2009); in particular, I try to build risk factors which are similar to the ones developed by these authors and apply them to my analysis, examining whether these are correlated with the returns to my two carry trade strategies.

The FX volatility factor model is slightly different from the one developed by Menkhoff et al. (2012): while the latter defines the risk factor as the innovation, namely the unexpected change, in the FX market volatility, my version of the model uses as single risk factor the monthly volatility of foreign exchange markets. Since my analysis is carried out with a monthly frequency, I need monthly observations for the FX volatility, thus, I derive the monthly volatility starting from daily data on the exchange rates for the sample period, following a procedure similar to the one used by Menkhoff et al. (2012): I compute the absolute variation in spot exchange rates, $s_{t+1} - s_t$, for each currency on each trading day in the sample; then, I average these variations among all the currencies to derive the mean variation for the sample on each day and, finally, the monthly volatility is defined as the average of daily variations for each month in the sample. Therefore, my proxy for the foreign exchange volatility is

$$\sigma_t^{FX} = \frac{1}{T_t} \sum_{\tau \in T_t} \sum_{k \in K} \frac{\left|\Delta s_t^k\right|}{K}$$

Where T_t denotes the number of trading days in month t and K is the number of foreign currencies. The following figure displays a time series-plot of the risk factor σ_t^{FX} over the sample period considered.

Figure 3.13 – *FX volatility factor.*



Source: Refinitiv Workspace, personal computation.

The second model, instead, involves the two currency risk factors proposed by Lustig et al. (2009): the level factor RX, named as Dollar risk factor, and the slope factor HML_{FX}, referred to as Carry trade risk factor. I build these two risk factors applying the definition provided by Lustig et al. (2009) to my data sample; the first factor, RX, is computed as the average of all the currency excess returns, while the Carry trade factor is defined as the return to a portfolio that each month invests in the currency with the highest interest rate, shorting the one with the lowest yield.

Again, the two models are estimated running time-series regressions of the log monthly excess returns to the carry trade portfolios considered on the risk factors just described, in order to derive the exposure (beta coefficients) of the strategies to these sources of risk; the regressions estimated are

$$x_t = \alpha + \beta_{FX_{vol}} \sigma_t^{FX} + \varepsilon_t$$

For the FX volatility model and

$$x_t = \alpha + \beta_{RX} RX + \beta_{HML_{FX}} HML_{FX} + \varepsilon_t$$

For the currency factor model. The estimates for the corresponding coefficients are reported in the following table (figure 3.14), together with the R^2 and the p-values for the models.

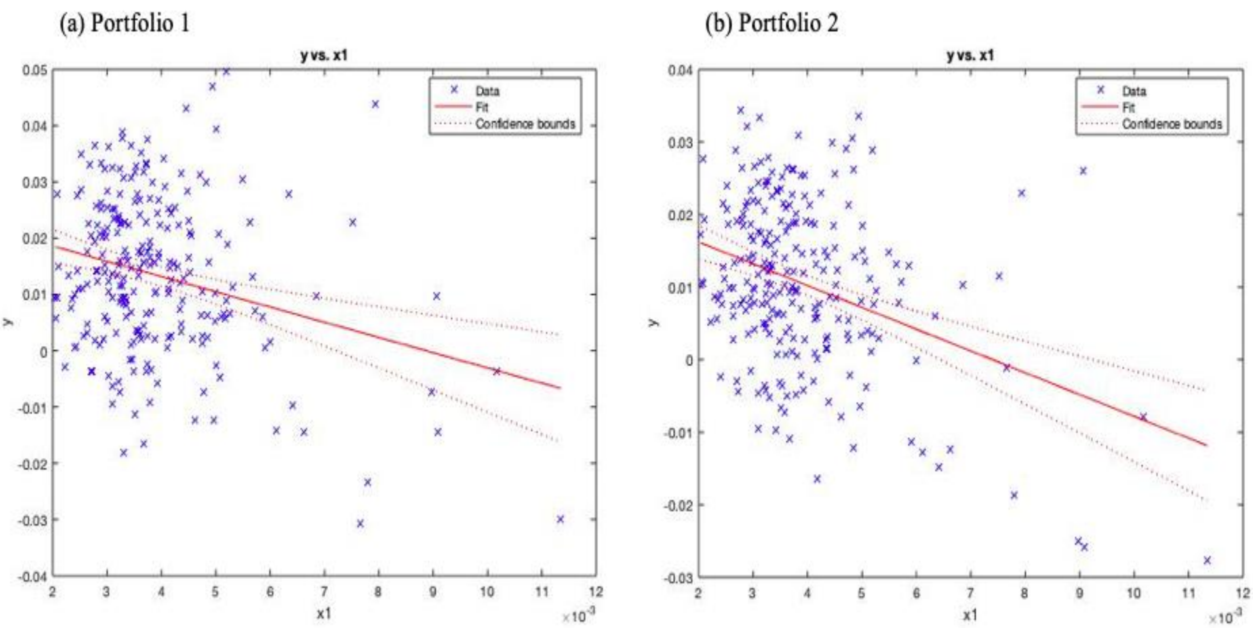
Figure 3.14 - *Specific factor models for carry trade portfolios.*

	Panel I: *FX volatility factor*				
	α	β_{FXvol}		R^2	p-value
Portfolio 1	0.0240 [0.0026] ($3.51\ e^{-17}$)	-2.7045 [0.6381] ($3.22\ e^{-5}$)		0.0702	$3.22\ e^{-5}$
Portfolio 2	0.0222 [0.0021] ($1.07\ e^{-21}$)	-3.0035 [0.5087] ($1.21\ e^{-8}$)		0.128	$1.21\ e^{-8}$
	Panel II: *RX and HML_{FX} factors*				
	α	β_{RX}	$\beta_{HML_{FX}}$	R^2	p-value
Portfolio 1	0.0014 [0.0008] (0.0787)	-0.0564 [0.0347] (0.1052)	0.2834 [0.0124] ($6.65\ e^{-62}$)	0.689	$7.51\ e^{-61}$
Portfolio 2	0.0008 [0.0008] (0.3148)	0.1296 [0.0352] (0.0003)	0.1988 [0.0126] ($7.26\ e^{-39}$)	0.526	$3.36\ e^{-39}$

Note: the models are estimated running time-series regression of monthly log excess returns to portfolio 1 and 2 on the corresponding risk factors, over the sample period December 2001 – December 2021. The R^2 of the model is a measure of goodness of fit, which represents the proportion of the variance of the dependent variable that is explained by the independent variables in the regression. The p-value of the model is associated with the F-test of the overall significance of the model, which compares the fit of the specified model to the fit of an only-intercept model, that is, a model with only the constant term; the null hypothesis is that the two fit are equal, thus a small p-value implies the rejection of the null, supporting the significance of the model considered. For each of the coefficients estimated, standard errors and p-values for the t-statistic are reported in square and round brackets, respectively. The standard error represents the standard deviation of the estimated coefficients and represents the precision of the estimate: the smaller the standard error, the more precise the estimate; if a coefficient is large compared to the standard error, it is probably different from zero. The t-statistic is computed dividing the coefficient by its standard error and is used to test the null hypothesis that the coefficient is equal to zero; thus, small p-values for the t-test (behind a determined significance level) lead to reject the null, implying that the coefficient is significantly different from zero.
Source: Bloomberg and Refinitiv Workspace, personal computation.

The first panel of the table reports the results obtained from the estimation of the FX volatility model, for both the carry trade portfolios; the coefficients for the volatility risk factors are large and negative (i.e. -2.0745 and -3.0035 for Portfolio 1 and 2, respectively), implying that the strategies have a negative exposure to volatility in FX markets: the carry trade strategies perform well when the volatility is low, while the returns decline in periods of high volatility, which are typically periods of market turmoil; therefore, the results suggests that the profitability of carry trade can be in part explained as a compensation for investors' exposure to this source of risk. The beta coefficients for both the portfolios are statistically significant at the 1% level, as supported by the small p-values associated with the t-test; however, the R^2 of the model are rather low for both the strategies, meaning that only a small portion of the variance of excess returns is explained by the volatility factor; finally, the p-value for the F-statistic are very small, suggesting that the model is overall significant, since it provides a better fit than an only-intercept model. The following chart (figure 3.15) gives a graphical representation of the fit of the model, through the scatterplot of the data along with the fitted line of the regression and confidence bounds.

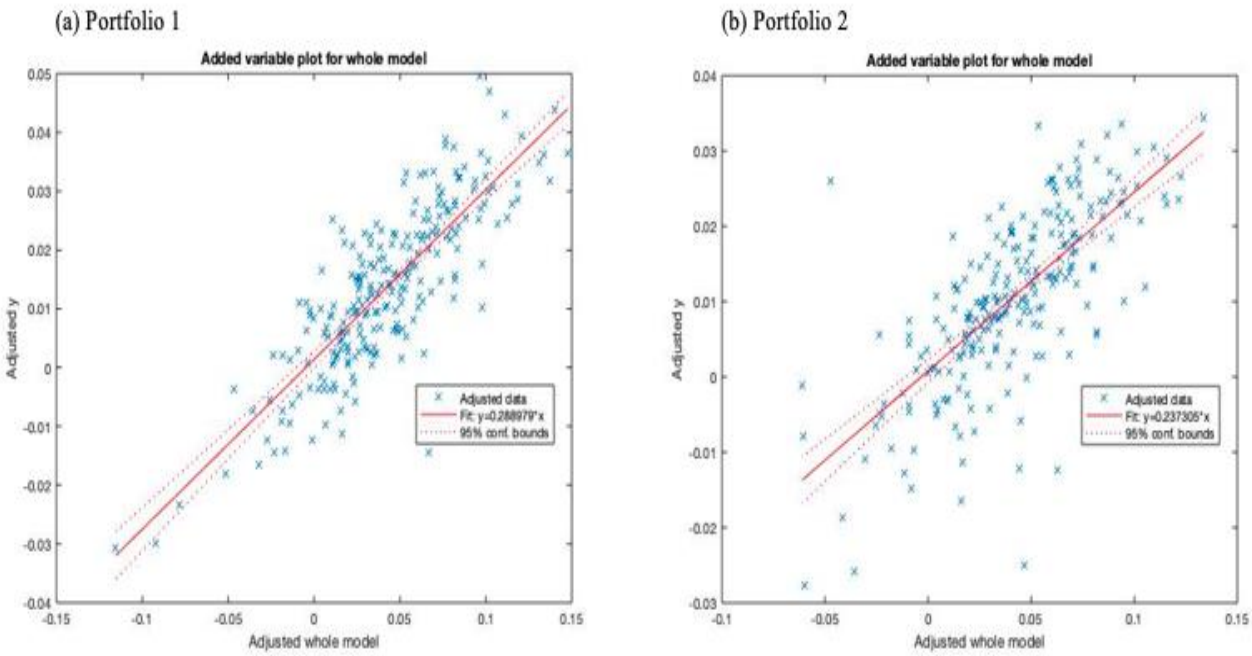
Figure 3.15 – *Fit of the FX volatility factor model.*



Note: the figure represents graphically the fit of the FX volatility factor model for the two carry trade portfolios, displaying a scatterplot of the data together with the fitted curve of the linear regression model and confidence bounds.
Source: Bloomberg and Refinitiv Workspace, personal computation.

The estimates for the currency factor model, instead, are reported in the second panel of the table in figure 3.14. The first row displays the results of the model estimated for Portfolio 1: it shows a small and negative estimate for the RX coefficient, which is not significantly different from zero, given the p-value greater than 10%; the beta coefficient associated with the slope factor, HML_{FX}, instead, is statistically significant and assumes a positive value of 0.2834. This means that the portfolio is positive exposed to the carry trade factor, as expected from the definition of the factor: both the factor and Portfolio 1 are defined as investments in high yielding currencies, funded by short positions in low interest rate currencies. According to the small p-value for the F-test, the model is significant, and it is also associated with a fairly high value for the R^2: the independent variables explain almost 70% of the variance of portfolio excess returns. The second row of the panel exhibits similar results for Portfolio 2: the coefficient for the carry trade factor is again positive and statistically significant, but it is slightly lower than the estimate for Portfolio 1 (i.e. 0.1988); the coefficient associated with the RX factor is positive in this case, and it is also statistically different from zero at the 1% significance level. The model is significant, with an R^2 which is lower than the one obtained for the first portfolio, but still reasonably good (i.e. 52.6%); figure 3.16 shows the fit of the model for Portfolio 1 and 2 in panel (a) and (b), respectively.

Figure 3.14 – *Fit of the currency factor model.*



Note: the figure represents graphically the fit of the currency factor model for the two carry trade portfolios, displaying an added variable plot for the linear regression model, which consists in a scatter plot of adjusted response values against adjusted predictor variable values, the fitted line for adjusted response values as a function of adjusted predictor variable values and 95% confidence bounds of the fitted line.
Source: Bloomberg and Refinitiv Workspace, personal computation.

The model overall provides an explanation for the returns to the two carry trade portfolios in terms of remuneration for the exposure to these two factors: as exposed by Lustig et al. (2009), the risk premium to a currency is determined by two components, namely, the dollar risk premium, which represents a compensation for home country risk, and the carry trade risk premium, that can be considered as a compensation for global risk. Therefore, since carry trade strategies load up on global risk, the large excess returns are due to the exposure to this source of risk and remunerate the investor for bearing it.

CONCLUSIONS

The profitability of carry trade is a phenomenon largely investigated in empirical literature, which remains still largely unexplained; it is closely related to one of the most studied empirical anomalies in FX markets, namely, the so-called "forward premium puzzle", which refers to the failure of two basic relationships in international finance, the uncovered interest parity (UIP) and the forward rate unbiasedness (FRU). Several studies have shown through years how these conditions are empirically violated, since currencies with high interest rate (or, alternatively, trading at a forward premium) tend to appreciate rather than depreciate. This allow speculators to earn significant positive excess returns from carry trade activity: investors entering these trades profit both from the positive interest rate differential and the appreciation of the currency.

The academic literature has reported a significantly positive profitability of carry trade, from 1980s to recent years, with large excess returns and fairly high positive values for the Sharpe ratio, suggesting that the performance of the strategy is positive also when adjusted for risk. These empirical findings have led many researchers to start investigating possible explanations for the observed profitability, trying to check, in particular, whether this can be considered as a compensation for the exposure to some sources of risk. Accordingly, several studies estimate factor models in order to examine the exposure of the strategy to different risk factors, from the traditional ones, like, in particular, those connected with the business cycle, to more specific ones, related to the nature of the strategy.

As pointed out by Burnside et al. (2006), conventional factor models are not able to explain carry trade positive excess returns, since the latter are low correlated with traditional risk factors. Lustig et al. (2009) and Menkhoff et al. (2012), instead, developed models involving risk factors specifically designed for the nature and the features of the strategy; the former proposed a model with two currency factors: the Dollar risk factor (RX), that is a level factor defined as the average return for a U.S. investor that buys all the foreign currencies in the FX market, and the Carry trade risk factor (HML_{FX}), a slope factor interpreted as the return on a zero-cost strategy involving a long position in high interest rate currencies and a short position in low-yielding currencies. This two-factor model provides a good fit of the data on carry trade portfolios, thus suggesting that the risk premium for carry trade is determined by the exposure to two different sources of risk: the dollar risk premium represents a compensation for home country risk, while the carry trade risk premium compensates the investor for global risk. Menkhoff et al. (2012), instead, developed a different model which involves the same RX factor and a global FX volatility risk factor, that is a proxy for unexpected changes (innovations) in the FX market volatility. The results of the model estimation reveal that these factors are able to explain carry trade excess returns, which thus can be considered as a compensation for the exposure of the strategy to volatility risk; in other words, carry trade performs particularly poorly during periods of market turmoil and, consequently, delivers large payoffs to investors as compensation for higher risk-exposure.

However, the different factor models proposed by researchers do not result in a general risk-based explanation for the profitability of carry trade, since there is no agreement on which factors are able to explain the excess returns. Consequently, academics have proposed also alternative explanations to the phenomenon, like, among others, the negative skewness of returns, which imply that carry trades are subject to crash risk, and the presence of a peso problem, namely. the problem arising when the risk of low-probability events (i.e. peso-events) is priced by the market.

The aim of this thesis is to contribute to the empirical evidence by studying the performance of carry trade strategies involving the G10 currencies over the last 20 years, considering the euro as base currency; in particular, the analysis covers the sample period from December 2001 to December 2021 and is carried out with monthly frequency. End-of-month observations for data on deposit rates and spot exchange rates for the basket of currencies involved are collected from Bloomberg and Refinitiv Workspace, in order to simulate carry trade strategies and assess the related profitability.

The first step of the analysis is the computation of the excess returns and the corresponding statistics; these results are derived first from a currency-by-currency perspective, namely considering investments in each of the foreign currencies in the sample, funded borrowing the domestic currency (i.e. the euro). The results show that currency excess returns increase together with the interest rate differential: they are negative for currencies associated with a negative average differential (JPY and CHF) and positive for currencies that have positive average differentials, reaching considerably large values for high-yielding currencies, as the Australian dollar (2.54%) and the New Zealand dollar (2.92%), which are also associated with a positive and high Sharpe ratio. Then, the same analysis is carried out for two carry trade portfolios, built combining currency positions according to different criteria: Portfolio 1 is made up of a long position in the three currencies associated with the highest interest rate differentials and a short position in the three currencies with the lowest differentials, while Portfolio 2 invests instead in all the nine foreign currencies, taking long or short positions according to the sign of the yield-spread with the euro. The two strategies deliver large average monthly excess returns over the period considered (i.e. 1.58% and 1.28%, respectively) and exhibit fairly positive values for the Sharpe ratio (i.e. 0.355 and 0.162). The analysis just illustrated is repeated employing bid-ask quotes for interest and exchange rates, in order to consider the impact of transaction costs: in this case, the average excess returns are slightly lower, but the strategy is still profitable. Therefore, the results derived are consistent with findings in the empirical literature, pointing out a significantly positive profitability for carry trade.

Then, the analysis moves on to the investigation of the possible explanations for carry trade positive returns, in terms of compensation for the exposure to sources of risk. First of all, the statistics derived reveal that excess returns to high-yielding currencies, like the AUD and the NZD, and to the carry trade portfolios are negatively skewed, consistently to the alternative explanation proposed by Brunnermeier et al. (2008), which suggested that the strategy is subject to crash risk. To assess other risk-based explanation, different factor models are estimated, through time-series regressions of monthly excess returns to the two portfolios on the considered risk factors. The analysis starts from traditional factor models, namely, the CAPM, the Fama-French model and a real consumption growth model; the estimated betas are very small and none of the three models provides a good fit of the data, thus leading to the conclusion that profits to carry trade strategies are not a compensation for the investor's exposure to conventional sources of risk. Then, two specific factor models are estimated, developed following those proposed by Menkhoff et al. (2012) and Lustig et al. (2009): the first one uses as single risk factors the monthly volatility of FX markets, while the second one involves the two currency factors (i.e. the dollar and the carry trade risk factors), derived applying the definition provided by the author to my sample of data. These models provide a fairly good fit of the data, revealing that the two portfolios have a negative exposure to FX volatility and a positive exposure to the carry trade risk factor, that is, global risk; therefore, the profitability of the strategies may be justified as compensation for bearing these risks.

In conclusion, the results of the empirical analysis carried out are overall consistent with major findings in academic literature: the statistics derived for the simulated strategies support carry trade profitability, reporting large positive excess returns and fairly high value for the associated Sharpe ratio. The observed profitability cannot be justified by a conventional risk-based explanation, but it may be explained in terms of exposure to specific sources of risk: volatility risk on FX markets, global risk, represented by the carry trade risk factor, and crash risk, as implied by the negative skewness of returns.

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