Off the Golden Fetters: Examining Interwar Carry Trade and Momentum

Jason Cen* **and** **Ian W. Marsh†**

November 2013

Abstract

We study the properties of carry trade and momentum returns in the interwar period, 1921:1-1936:12. We find that currencies with higher interest rates outperform currencies with lower interest rates by about 7% per annum, consistent with estimates from modern samples, while a momentum strategy that is long past winner and short past loser currencies rewards an average annual excess return of around 7% in the interwar sample, larger than its modern counterparts. On the grounds that the interwar period represents rare events better than modern samples, we provide evidence unfavorable to the rare disaster based explanation for the returns to the carry trade and momentum. Global FX volatility risk, however, turns out to account for the carry trade return in the interwar sample as well as in modern samples.

Keywords: Interwar, Carry, Momentum, Risk Premia, Rare Disasters, FX Volatility Risk.

JEL classification: G12, G15, F31

*Faculty of Finance, Cass Business School, City University London, 106 Bunhill Row, London, EC1Y 8TZ, UK, Email: jason.cen@city.ac.uk

†Faculty of Finance, Cass Business School, City University London, 106 Bunhill Row, London, EC1Y 8TZ, UK, Email: i.marsh@city.ac.uk

1 Introduction

In this paper, we study returns to two types of popular currency speculation in the context of the interwar period from 1921:1 to 1936:12. We consider the carry trade, in which an investor borrows a basket of currencies with lower interest rates and invests in a basket of currencies with higher interest rates, and the momentum strategy, in which an investor holds a long position in currencies with superior past returns and a short position in currencies with poor past performance. Both of these strategies have proved profitable to follow over prolonged periods during the recent float (post 1973). Explaining these positive returns has been more difficult, and competing explanations each have merit and have found some support from data from the recent period.

Our contribution is two-fold. First, we document the returns to currency strategies in the interwar period. Note that we do not assume these strategies were being followed by investors in the interwar period. Rather, we examine the performance of the strategies viewing the interwar sample period as a hitherto unexplored test period. Second, we evaluate two competing explanations for currency returns, global FX volatility risk [Menkhoff, Sarno, Schmeling, and Schrimpf (2012a)] and the rare disaster explanation [Farhi and Gabaix (2011)], using evidence from the interwar sample.

We find that forward discounts, or equivalently interest rate differentials, and past returns continue to be strong predictors for future currency returns in the interwar sample. Both the carry trade and momentum strategies are profitable in the interwar period. Further, the average payoffs are virtually the same as their modern sample counterparts. In particular, an US investor would have been rewarded with a 7% annual excess return on average in the interwar period, had she followed either the carry trade or the momentum strategy. The magnitude of these profits is similar in the modern samples, except that momentum effect seems absent in the post Euro sample 1999:1-2013:3. Although the interwar carry trade and momentum may not seem impressive given their Sharpe ratios of 0.3∼0.4, the US stock market also provides a Sharpe ratio of similar magnitude in the interwar period.

We highlight that the interwar carry trade and momentum strategies resemble each other in terms of their source of profitability. The interwar carry trade is profitable not only due to the interest rate spread between high-yielding countries and low-yielding countries but also because the appreciation of high-interest-rate currencies relative to low-interest rate currencies contributes 21 percent of the total profits. For interwar momentum, currencies with positive past returns are those with high interest rates and currencies with negative past returns are those with low interest rates; hence, 14 percent of momentum profits are produced by interest rate differential. This contrasts with the modern data where momentum and carry strategies typically invest in different currencies and gain returns from different sources - carry from the interest differential and momentun from exchange rate changes.

Another key contribution of our paper is that we examine the validity of competing explanations for profitable currency speculation using interwar evidence. It is of interest to examine the interwar period since it contained many 'rare' events, while these are arguably absent or at least under-represented in modern samples. To be specific, we evaluate two streams of explanations that have proved successful in modern data: the rare disaster based explanation and the importance of global FX volatility risk.

We start by evaluating whether a rare disaster distribution for currency returns can account for the average carry trade and momentum returns. We estimate the empirical likelihood of each return observation under the null hypothesis that the true mean return is zero. We find that if one maintains that carry trade or momentum returns are generated from a "special" distribution such that the true mean returns are zero, then we also have to accept (i) that it is extremely unlikely that empiricists would observe the sizable average returns to currency speculation documented in the interwar and modern periods, and/or (ii) that this "special" distribution features more negative skewness which implies, we feel, an unrealistically high frequency of disastrous events, and (iii) that such a "special" distribution is in any case unable to reconcile carry trade returns and momentum returns simultaneously. Consequently, our evidence is unfavorable to the pure rare disaster based explanation.

We then explore the robustness the global FX volatility risk explanation in the interwar data. We find that global FX volatility risk explains the majority of both the carry trade and momentum strategies in the interwar sample. In modern samples, volatility risk can only account for carry trade returns. In the interwar sample, financing currencies, either those with lower interest rates or those with poorer past performance, hedge volatility risk while investment currencies, either those with higher interest rates or those with superior past performance, incur losses when global FX volatility is unexpectedly high. Even though the spread in volatility beta, or the covariation of portfolio returns to the global FX volatility innovations, is smaller in the interwar sample than in the modern period, the interwar price of volatility risk is double that of the post Bretton Woods sample (1976:1-1998:12) and is six times that of the post Euro sample. Therefore, around 6% (5%) out of the 7% annual average returns of the carry trade (momentum) is accounted for by compensation for global FX volatility risk.

Related literature. We build on a growing literature that addresses the risk-return nexus in foreign exchange market speculation, focusing in particular on the carry trade and momentum.

This literature starts from the empirical documentation of violations of uncovered interest parity or the forward premium puzzle in the seminal papers by Hansen and Hodrick (1980) and Fama (1984) and has made progress due to the work by Lustig and Verdelhan (2007) who apply standard asset pricing techniques to examine risk-return relationships based on currency portfolios. Although their claim that consumption risk can explain carry trade returns is controversial, [see Burnside (2011) and Lustig and Verdelhan (2011)] their finance-oriented approach to understanding the foreign exchange market has led to a resurgence in the literature seeking to explain exchange rates. For example, Menkhoff, Sarno, Schmeling, and Schrimpf (2012b) provide a comprehensive empirical documentation on the return to a variety of currency momentum strategies.

We follow this literature and make our first contribution by documenting carry trade and momentum returns in the interwar period. This is a period that has been widely examined in the time-series/economic literature, especially with regard to covered interest parity [e.g. Peel and Taylor (2002)] and regime credibility [e.g. Hallwood, MacDonald, and Marsh (1997a,b, 2000)]. However, data from this period have not been used to consider the new cross-section/finance explanations of exchange rate behaviour. We consider the examination of the interwar period as an 'out of sample' test of competing theories hitherto tested only on data from the modern era.

An important aspect of the new branch of the literature is to account for currency returns by various types of risk.[1] Lustig, Roussanov, and Verdelhan (2011) conduct principal component analysis of the cross section of currency portfolios sorted on interest rates (or, equivalently, forward discounts) and derive two factors, a "level" or dollar factor and a "slope" or carry factor, to explain carry trade returns. Using a similar approach, Menkhoff, Sarno, Schmeling, and Schrimpf (2012a) attribute carry trade returns to compensation for global FX volatility risk. Recent progress

[1] Lustig and Verdelhan (2012) provide a detailed exposition of risk-based analysis of exchange rates and currency returns in the stochastic discount factor framework.

in considering higher-order moment risks has been made by Mueller, Stathopoulos, and Vedolin (2012) who show that carry trade returns also reflect compensation for global FX correlation risk, while Della Corte, Riddiough, and Sarno (2013) establish global imbalances as a macroeconomic risk factor to explain currency premia.

In addition to the risk-based explanations, many papers explore non-risk-based frameworks, including the peso problem explanation. This is investigated by Burnside, Eichenbaum, Kleshchelski, and Rebelo (2010) who argue that carry trade returns reflect some peso states featuring large stochastic discount factors but modestly large carry trade losses. Related to this, the rare disaster based explanation[2] argues that the observed recent float sample under-represents some rare disastrous events [see Farhi and Gabaix (2011), Farhi, Fraiberger, Ranciere, and Verdelhan (2013), Brunnermeier, Nagel, and Pedersen (2008).] A common feature of empirical papers in this field is that they use currency options data to infer the properties of the unknown rare events.

We make our second contribution by exploring the interwar data to re-examine the power of these explanations. In order to make our analysis clear and parsimonious, we only make the case for global FX volatility risk explanation and the peso/rare disaster based explanations. The distinction of our paper is that although options data are not available in the interwar period, we are able to evaluate rare disaster/peso based explanations on the grounds that rare events are better represented in the interwar sample. We find evidence unfavourable for non-risk based explanations.[3]

This literature has focused on explaining carry trade returns, whereas currency momentum returns are left virtually unexplained. Menkhoff, Sarno, Schmeling, and

[2]The rare disaster based theory was initially proposed by Rietz (1988) as a solution to the equity premium puzzle [see Mehra and Prescott (1985)], and was revived by Barro (2006) who calibrates rare disaster probabilities using international data in the twentieth century.

[3]Our results resonate with Jurek (2014) who compares the returns to hedged and unhedged carry trades and points out that peso problem can account for only one-third of average carry trade return.

Schrimpf (2012a) test whether global FX volatility risk can explain momentum returns without success. On the other hand, rare disaster based explanations are not promising in explaining carry trade and momentum returns simultaneously because in modern data, during carry trade crashes, momentum strategies tend to profit [see Burnside, Eichenbaum, and Rebelo (2011)].

With unique evidence from interwar data, we push forward the joint explanation of returns to the carry trade and momentum. Our results suggest that global FX risk does appear to acount for a significant part of interwar currency portfolio returns.

The rest of this paper is organized as follows. Section 2 describes our data including both interwar and modern period forward and spot exchange rates. Section 3 demonstrates the profitability of the carry trade and currency momentum strategies in the interwar period, and compares performance to the modern sample evidence. Section 4 uses the interwar data to re-evaluate risk-based and non-risk based explanations for the returns to carry trade and momentum. Section 5 concludes.

2 Data Description

This section describes the data used in our empirical analysis, namely spot and forward exchange rates in the interwar period from 1921:1 to 1936:12 and in the modern period from 1976:1 to 2013:3.

2.1 Interwar Spot and Forward Rates

We use weekly spot and one-month forward exchange rates from the interwar sample period, November 1921 to December 1936. We use exchange rates for the following seven countries: Belgium (BEF), France (FRF), Germany (DEM), Italian (ITL), Netherlands (NLG), Switzerland (CHF), United States (USD). The data initially use the British pound (GBP) as the base currency.

The data are sourced by Enzig (1937) from the weekly publication by the Anglo-Portuguese Colonial and Overseas Bank, Ltd. (Originally the London branch of the Banco Nacional Ultramarina of Lisbon). The rates are for the Saturday of each week, except when the market was closed on the Saturday or there were no rates available; in these cases, the latest rates available prior to that Saturday was used. Note that Saturday was an active trading day during this period. The raw exchange rates are quotes against the British Pounds. However, we change the reference currency to the US dollar through the assumption of a lack of triangukar arbitrage in order to be consistent with studies using modern data. We transform the weekly data into monthly data by selecting the end-of-month observations since this literature typically analyses data at the monthly frequency.

A major concern with regard to the implementability of currency speculation in the interwar period is the German hyperinflation and German mark's devaluation at an exponential rate in the early 1920s. We argue that our results are not impacted for the following reasons. First and foremost, Panel a. in Table 1 indicates that the German mark is neither a primary financing currency nor is it a major investment currency. Second, the forward exchange rate data are not available from 1923:9 to 1924:11, the most severe phase of the German hyperinflation. Finally, our implementation of currency strategies are based on a cut-off rule for the interest rate spread such that we do not consider countries whose interest rates are 22% per annum higher than the US interest rate. According to Bansal and Dahlquist (2000), the forward premium puzzle is more prominent in countries with hyperinflation and thereby spurious nominal interest rates.

For the purpose of constructing a foreign exchange market volatility index (detailed below), we also gather daily spot rates of the US dollar against the British pound, French franc, Deutsch mark, and Swiss franc for the interwar period from the Global Financial Database.

The interwar foreign exchange market saw considerable exchange rate variations at least in the case of the developed european economies we study. For instance, as Figure 1 illustrates, in the early 1920s, major economies faced heightened pressure to adjust the value of their currencies to a new parity in line with their relative post World War I price levels. This induced an ideal speculative environment for betting on whether countries with already high cost of debt would devalue their currencies and caused substantial exchange rate fluctuations until 1927 when all major european countries returned to the gold standard. The interwar gold standard was shortlived and any stability ended soon after the Wall Street Crash of 1929. Figure 2 shows that currencies followed a series of large valuation changes in the subsequent years.

It is important to stress that the FX markets were active during the interwar period. Enzig (1937) notes that the forward market developed in London soon after the end of World War I, and both spot and forward foreign exchange was actively traded, especially in the 1920s. He also specifically reports that the foreign exchange markets were actively ued for hedging trade or investment ransactions and for arbitrage and speculation. Initially, trading was dominated by professional investors but considerable retail activity was recorded as the decade progressed. Trading was greatly reduced during the fixed fixed rate period (late 1920s) but recovered once the managed float period began, although the global depression limited volumes relative to the boom years of the early 1920s.

2.2 Post Bretton Woods and the Euro Era

We follow Menkhoff et al. (2012) by complementing BBI data on spot and one-month forward rates quoted against the US dollar with Reuters data converted to quotations against the US dollar. This extended sample starts from January 1976 and ends in March 2013. We further divide the sample into two categories: 1) the Post Bretton Wood Period from January 1976 to December 1998, and 2) the euro-era from January 1999 to March 2013. This partition of the modern sample is not arbitrary because it gives us three samples (one interwar and two modern) with approximately equal length and within each sample, the cross section is relatively fixed and therefore it helps us make more sensible historical comparisons.

The cross section of our modern sample consists of 15 developed countries, namely, Australia, Belgium, Canada, Denmark, Euro Zone, France, Germany, Italy, Japan, the Netherlands, Norway, New Zealand, Sweden, Switzerland, and the UK.

It is a concern that our comparative analysis is based on different sets of currencies in different historical samples. One solution might be to just use the seven currencies that are common across the three historical samples. However, we argue that fixing the cross sectional dimension for our historical comparison ignores the fact that the financial markets and in particular, the foreign exchange markets, have expanded through time. The group of seven european countries which used to be large enough to be counted as global in the 1920s, is not global in the modern era. Further, if we limit analysis to the seven european currencies (against the dollar) there will be only four currencies in the post Euro era due to the introduction of euro. Finally, keeping a common cross section through the modern era would exclude three of the four currencies most closely associated with the carry trade - the yen as a funding currency and the Australian and New Zealand dollars as investment currencies.

On the other hand, one may be concerned that limiting analysis to developed countries is too narrow to well represent currency speculation, especially for the modern era. As Burnside, Eichenbaum, and Rebelo (2008) document, diversification can significantly boost the Sharpe ratio of the carry trade and Menkhoff et al. (2012b) show that the inclusion of both developed and emerging countries is important to generate large positive average momentum returns. Nonetheless, the findings by Burnside, Eichenbaum, and Rebelo (2007) suggest a significant effect of transactions costs on emerging country carry trades given that spreads are two to four times larger in emerging markets than in developed countries. The focus on developed countries is also supported by the evidence in Bansal and Dahlquist (2000) who find violation of the uncovered interest parity is more prevalent for developed countries than emerging economies.

Therefore, we believe that our choice of the cross section is the best tradeoff between comparability across samples and the representativeness of the currency market.

3 Profitability of the Carry Trade and Momentum Strategies

This section examines the robustness and pervasiveness of the profitability of the carry trade and currency momentum strategies in the interwar period, as compared to the modern period. We begin by briefly outlining the implementation of the key foreign exchange strategies and the measurement of returns.[4]

3.1 Decomposition of Currency Returns

Following the notation of Burnside (2012) and Koijen, Moskowitz, Pedersen, and Vrugt (2013), we denote the time t spot and forward rates of a country against the US dollar as S_t and F_t respectively, in terms of the dollar price of one foreign currency unit. As is standard in the literature, we implement currency investments via the forward markets. Accordingly, a long position in a currency is carried out by buying forward currency. Under the assumption of full collateralization, the payoff or excess return is

$$Z_{t+1} = \frac{S_{t+1} - F_t}{F_t} \tag{1}$$

$$= C_t + \mathbf{E}_t \left[\frac{\Delta S_{t+1}}{F_t} \right] + u_{t+1} \tag{2}$$

where

$$C_t = \frac{S_t - F_t}{F_t} \tag{3}$$

Eq. 2 presents an explicit decomposition of currency return into three components: 1) the carry component of the expected return, C_t, 2) the expected appreciation component of the expected return, and 3) the return innovation. Given that the carry is observable at time t and is a key element of the currency return, we would expect other return predictors to have predictive powers for exchange rate appreciation. It is worth noting, however, that the carry arguably predicts the appreciation rate; on the other hand, potential forecasting variables for the appreciation rate are in general

[4] Koijen, Moskowitz, Pedersen, and Vrugt (2013) provides detailed explanation and comprehensive empirical analysis to show the 'carry everywhere' phenomenon. We recast their intuition back into the currency context in order to provide the basic intuition underlying the predictability of carry and momentum for currency returns.

not independent of the carry.

In complete markets the depreciation rate of the home currency is equal to the relative (foreign v.s. domestic) marginal utility growth rates,

$$\frac{S_{t+1}}{S_t} = \frac{M^*_{t+1}}{M_{t+1}} \tag{4}$$

The expected foreign currency appreciation rate can therefore be written as

$$\begin{aligned}
\mathbf{E}_t\left[\frac{\Delta S_{t+1}}{F_t}\right] &= \mathbf{E}_t\left[\frac{\Delta S_{t+1}}{S_t}\frac{S_t}{F_t}\right] && (5)\\
&= \mathbf{E}_t\left[\frac{M^*_{t+1}/\mathbf{E}_t[M^*_{t+1}]}{M_{t+1}/\mathbf{E}_t[M_{t+1}]} - 1\right] - C_t && (6)\\
&\approx \frac{1}{2}(\lambda_t^2 - \lambda_t^{*2}) - C_t && (7)
\end{aligned}$$

where the third Eq. holds approximately by log-linerization and under the assumption of a Gaussian one-factor model for stochastic discount factors shown below with $\lambda_t^{(*)}$ denoting the domestic (foreign) price of risk, and $r_t^{(*)}$ denoting the domestic (foreign) short rate:

$$M^{(*)}_{t+1} = \exp\left\{-r_t^{(*)} - \frac{1}{2}\lambda_t^{(*)2} - \lambda_t^{(*)}\epsilon_{t+1}\right\} \tag{8}$$

Combining Eq. (2) and Eq. (7), we see that no matter how we decompose the return, a variable predicts the currency return if and only if it reflects the relative price of risk between the domestic country and the foreign country. A foreign currency with 1% higher carry is supposed to deliver 1% higher return in excess of the domestic currency. However, unless the carry contains information about the relative price of risk or put differently, as long as the uncovered interest parity holds, the foreign currency is expected to depreciate by exactly 1%, thereby wiping out gains from higher carry and resulting in zero net profit.

Despite the fact that the essence of predictability of currency return lies in time varying relative price of risk across countries, it is worth emphasizing that the decomposition of return into a carry component and an appreciation component is intuitive for three reasons. First, a currency investment is risky only to the extent that the exchange rate fluctuates. Second, the literature has provided plenty of empirical evidence that the change in the exchange rate is largely unpredictable, at least in the one-month horizon. It makes sense to partition the return into the carry which involves no uncertainty at all and is directly observable from the market data without any time series model, and the appreciation whose forecast is far from being stable and reliable. Third, from the perspective of investors in the foreign exchange market, the carry offers a natural benchmark for performance evaluation as investors do not need to have any econometric skills or fund management experience to obtain it. By contrast, the hard-to-capture currency appreciation is likely to benefit from investment experience, model stability, talent, or pure luck.

We next outline two major currency return predictors, carry (for the carry trade) and past excess return (for currency momentum), that have been extensively studied in the literature and briefly discuss their relationship with returns. Ang and Chen (2010) extends this idea by documenting the predictability due to the link between risk premia and yield curve predictors including the short interest rate, the long-term interest rate, the term spread, and the change in interest rate. In untabulated results, we show that the carry (interest rate differential) is the only robust predictor for currency returns across different subsamples, controlling for other predictors.

3.2 Currency Return Predictors

Carry. It is well known that the short term interest rate moves in the opposite direction to the risk premium. This can easily be seen within a simple consumption based model within which the risk premium is high when uncertainty goes up, and at the same time the short rate drops due to precautionary saving motives.

On the empirical front, the well documented failure of uncovered interest parity suggests the foreign currency with higher interest rate tends not to depreciate enough to erase the deterministic interest profits. In fact, exchange rate movements are likely to enhance gains from the carry.

To sum up, the currency with higher carry C_t earns higher returns.

Momentum. In spite of the voluminous literature documenting various types of momentum phenomena in different asset markets, there is no unified theory explaining why high past returns forecast high future returns.

Nonetheless, a decomposition of the momentum predictor, the past return Z_t, into past carry C_{t-1} and past spot appreciation $Q_t^S \equiv \Delta S_t / F_{t-1}$ may shed some light on the intuition behind momentum. Interest rates are highly persistent and therefore high interest rates are followed by high subsequent interest rates. Further, auto-correlation of exchange rate changes is arguably weakly positive and hence the bull market for a currency tends to continue and investors expect to earn higher returns.

In sum, the return momentum, or the past return is a combined signal which seeks the tradeoff between the carry component and the appreciation component of the currency return.

3.3 Evidence from Individual Currencies

We start with currency speculation exploiting individual bilateral exchange rates before considering portfolio-based stategies in the following sub-section. Table 1 presents key statistics for the interwar sample versus the modern samples. We find, on average, that the interest rate differential or carry is not as dispersed in the cross section of interwar currencies as in the cross section of modern currencies. This is partly because we have a relatively small set of solely european countries during the interwar period. However, the dispersion of average appreciation is much larger in the interwar sample than in modern samples, indicating the potential attractiveness of currency momentum in the interwar period, and potentially a large appreciation component in the carry trade.

We also find that interwar exchange rate returns feature substantially larger standard deviations, more negative skewness, and heavier tail distributions than modern exchange rate returns. These higher moments highlights the our basic idea that the interwar sample accommodates more disastrous events that are rarely seen in the modern samples.

The second and the fourth columns indicates the positive carry-mean excess return relationship in the cross section for the interwar sample as well as the two modern samples.

Turning to the last two columns of table 1, we show that in the time series individual currency carry trade and momentum are mostly profitable in the interwar period as well as in the modern periods. This is especially true for the momentum strategy. This interwar evidence provides an out-of-sample verification of the profitability of not only the equally-weighted carry trade [see Burnside et al. (2010)] which is essentially the cross sectional average of our individual currency carry trades , but also the time-series momentum strategy proposed by Moskowitz, Ooi, and Pedersen (2012). In the interwar sample, an equally-weighted carry trade, which may not cancel out dollar effect, turns out delivers a mean excess return of much smaller size than a zero-cost carry trade that cancels out the dollar effect. Profits of equally-weighted time series momentum, however, is virtually as profitable as zero-cost momentum in the interwar period.

3.4 Evidence from Currency Portfolios

We form sets of portfolios on the basis of each predictor in the interwar period, the post Bretton Woods period, and the Eurozone period respectively. We aim to make sensible comparisons of portfolios across these three historical samples. For the interwar sample, we sort the seven european currencies into three portfolios at the end of each month based on the end-of-month observations of the predictor. In detail, we allocate currencies with carry in the bottom 33% into portfolio 'L', the middle 34% into portfolio 'M', and the top 33% into portfolio 'H'. We follow the same procedure for the two modern samples except that we can exploit the larger dimensions of this data set and in line with the literature form five portfolios.

To get more sense from our portfolio allocation, we show in Table A.1 that the size of our portfolios is similar over the three samples. Corner portfolios, either 'L' and 'H' or '1' and '5', typically contains two to three currencies, though there are a few cases in which intermediate portfolios may contain currencies of varying numbers.

We discuss in detail below summary statistics of the currency strategies which are long the portfolio with the highest value of the predictors and short the portfolio with the lowest value of the predictor. Perhaps the key finding from the comparative analysis across three different historical environments is that carry is not only a robust predictor of currency returns, but also has fairly stable predictive power.

Mean Return and Sharpe Ratio. Table 2 reports key statistics of currencies portfolios sorted according to carry and momentum, respectively. The first row in each panel shows the average annualized excess return of currency investments against the US dollar. It is evident that for the interwar sample that carry predicts currency excess returns. Currencies at larger forward discounts or with higher interest rates perform better than those with forward premia or with lower interest rates. These observations from the interwar era are consistent with modern sample evidence as shown in Panels b and c. Past return is also a strong predictor for currency excess returns in the interwar period and in the post Bretton Woods era; past winners continue to outperform past losers. However, momentum is absent in the post Euro era, at least for our set of developed countries.

The second row of each panel presents mean excess returns of the zero-cost *carry* and *momentum* strategies. For the carry strategy, for example, this means being long a portfolio with a large forward discount (portfolio 'j') while short the portfolio with the lowest forward discounts (portfolio '1'). The t-statistics of mean returns are given in the third row. It is evident that both carry and momentum strategies yield economically sizable and statistically significant excess returns in the interwar era as well as in the post Bretton Woods era. The largest return spread is always given by the long/short strategy involving the two extreme portfolios (which we denote high-minus-low or HML). It is notable that the HML carry strategy on average delivers around 7% per annum in all three historical samples while average returns to the HML momentum strategy is around 6% per annum interwar and post Bretton Woods. The outlier case is momentum in the post Euro sample where statistically significant returns are absent.

Turning to the annualized Sharpe ratios (row four), we find that the both carry and momentum strategies deliver decent risk-return tradeoffs in most historical samples. In the interwar era, the annualized Sharpe ratio of 37% for the carry strategy and 31% for the momentum strategy may seem less impressive. However, we argue that the risk-return tradeoffs of the strategies are reasonably good in that exchange rate movements are of substantially larger magnitude in the interwar sample than in the modern sample. As a result, the standard deviation of the excess return is most likely to be overestimated. It is also worth noting that the nominal mean excess return may have underestimated the numerator of the Sharpe ratio given the deflation of the reference currency (USD) in the interwar period and its inflation in the modern era. Furthermore, the Sharpe ratio of the US stock market was also around 40% in the interwar period, of similar magnitude to the currency strategies.

Carry vs Appreciation. We then take an in-depth look at the sources of currency strategy profits by decomposing the mean excess return into a (ex ante known) carry component and the (ex ante unknown) exchange rate appreciation component highlighted in Eq.2.The decomposition suggested by Eq.2 reflects a simple idea: the excess return of any currency strategy should be earned from either the interest rate difference between the investment and funding currencies or the relative change in spot exchange rates. There is no other source of profit. Consequently, the decomposition of excess return into a carry component and a price appreciation component helps us understand the information the various predictors exploit to forecast future returns.

Our results in Table 3 suggest that the *carry* trade derives the majority of its profits from the interest rate difference whereas the momentum strategy's main source of profits is price change or appreciation of investment currencies relative to the financing currencies. In the interwar period, more than one-fifth of the 7% annual return of the carry strategy is contributed by appreciation. The share of profits is similar in the post Euro sample. The post Bretton Woods period features a substantial average depreciation of the high interest rate currencies relative to low interest rate currencies, partially eroding the gain from interest differentials. However, this still suggests that spot rate changes play an important role in carry strategy profits. In spite of the dominance of the appreciation component for the momentum strategy, the interest differential contributes non-negligible shares of profits to the average returns of the momentum strategy - 15% in the interwar sample and 43% post Bretton Woods.

Dynamics of carry trade and momentum. In order to understand how the profit/loss of the carry trade and momentum strategies are accumulated through time, we present the simple cumulative excess returns along with the corresponding cumulation of carry component and appreciation component for each currency strategy in each historical sample in Figure 3. The interwar carry trade and momentum are quite similar: they both benefit from interest rate spread and appreciation of the investment currencies relative to the financing currencies. In contrast, modern carry trade and momentum returns display rather different composition.

Another aspect worth discussion is the return cumulation dynamics. Interwar carry trade and momentum displays unparalleled variation during the post-WWI floating exchange rate regime from the beginning of 1921 till about 1928 when all major economies returned to the gold standard, and carry trade stopped generating profits. Following the collapse of interwar gold standard, marked by the departure of UK from gold, the carry trade initially crashes and then starts to accumulate gradual profits in the managed floating regime of the early 1930s. Different from the interwar period, the modern era subsequent to the collapse of the Bretton-Woods system has never seen such large scale foreign exchange regime transitions. As a result, the cumulative returns look smoother in the modern era in spite of several notorious carry trade crashes during the Asian financial crisis and the 2008/9 financial crisis.

4 Competing Explanations

In this section, we examine the risk profile of the carry and momentum strategies in order to re-evaluate a number of explanations proposed in the literature. In particular, we consider two key explanations of carry and momentum profits: 1) rare disasters, and 2) global FX volatility risk. These explanations have proved successful to some extent in rationalizing the average return of the carry trade in the recent floating rate period. We extend our understanding by adding the interwar float data.

4.1 Rare Disasters

We start with the rare-disasters-based explanation that assumes all states are present in the sample but that the true probability density is not well represented by the sample.

We examine what the most likely rare disaster distribution for payoffs under the null of a zero mean would imply for our actual observation of sizable carry trade and momentum returns in-sample.[5] We estimate the rare disaster distribution via the empirical likelihood method (EL) according to Ghosh and Julliard (2013) who adopt the EL method to investigate the implication of rare disaster models for the equity risk premium.[6]

To be precise, we estimate the probability of each sample observation by maximizing the empirical likelihood function under the constraint that the mean excess return of

[5] In the online appendix to Menkhoff et al. (2012a), the authors report their asset pricing results based on empirical likelihood estimation and verify that global FX volatility risk is priced in the cross section of carry trade portfolios in the sample from 1983:12 to 2009:8. In this paper, however, we do not verify whether the FX volatility risk model is robust to empirical likelihood estimation.

[6] For detailed reference, see Kitamura (2006) and Owen (2001).

the estimated probability is zero, i.e.

$$\{\hat{p}_t\}_{i=1}^{T} = arg \max_{\{p_t\}_{t=1}^{T}} \sum_{t=1}^{T} \log(p_t) \tag{9}$$

$$s.t. \sum_{t=1}^{T} p_t = 1 \tag{10}$$

$$\sum_{t=1}^{T} p_t Z_t = 0 \tag{11}$$

where Z_t denotes the excess return of the trading strategy and p_t is the probability of observing Z_t in the sample under the rare disaster distribution with zero mean. Our estimation is conducted separately for carry trade and momentum strategies and over the three historical samples.

Given the estimated empirical likelihood $\{\hat{p}_t\}_{t=1}^{T}$ such that $\mathbf{E}_T^{\hat{p}}[Z] = \sum_{t=1}^{T} \hat{p}_t Z_t = 0$, we resample the return data $\{Z_t\}_{t=1}^{T}$ with replacement and generate 10,000 artificial samples of the same size as the actual sample (T). We compute the average return for each bootstrap sample: $\overline{Z}^{(r)} = \sum_{t=1}^{T} Z_t^{(r)}$, where $r = 1, 2, \cdots, 10,000$ indexes the bootstrap samples. As a result, the EL-implied distribution for the **average excess return** can be constructed using the sequence $\left\{\overline{Z}^{(r)}\right\}_{r=1}^{10,000}$.

Figure 4 gives the distribution of **average excess returns** (blue shade) along with the actual sample average return (red vertical line). The distribution is obviously centered around zero due to the null hypothesis that the average return should be zero. The plots in the second and third row suggest that the probability of observing the sizable average carry trade and momentum payoff that have actually been seen in the modern periods is close to zero given the (sample specific) rare disaster distribution of payoffs with zero mean. For the carry trade, for example, the probability of observing an average return $6 - 7\%$ per annum is 0.01% in the post-Bretton Woods sample, as shown in panel a1 of Table 4. The probability of experiencing carry trade returns as high as observed during the post-Euro era under a rare disaster distribution is slightly higher, but is still only 1.74%. Panel b2 shows that the momentum profits in the post Bretton Woods sample are also highly unlikely under the null.

Under rare disaster distributions, the chance to observe the large positive carry trade return is slightly higher in the interwar sample than in the modern samples, though it is still only about eight percent. However, we argue that disastrous states tend to be over-represented in the interwar sample: supposedly rare events are actually quite regular in this period. Table 5 shows that in order to generate the rare disaster distribution with zero mean, the empirical likelihood method has to substantially reduce the skewness of the data[7] by weighing more on bad states with drastic losses to currency speculation and thereby making what we consider to be already unusually frequent disastrous events even more frequent. Figure A.2 visualizes how the empirical likelihood estimation operates on the frequency of each observation in order to push the average excess return to zero. Panel (a) illustrates that in order for the true mean excess return to be zero in the full sample, the true density (the red line) needs to weight more on the negative side than the sample-based density (the green line). Further, Comparing Panel (c) with Panel (e) and (f), we find that in the modern sample, the empirical likelihood estimation tends to shift the whole distribution toward left while in the interwar sample, the empirical likelihood estimation operates more on the left tail. This squares with the fact that there are far more extreme losses to currency carry trade and momentum in the interwar sample than in the modern samples.

The final row of each block in Table 4 pools all three samples and results are based on a single generated rare disaster distribution (one each for carry and momentum). The probability of observing a mean return in excess of of 6.61% from the carry trade

[7] Other moments, however, remain at similar levels.

is just 0.05% under the null. The full sample mean momentum return is more likely - 2.2% - driven by the post-euro failure of this strategy.

We now ask whether rare disaster-based explanations can rationalize returns to the carry trade and momentum in a consistent way. To this end, we examine the distribution of average *carry trade* returns implied from empirical likelihood estimates based on *momentum* returns under the null hypothesis that the mean return to the momentum is zero. As Table 4, Panel b1 shows, momentum-based EL cannot rationalize the average return to the carry trade because even if the true mean of momentum return is zero, the average return to the carry trade is still at the level of 6∼7 % per annum. Turning to Panel a2, the results indicate it is impossible to explain momentum return by carry trade-based EL. Even if the carry trade produces zero average return, the momentum is as profitable as the simple sample average suggests. As Figure 5 demonstrates, zero mean carry trade return implies large positive average momentum returns of virtually the same magnitude as the simple sample average; likewise, zero mean momentum return implies large positive average carry trade returns similar to the sample average.

To summarize our findings for rare disaster-based explanations, we claim that it is always possible to construct a rare disaster distribution in favor of zero-profit carry trade or momentum. However, if one is to believe this rare disaster-based explanation, one has also to believe that (i) it is almost impossible to observe the currency investment strategy profits we have actually witnessed; and (ii) it is unrealistically likely to see so-called "rare" disasters. Because neither of these two beliefs sounds convincing, our evidence is therefore unfavorable to the rare disaster-based explanation for profitable carry trade and momentum strategies. Furthermore, our results show that either the carry trade or currency momentum is profitable since returns to the carry trade and momentum cannot be explained simultaneously by rare disasters.

4.2 Global FX volatility risk

Global FX volatility measure. We initially follow Menkhoff et al. (2012a) and measure global FX volatility in the following way. First, we compute absolute daily log exchange rate returns for each currency. Next we average over all currencies available on any day. Finally we calculate within-month averages of daily values to give our monthly measure of global FX volatility. To be consistent with our portfolio construction, we only use developed countries' currencies to construct our global FX volatility measure.

In the case of the interwar sample, the daily data for only five currencies are available, namely, the British pounds, Deutsche mark, French franc, Italian lira, and Swiss franc against the US dollar. In order to investigate whether this relatively small cross section is able to measure the global FX volatility effectively, we compare, in the modern samples, FX volatility measured using 15 developed countries and that using only the five currencies. The lower panel of Figure 6 exhibits the comparison of these two volatility measures and their corresponding AR(1)-innovations. It is clear that the two volatility levels and their corresponding innovations closely track each other. The correlation between both pairs is more than 90%. [8]

Exposure to global FX volatility risk. In Table 6, we present the global FX volatility beta of each of the carry and momentum portfolios and the corresponding zero-cost HML strategies. In detail, we run time-series regressions of portfolio returns on the global FX volatility risk factor and the dollar factor in each of the three historical samples. The dollar factor is a simple cross-sectional average excess return of developed countries (seven european countries for the interwar sample) and it is used to control the "level" effect, i.e. the common time series variation across

[8] We also calculate the global FX volatility index using all countries data and find that its correlation with that based on five european countries is 87%.

currencies or currency portfolios. Accordingly, the global FX volatility risk factor captures the "slope" effect in some sense.

The left panel shows that portfolios of currencies with the lower forward discounts hedge volatility risk, whereas portfolios of currencies with higher forward discounts are subject to devaluation when volatility is unexpectedly high. Importantly, this pattern holds for the interwar sample as well as the two modern samples.

Interestingly, exposure to volatility risk, consistently measured, varies over the three samples. Volatility risk of the post Bretton Woods carry trade doubles that of the interwar carry trade while the post euro carry trade is exposed to volatility risk three times as large as the interwar carry trade. In spite of the extremely large volatility spikes in the interwar period, this should not happen in a world with constant currency volatility risk exposure. Given that over the three samples, volatility risk varies whereas returns to the carry trade or momentum are of similar magnitude, we conjecture and empirically verify that the volatility risk price estimates must be varying in the opposite way over the three samples in order to account for the similar mean excess returns.

Momentum, on the other hand, displays an even more puzzling risk profile over the three samples. The volatility beta is tiny in the post Bretton Woods sample and takes a large positive value in the post euro sample, consistent with what the extant literature has documented. However, in the interwar sample, momentum bears negative loadings on volatility shocks in the same way as the carry trade, i.e. their volatility betas are both -2.38, pointing toward the potential for volatility risk to account for returns to the carry trade and momentum at the same time.

Price of global FX volatility risk. We follow the standard Fama-McBeth procedure [see Fama and MacBeth (1973) and Cochrane (2005)] to estimate the market price of global FX volatility risk, along with the dollar risk price, as reported in Table 7. The key messages from these results are, first, that the price of global FX volatility risk is negative and, second, that the level of the price of risk varies over different historical samples.

The left panel shows estimates of the price of risk for the cross section of portfolios sorted by forward discounts. In line with our intuition from volatility betas, the price of global FX volatility risk is substantially higher in the interwar period than in the two modern periods. In fact, the absolute magnitude of the volatility risk price in the interwar period is twice as large as that in the post Bretton Woods era, and six times that in the post Euro era. Given these volatility betas and volatility risk prices, we find that volatility risk premium amounts to nearly 6% per annum in the interwar sample and the post Bretton Woods sample, leaving only about 1% out of the 7% average excess return of the carry strategy unexplained by the global FX volatility risk. The volatility risk premium explains about 4% out of the 6% annual mean excess return in the post Euro sample. Overall, a significant proportion of excess returns from the carry trade can be explained by compensation for global FX volatility risk.

Risk price estimates for momentum portfolios are shown in the right panel. Similar to results for the carry portfolios, global FX volatility risk price varies considerably over the three historical samples. Around 5% out of the 7% return from momentum is attributed to a volatility risk premium in the interwar sample but this falls to less than 1% out of the 5% momentum return in the post Bretton Woods sample. Recall that there is no excess return from momentum in the post-Euro sample.

In terms of the χ^2 statistics, we cannot reject the null hypothesis that pricing errors are jointly zero for the carry trade in the interwar sample. Interestingly, the null hypothesis is also rejected for currency momentum in the interwar sample, which lends considerable support to the global FX volatility risk model for both carry trade and momentum returns in this period.

Statistical Significance. We note that the standard errors suggest that the volatility beta estimates and the volatility risk price estimates are not statistically significant. This is in spite of the economic (and statistical) significance of the risk premium which is able to account for the majority of average excess returns to the carry trade and momentum. Given the extremely volatile interwar sample, it is not surprising to see noisy estimates from time series regressions. The relatively smaller interwar cross section of currency portfolios may also impact the statistical power of our cross sectional tests. Another key reason for the statistically weakly results is that the global FX volatility and its innovations are likely to be poorly estimated following the procedure in Menkhoff, Sarno, Schmeling, and Schrimpf (2012a) given the much smaller cross section for the daily interwar exchange rates.

To address this issue, we consider a GARCH-based proxy for global FX volatility that better incorporates information about exchange rate volatility from the time series. Specifically, we estimate a univariate GARCH(1, 1) model for demeaned monthly spot exchange rate returns at the monthly frequency and obtain an aggregate FX volatility measure from the cross-sectional average of the square roots of each individual variance forecast $\widehat{\sigma}^2_{i,t|t-1}$. The GARCH-based FX volatility innovation is then computed as the difference between realized volatility and forecasted volatility, represented by $dFXVOL = \frac{1}{22}\left(|\Delta s_t| - \frac{1}{N}\sum_{i=1}^{N}\widehat{\sigma}_{i,t|t-1}\right)$. We scale the measure by 22 in order to compare volatility derived from daily exchange rate changes.

We then repeat the above asset pricing tests with this new proxy for global FX risk. The results, shown in Table 8 for the carry trade portfolios in the interwar period, demonstrate the ability of volatility risk to account for the average excess return to the carry trade. High interest-rate currencies tend to load negatively on volatility risks (i.e., lose when volatility is heightened) while low interest-rate currencies turn out to be a hedge for volatility risks. The zero-cost carry strategy has a statistically significantly negative volatility beta of -13.11 and the compensation for volatility risk amounts to a statistically significant 6.11% per annum. [9]

Overall, the foreign exchange volatility risk explanation of carry trade returns appears to have some power according to interwar evidence, as well as from evidence relating to the modern era.

5 Concluding Remarks

Putting a spotlight on the interwar foreign exchange market, we document that returns to two popular currency trading strategies, namely the carry trade and momentum, were both profitable. Further, average returns to the carry trade and momentum were of virtually the same magnitude in the interwar sample as in the modern samples.

We examine two competing explanations that have been proposed in the literature to rationalize the returns to currency speculation. Our interwar evidence implies that global FX volatility risk remains an economically sensible explanation for both the carry trade and, to a lesser extent, momentum. Because both the carry trade and momentum are exposed to volatility risk and since the average investor dislikes volatility risk and so requires compensation for taking on volatility risk, the carry trade and momentum have to earn sizable average returns.

[9] We note that untabulated results sugest that the GARCH-based volatility measure does not seem to improve the explanatory power of volatility risk for average excess returns to the momentum strategy.

On the other hand we show that non-risk based explanations such as rare disasters lead to economically implausible and unrealistic inference. We show that believing the average return to the carry trade is in reality zero is difficult because it follows that either the sizable in-sample average returns observed in each of three distinct samples are themselves rare events, or that disasters are not rare at all. A further implication is that zero mean returns to carry (momentum) imply that momentum (carry trade) produces a large positive mean return. We argue that our evidence is unfavorable to the pure rare disaster-based explanations, although we do not claim that non-risk based explanations are completely unappealing.

References

Andrews, D. W. K. (1991). Heteroskedasticity and autocorrelation consistent covariance matrix estimation. *Econometrica 59*, 817–858.

Ang, A. and J. Chen (2010). Yield curve predictors of foreign exchange returns. Working Paper, Columbia Business School.

Bansal, R. and M. Dahlquist (2000). The forward premium puzzle: different tales from developed and emerging economies. *Journal of International Economics 51*, 115–144.

Barro, R. (2006). Rare disasters and asset markets in the twentieth century. *Ouarterly Journal of Economics 121*, 823–866.

Brunnermeier, M. K., S. Nagel, and L. H. Pedersen (2008). Carry trade and currency crashes. *NBER Macroeconomics Annual 23*, 313–347.

Burnside, C. (2011). The cross-section of foreign currency risk premia and us consumption growth risk: Comment. *American Economic Review 101*, 3456–3476.

Burnside, C. (2012). Carry trades and risk. In J. James, I. W. Marsh, and L. Sarno (Eds.), *Handbook of Exchange Ratesates*. Hoboken: John Wiley and Sons.

Burnside, C., M. Eichenbaum, I. Kleshchelski, and S. Rebelo (2010). Do peso problems explain the returns to the carry trade? *Review of Financial Studies 24*, 853–891.

Burnside, C., M. Eichenbaum, and S. Rebelo (2007). The returns to currency speculation in emerging markets. *American Economic Review Papers and Proceedings 97*, 333–338.

Burnside, C., M. Eichenbaum, and S. Rebelo (2008). Carry trade: The gains of diversification. *Journal of the European Economic Association 6*, 581–588.

Burnside, C., M. Eichenbaum, and S. Rebelo (2011). Carry trade and momentum in currency markets. *Annual Review of Financial Economics 3*(511-535).

Cochrane, J. H. (2005). *Asset Pricing* (Revised ed.). Princeton: Princeton University Press.

Della Corte, P., S. J. Riddiough, and L. Sarno (2013). Currency prema and global imbalances. Working Paper, Imperial College Business School.

Enzig, P. (1937). *The Theory of Forward Exchange*. London: MacMillan and Co., Limited.

Fama, E. F. (1984). Forward and spot exchange rates. *Journal of Monetary Economics 14*, 318–338.

Fama, E. F. and J. D. MacBeth (1973). Risk return and equilibrium: Empirical tests. *Journal of Political Economy 71*, 607–636.

Farhi, E., S. Fraiberger, R. Ranciere, and A. Verdelhan (2013). Crash risk in currency markets. Working Paper, Harvard University.

Farhi, E. and X. Gabaix (2011). Rare disasters and exchange rates. *Working Paper, Harvard University*.

Ghosh, A. and C. Julliard (2013). Can rare events explain the equity premium puzzle? forthcoming in the Review of Financial Studies.

Hallwood, C. P., R. MacDonald, and I. W. Marsh (1997a). Crash! expectational aspects of the uk's and the usa's departures from the inter-war gold standard. *Explorations in economic history 34*, 174–194.

Hallwood, C. P., R. MacDonald, and I. W. Marsh (1997b). Credibility and fundamentals: Was the gold standard a well-behaved target zone? In T. Bayoumi, B. Eichengreen, and M. Taylor (Eds.), *Modern Perspective on the Gold Standard*. Cambridge: Cambridge University Press.

Hallwood, C. P., R. MacDonald, and I. W. Marsh (2000). An assessment of the causes of the abandonment of the gold standard by the usa in 1933. *Southern Economic Journal 67*, 448–459.

Hansen, L. P. and R. J. Hodrick (1980). Forward exchange rates as optimal predictors of future spot rates: An econometric analysis. *Journal of Political Economy 88*, 829–853.

Jurek, J. W. (2014). Crash-neutral currency carry trades. forthcoming in the Journal of Financial Economics.

Kitamura, Y. (2006). Empirial likelihood methods in econometrics: Theory and practice. Cowles Foundation Disussion Papers 1569, Yale University.

Koijen, R. S., T. J. Moskowitz, L. H. Pedersen, and E. B. Vrugt (2013). Carry. Working Paper, London Business School.

Lustig, H., N. Roussanov, and A. Verdelhan (2011). Common risk factors in currency markets. *Review of Financial Studies 24*, 3731–3777.

Lustig, H., N. Roussanov, and A. Verdelhan (2013). Countercyclical currency risk premia. forthcoming in the Journal of Financial Economics.

Lustig, H. and A. Verdelhan (2007). The cross-section of foreign currency risk premia and us consumption growth risk. *American Economic Review 97*, 89–117.

Lustig, H. and A. Verdelhan (2011). The cross-section of foreign currency risk premia and us consumption growth risk: A reply. *American Economic Review 101*, 3477–3500.

Lustig, H. and A. Verdelhan (2012). Exchange rates in a stochastic discount factor framework. In J. James, I. W. Marsh, and L. Sarno (Eds.), *Handbook of Exchange Rates*. Hoboken: John Wiley and Sons.

Mehra, R. and E. C. Prescott (1985). The equity premium: A puzzle. *Journal of Monetary Economics 15*, 145–161.

Menkhoff, L., L. Sarno, M. Schmeling, and A. Schrimpf (2012a). Carry trades and global foreign exchange volatility. *Journal of Finance 67*, 681–718.

Menkhoff, L., L. Sarno, M. Schmeling, and A. Schrimpf (2012b). Currency momentum strategies. *Journal of Financial Economics 106*, 620–684.

Moskowitz, T. J., Y. H. Ooi, and L. H. Pedersen (2012). Time series momentum. *Journal of Financial Economics 104*, 228–250.

Mueller, P., A. Stathopoulos, and A. Vedolin (2012). International correlation risk. Working Paper, London School of Economics.

Newey, W. K. and K. D. West (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica 55*, 703–708.

Owen, A. B. (2001). *Empirical Likelihood, Monographs on statistics and applied probability*, Volume 92. Chapman and Hall, CRC.

Peel, D. A. and M. P. Taylor (2002). Covered interest rate arbitrage in the interwar period and the keynes-enzig conjecture. *Journal of Money, Credit and Banking 34*, 51–75.

Rietz, T. (1988). The equity risk premium: A solution. *Journal of Monetary Economics 22*, 117–131.

Shanken, J. (1992). On the estimation of beta pricing models. *Review of Financial Studies 5*, 1–34.

Table 1: Descriptive Statistics of Individual Currencies.
This table reports summary statistics of individual bilateral exchange rates including the number of observations, the mean forward discount or carry, the average exchange rate return "ΔS", the average excess return "rx" and its standard deviation "StD" , skewness, and excess kurtosis "KurtX". The last two columns reports the mean return of the carry trade and momentum based on individual currencies. Panel a. presents the above statistics calculated by interwar data from 1921:1 to 1936:12, while Panel b. and c. present these statistics calculated by modern sample data from 1976:1 to1998:12, and from 1999:1 to 2013:3, respectively. The mean and standard deviation are expressed in terms of percentage per annum.

a. 1921:1-1936:12

	obs	Carry	ΔS	rx	StD	Skew	KurtX	sign(carry)*rx	sign(mom)*rx
AUD	—	—	—	—	—	—	—	—	—
BEF	190	-0.14	-2.85	-2.89	18.65	0.39	5.90	3.05	-1.07
CAD	—	—	—	—	—	—	—	—	—
CHF	180	0.33	1.61	2.02	9.84	-5.09	60.30	-0.99	3.84
DEM	103	0.48	-17.75	-17.26	42.60	-0.83	14.73	-0.73	11.74
DKK	—	—	—	—	—	—	—	—	—
EUR	—	—	—	—	—	—	—	—	—
FRF	189	1.72	0.24	2.01	18.13	1.03	6.42	0.87	2.10
GBP	192	-0.45	2.10	1.65	9.25	-2.62	29.24	-2.01	2.28
ITL	178	2.60	5.01	7.42	16.37	0.87	5.87	6.92	11.45
JPY	—	—	—	—	—	—	—	—	—
NLG	192	0.76	3.45	4.22	8.44	-1.46	23.84	0.41	3.96
NOK	—	—	—	—	—	—	—	—	—
NZD	—	—	—	—	—	—	—	—	—
SEK	—	—	—	—	—	—	—	—	—

b. 1976:1-1998:12

	obs	Carry	ΔS	rx	StD	Skew	KurtX	sign(carry)*rx	sign(mom)*rx
AUD	168	3.97	-1.54	2.43	10.81	-0.68	2.13	5.82	6.92
BEF	275	1.10	1.26	2.36	11.66	-0.03	0.90	8.18	5.80
CAD	275	1.20	-1.76	-0.55	4.74	-0.45	1.18	3.37	0.36
CHF	275	-3.73	3.61	-0.12	12.99	-0.04	0.53	1.55	5.04
DEM	275	-2.03	2.58	0.55	11.56	-0.10	0.48	0.82	5.69
DKK	275	2.85	0.49	3.34	11.47	0.03	0.52	10.46	5.94
EUR	—	—	—	—	—	—	—	—	—
FRF	275	2.05	-0.36	1.70	11.11	-0.14	0.44	5.87	3.61
GBP	275	2.57	-0.21	2.36	11.55	0.01	1.38	7.03	4.38
ITL	275	5.76	-2.82	2.94	10.83	-0.38	1.27	3.53	7.50
JPY	246	-3.58	3.74	0.15	13.25	0.62	1.34	4.68	6.74
NLG	275	-1.25	2.19	0.94	11.59	-0.01	0.61	3.97	6.32
NOK	275	2.76	-0.90	1.86	9.98	-0.19	1.26	4.77	5.89
NZD	168	6.10	1.34	7.43	11.10	0.21	2.39	6.69	5.08
SEK	275	3.17	-2.13	1.04	10.60	-0.90	3.38	6.34	6.85

c. 1999:1-2013:3

	obs	Carry	ΔS	rx	StD	Skew	KurtX	sign(carry)*rx	sign(mom)*rx
AUD	171	2.63	4.58	7.21	12.90	-0.60	1.88	8.45	3.28
BEF	—	—	—	—	—	—	—	—	—
CAD	171	0.32	3.26	3.58	8.92	-0.41	2.99	-0.28	-1.08
CHF	171	-1.54	3.24	1.69	11.25	0.29	1.51	-0.07	3.99
DEM	—	—	—	—	—	—	—	—	—
DKK	171	0.02	1.21	1.23	10.57	0.01	0.79	5.92	5.67
EUR	170	-0.23	1.43	1.20	10.67	-0.06	0.72	5.43	5.61
FRF	—	—	—	—	—	—	—	—	—
GBP	171	0.93	-0.26	0.67	8.80	-0.21	1.34	2.66	1.03
ITL	—	—	—	—	—	—	—	—	—
JPY	171	-2.62	1.77	-0.86	9.74	-0.19	0.01	0.52	0.49
NLG	—	—	—	—	—	—	—	—	—
NOK	171	1.41	2.50	3.91	11.30	-0.31	0.88	2.69	-1.37
NZD	171	2.89	4.14	7.04	13.62	-0.32	1.42	10.38	5.67
SEK	171	-0.02	2.23	2.21	11.90	0.01	0.17	9.25	5.89

Table 2: Descriptive Statistics of Portfolios.
This table reports mean portfolio returns to the carry trade and currency momentum strategies, categorized according to the subsample: Panel a. for the interwar sample from 1921:1 to 1936:12, Panel b. for the post-Bretton-Woods sample from 1976:1 to 1998:12, and Panel c. for the post-euro sample from 1999:1 to 2013:3. In each panel, the first row reports mean returns to currency portfolios indexed by $j = 1, 2, \cdots, 5$, with higher j indicates higher interest rate for the carry trade portfolios and higher past excess return for the momentum portfolios; the second row reports mean returns to the zero-cost currency strategies long $j = 2, 3, \cdots, 5$-short $j = 1$; the third row reports the t-ratio for the above zero cost strategies based on Newey-West standard errors with optimal number of lags [see Newey and West (1987) and Andrews (1991).]; and the last row reports the annualized Sharpe ratio of these zero-cost currency strategies. The mean return and standard deviation are expressed in terms of percentage per annum. The Sharpe ratio is annualized.

	Carry					Momentum				
	1L	2	3M	4	5H	1L	2	3M	4	5H
	a. 1921:1-1936:12					a. 1921:1-1936:12				
j	-2.16	—	0.29	—	4.50	-3.93	—	-0.56	—	3.52
j-1	—	—	2.46	—	6.66	—	—	3.37	—	7.45
tstat	—	—	0.76	—	1.98	—	—	1.19	—	1.28
S.R.	—	—	0.17	—	0.37	—	—	0.19	—	0.31
	b. 1976:1-1998:12					b. 1976:1-1998:12				
j	-1.72	0.76	0.68	2.66	5.03	-2.27	1.06	3.10	2.57	3.11
j-1	—	2.62	2.40	4.39	6.75	—	3.34	5.38	4.85	5.39
tstat	—	2.46	1.85	2.48	4.01	—	2.20	3.46	3.70	3.66
S.R.	—	0.52	0.39	0.53	0.79	—	0.52	0.76	0.60	0.61
	c. 1999:1-2013:3					c. 1999:1-2013:3				
j	0.65	0.35	2.16	3.36	6.98	2.34	2.30	2.52	4.75	1.99
j-1	—	-0.30	1.51	2.72	6.34	—	-0.04	0.18	2.42	-0.35
tstat	—	-0.13	0.67	1.22	2.80	—	-0.05	0.14	1.16	-0.23
S.R.	—	-0.04	0.19	0.31	0.60	—	-0.01	0.02	0.29	-0.04
	d. Full sample					d. Full sample				
j	-1.21	—	0.96	—	5.39	-1.53	—	1.84	—	2.93
j-1	—	—	2.18	—	6.61	—	—	3.38	—	4.46
tstat	—	—	1.71	—	5.21	—	—	2.93	—	2.26
S.R.	—	—	0.23	—	0.52	—	—	0.30	—	0.30

Table 3: Carry vs Appreciation.
This table presents the Carry Component and the Appreciation Component in the Mean Excess Return of long-short Carry (upper panel) and Momentum Strategies (lower panel). Column "Z" denote the mean excess return (% per annum), column "C" denotes the mean interest rate differential or carry component (% per annum), and column "A" denotes the mean spot exchange rate return or appreciation (% per annum). The columns "C/Z" and "A/Z" reports the portions of the carry component and the appreciation component in the mean excess return respectively.

	Carry				
	Z	C	A	C/Z	A/Z
Interwar	6.66	5.41	1.38	81%	21%
Post Bretton Woods	6.75	9.98	-3.24	148%	-48%
Euro Era	6.34	5.44	0.90	86%	14%

	Momentum				
	Z	C	A	C/Z	A/Z
Interwar	7.45	1.11	6.24	15%	84%
Post Bretton Woods	5.39	2.34	3.04	43%	57%
Euro Era	-0.35	0.81	-1.16	-231%	331%

Table 4: Distribution of **Average Excess Returns** Implied from Empirical Likelihoods.
This table reports key statistics of the distribution of average excess returns to the carry trade and momentum based on empirical likelihood estimates under the null hypothesis that the true mean return to the carry trade or momentum is zero. The distribution of average returns are obtained by resampling the actual data with replacement to generate bootstrap sample of the same size as the actual sample and compute the average in each bootstrap sample. The numbers reported in this table include the actual sample average return, and the mean, median, 2.5% percentile, 97.5% percentile, the probability that the average return is no smaller than of the distribution for the average return, and the probability that the average return is no larger than zero. Panel a1 presents the distribution for average carry trade returns based on empirical likelihood such that mean carry trade return is zero; Panel a2 presents the distribution for average momentum returns based on the same EL as in Panel a1. Separately, Panel b1 presents the distribution for average carry trade returns based on empirical likelihood such that mean momentum return is zero while Panel b2 presents the distribution for average momentum returns based on the same EL as in Panel b1. In each panel, we report results for each of the three subsamples and the full sample.

	Data	EL implied Distribution for Average Carry Return						Data	EL implied Distribution for Average Mom. Return					
	$\overline{Z}$	Mean	Med	2.5%	97.5%	P[$\geq \overline{Z}$]	P[≤ 0]	$\overline{Z}$	Mean	Med	2.5%	97.5%	P[$\geq \overline{Z}$]	P[≤ 0]
	a1. $Distr(\overline{Z}^{carry})$ implied from $\overline{Z}^{carry} = 0$							a2. $Distr(\overline{Z}^{mom})$ implied from $\overline{Z}^{carry} = 0$						
1921:1-1936:12	6.66	-0.02	0.04	-9.78	9.50	8.09	49.69	7.45	7.15	7.22	-5.84	20.02	48.38	14.24
1976:1-1998:12	6.75	-0.02	0.01	-4.17	4.07	0.01	49.82	5.39	5.00	5.02	0.78	9.18	42.92	1.07
1999:1-2013:3	6.34	-0.08	-0.03	-6.41	5.90	1.74	50.52	-0.35	0.85	0.84	-4.61	6.47	66.54	37.84
Full Sample	**6.61**	**0.00**	**0.02**	**-4.07**	**3.88**	**0.05**	**49.51**	**4.46**	**4.46**	**4.46**	**0.44**	**8.50**	**49.85**	**1.53**
	b1. $Distr(\overline{Z}^{carry})$ implied from $\overline{Z}^{mom.} = 0$							b2. $Distr(\overline{Z}^{mom.})$ implied from $\overline{Z}^{mom} = 0$						
1921:1-1936:12	6.66	6.54	6.60	-2.33	15.41	49.35	7.52	7.45	0.02	0.18	-12.31	11.71	10.90	48.68
1976:1-1998:12	6.75	5.45	5.46	1.80	9.06	24.35	0.21	5.39	0.01	0.03	-3.90	3.87	0.33	49.45
1999:1-2013:3	6.34	6.31	6.32	0.87	11.77	49.72	1.26	-0.35	-0.02	-0.02	-5.01	5.00	54.98	50.37
Full Sample	**6.61**	**6.12**	**6.12**	**2.59**	**9.56**	**32.67**	**0.04**	**4.46**	**0.01**	**0.02**	**-4.38**	**4.33**	**2.17**	**49.65**

Table 5: Sample v.s. Rare Disaster Moments for the **Realized Excess Return**. This table contrasts sample moments with the moments implied from a rare disaster distribution of excess returns. The rare disaster distribution is estimated using Empirical Likelihood methods under the null that the true mean excess return is zero.

	Carry					
	1921:1-1936:12		1976:1-1998:12		1999:1-2013:3	
	Sample	EL	Sample	EL	Sample	EL
Mean	6.66	0.92	6.75	0.17	6.34	-0.22
Median	2.84	2.29	8.85	4.98	9.11	4.43
StD	18.14	18.76	8.52	9.86	10.51	11.76
Skew	-0.58	-1.24	-0.90	-1.15	-0.73	-1.07
KurtX	9.11	9.00	2.62	2.48	2.68	2.91

	Momentum					
	1921:1-1936:12		1976:1-1998:12		1999:1-2013:3	
	Sample	EL	Sample	EL	Sample	EL
Mean	7.45	-1.50	5.39	0.37	-0.35	-0.68
Median	1.10	0.42	5.61	2.76	0.35	-0.22
StD	23.66	24.40	8.89	9.26	9.52	9.47
Skew	0.25	-0.91	0.01	-0.49	0.28	0.18
KurtX	10.36	10.23	2.62	2.48	1.90	1.62

Table 6: Volatility Beta.

This table reports volatility beta's of Portfolios sorted by carry and momentum respectively, i.e. the exposure of portfolio excess return to the innovations to foreign exchange market volatility measure as in Menkoff et al. (2012) while the exposure to dollar risk is controlled. Newey-West standard errors with optimally chosen lags are presented in parentheses [see Newey and West (1987) and Andrews (1991)]. We also report the time series R-squared.

	Carry						Momentum					
	1L	2	3M	4	5H	HML	1L	2	3M	4	5H	HML
	a. 1921:1-1936:12						a. 1921:1-1936:12					
β_{vol}	0.85	—	0.69	—	-1.53	-2.38	0.03	—	0.47	—	-2.35	-2.38
s.e.	(1.05)	—	(0.97)	—	(1.30)	(2.17)	(1.78)	—	(0.81)	—	(2.91)	(4.48)
R^2	0.62	—	0.63	—	0.68	0.03	0.74	—	0.70	—	0.36	0.20
	b. 1976:1-1998:12						b. 1976:1-1998:12					
β_{vol}	2.92	0.28	0.04	-1.66	-1.60	-4.53	0.82	-1.00	1.60	-0.53	-0.43	-1.25
s.e.	(0.71)	(0.60)	(0.56)	(0.94)	(0.88)	(1.30)	(0.94)	(0.70)	(0.61)	(1.06)	(0.82)	(1.66)
R^2	0.82	0.86	0.89	0.75	0.73	0.06	0.72	0.86	0.90	0.81	0.68	0.01
	c. 1999:1-2013:3						c. 1999:1-2013:3					
β_{vol}	6.20	0.02	-0.05	-2.73	-3.44	-9.65	-2.94	-0.35	0.58	-0.33	3.14	6.07
s.e.	(2.31)	(2.11)	(0.74)	(1.03)	(1.42)	(3.04)	(1.59)	(0.95)	(2.24)	(1.48)	(3.12)	(4.57)
R^2	0.60	0.80	0.84	0.83	0.81	0.28	0.74	0.82	0.79	0.79	0.69	0.05
	d. Full sample						d. Full sample					
β_{vol}	2.13	—	0.21	—	-1.67	-3.80	0.55	—	0.35	—	-1.42	-1.97
s.e.	(1.00)	—	(0.69)	—	(1.01)	(1.81)	(1.03)	—	(0.58)	—	(1.90)	(2.72)
R^2	0.67	—	0.76	—	0.72	0.06	0.68	—	0.78	—	0.51	0.09

Table 7: Fama-McBeth Estimates of Risk Prices.
This table reports prices of the dollar risk and the volatility risk estimated via the Fama-McBeth procedure. Standard errors with Shanken's adjustment [see Shanken (1992)], and Newey-West standard errors with optimally chosen lags [see Newey and West (1987) and Andrews (1991)] are presented in the parentheses. We also report the dollar risk premium and volatility risk premium respectively in the row "$\lambda\beta_{HML}$". The column "χ^2_{SH}" reports the χ^2 statistics based on Shanken's adjustment and the column "χ^2_{NW}" reports the χ^2 statistics based on Newey-West procedure with optimal number of lags according to Andrews (1991). The statistic $||\alpha||$, expressed in terms of percentage per annum, is calculated as the cross-sectional standard deviation of pricing errors under the null of zero mean. Panel a. reports results for the interwar sample from 1921:1 to 1936:12, Panel b. for the post-Bretton-Woods sample from 1976:1-1998:12, Panel c. for the post-euro sample from 1999:1 to 2013:3, and Panel d. for the full sample combining all the time series. The cross section analysis for the full sample only includes three portfolios $j = 1, 3, 5$ in the period from 1976:1 to 2013:3.

	Carry				Momentum			
a. 1921:1-1936:12								
	DOL	VOL	χ^2_{SH}	χ^2_{NW}	DOL	VOL	χ^2_{SH}	χ^2_{NW}
λ	0.80	-2.31	0.79	0.43	-1.86	-1.93	1.12	0.70
(SH)	(3.02)	(2.22)	[0.37]	[0.51]	(3.21)	(1.77)	[0.29]	[0.40]
(NW)	(3.36)	(1.68)			(3.40)	(1.35)		
			$\|\|\alpha\|\|$				$\|\|\alpha\|\|$	
$\lambda\beta_{HML}$	0.18	5.49	0.91		1.65	4.61	1.10	
b. 1976:1-1998:12								
	DOL	VOL	χ^2_{SH}	χ^2_{NW}	DOL	VOL	χ^2_{SH}	χ^2_{NW}
λ	1.47	-1.28	9.40	4.29	1.57	-0.33	14.02	12.03
(SH)	(1.83)	(0.49)	[0.02]	[0.23]	(1.84)	(0.40)	[0.00]	[0.01]
(NW)	(1.87)	(0.37)			(1.89)	(0.39)		
			$\|\|\alpha\|\|$				$\|\|\alpha\|\|$	
$\lambda\beta_{HML}$	-0.22	5.75	0.91		-0.13	0.41	1.98	
c. 1999:1-2013:3								
	DOL	VOL	χ^2_{SH}	χ^2_{NW}	DOL	VOL	χ^2_{SH}	χ^2_{NW}
λ	2.75	-0.41	7.14	7.06	2.78	-0.09	2.78	2.59
(SH)	(2.30)	(0.25)	[0.07]	[0.07]	(2.30)	(0.41)	[0.43]	[0.46]
(NW)	(2.38)	(0.25)			(2.38)	(0.38)		
			$\|\|\alpha\|\|$				$\|\|\alpha\|\|$	
$\lambda\beta_{HML}$	1.18	3.92	1.58		-0.02	-0.56	0.98	
d. Full Sample								
	DOL	VOL	χ^2_{SH}	χ^2_{NW}	DOL	VOL	χ^2_{SH}	χ^2_{NW}
λ	2.11	-1.65	1.38	0.76	0.63	-1.75	—	5.35
(SH)	(1.38)	(0.61)	[0.24]	[0.38]	(1.38)	(1.15)	—	[0.02]
(NW)	(1.53)	(0.47)			(1.51)	(0.76)		
			$\|\|\alpha\|\|$				$\|\|\alpha\|\|$	
$\lambda\beta_{HML}$	0.33	6.29	0.42		-0.27	3.45	1.33	

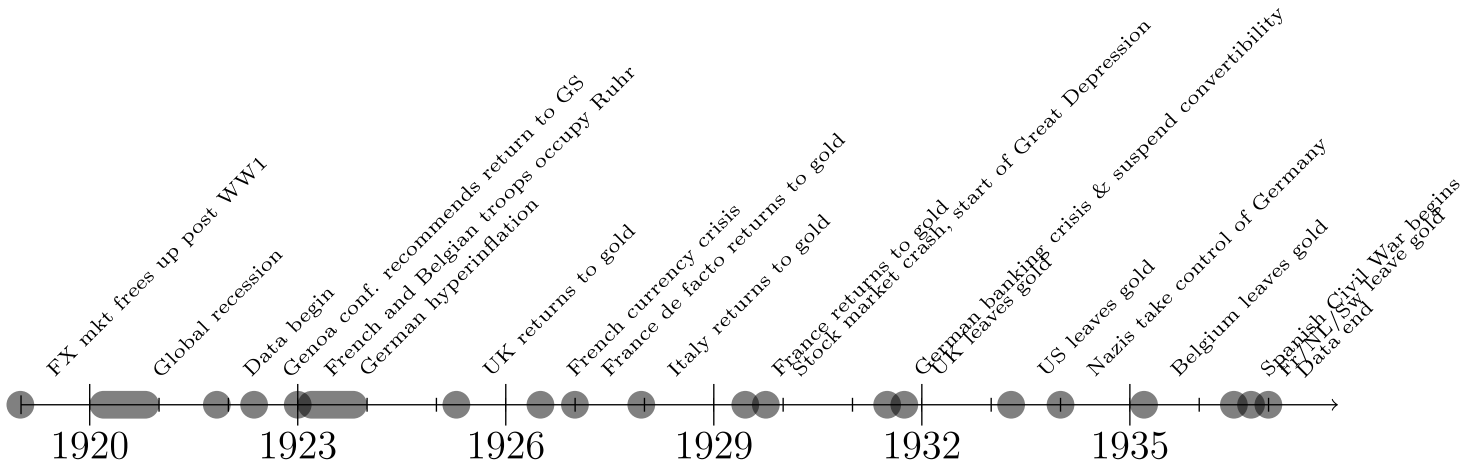
Table 8: GARCH-based FX Volatility Risk Premium in the Interwar Period.
This table presents Fama-MacBeth two-stage estimates for the GARCH-based FX volatility risk beta and the corresponding risk premium for the interwar sample spanning from 1921:1 to 1936:12. The standard errors, reported in parentheses, are computed based on the Newey-West procedure for the beta and lambda estimates and are based on bootstrapping for the risk premium estimates.

a. GARCH-based FX Volatility Beta

	1L	2	3	4	5H
β_{VOL}	7.23	—	-1.35	—	-5.88
s.e.	(3.19)	—	(2.52)	—	(2.79)
R2	0.65	—	0.63	—	0.69

b. Risk Premium for Carry HML

β_{DOL}	λ_{DOL}	rp_{DOL}	β_{VOL}	λ_{VOL}	rp_{VOL}
0.24	0.98	0.24	-13.11	-0.47	6.11
(0.30)	(3.02)	(1.11)	(5.35)	(0.35)	(3.88)



Three regimes of Interwar period:

- Free float: 1920 - December 1927 (73 observations in sample)
- Interwar Gold Standard: January 1928 - August 1931 (39 observations)
- Managed float: September 1931 - 1936 (63 observations)

Figure 1: Chronology of the Interwar Period.

1

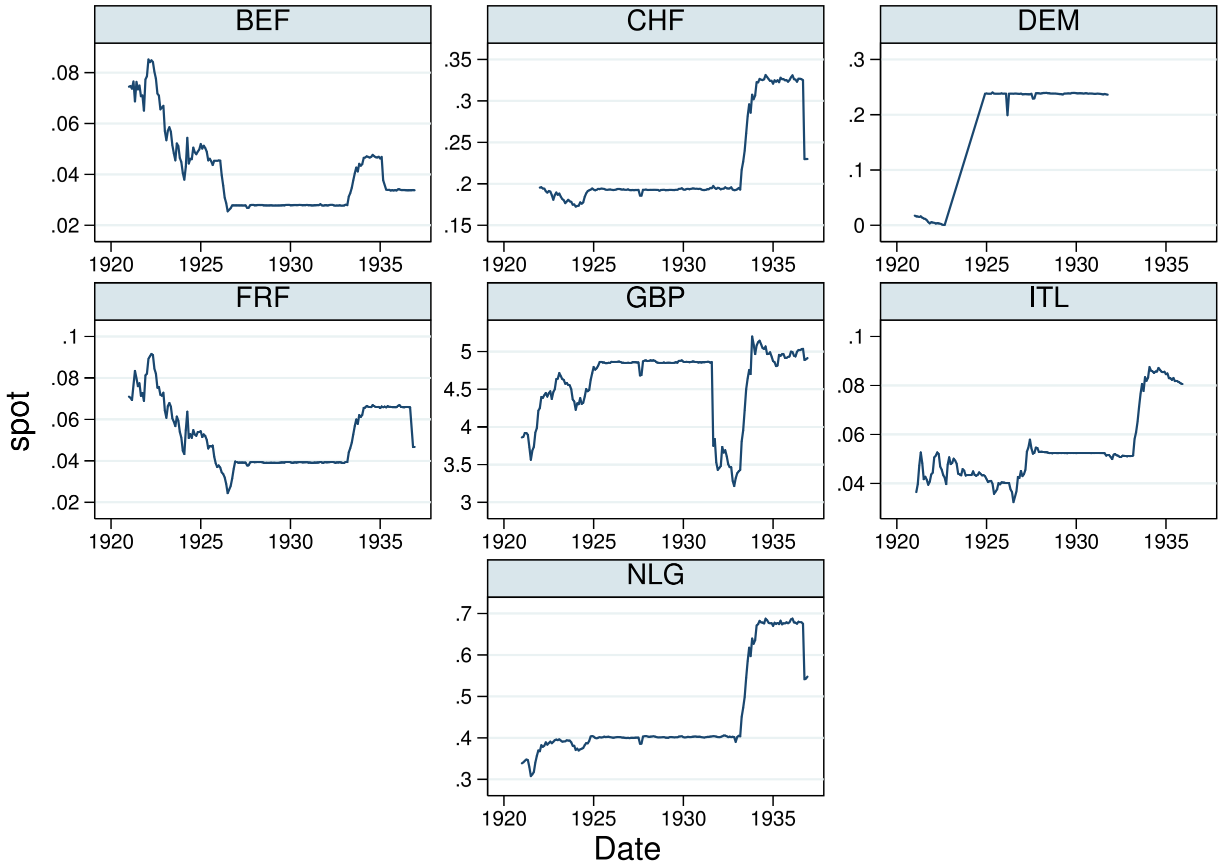


Figure 2: Interwar Exchange Rates against the US dollar.
The figure shows the dynamics of the spot exchange rate, in terms of the US dollar price of one foreign currency unit, of the seven european currencies in the interwar era, i.e. 1921:1-1936:12.

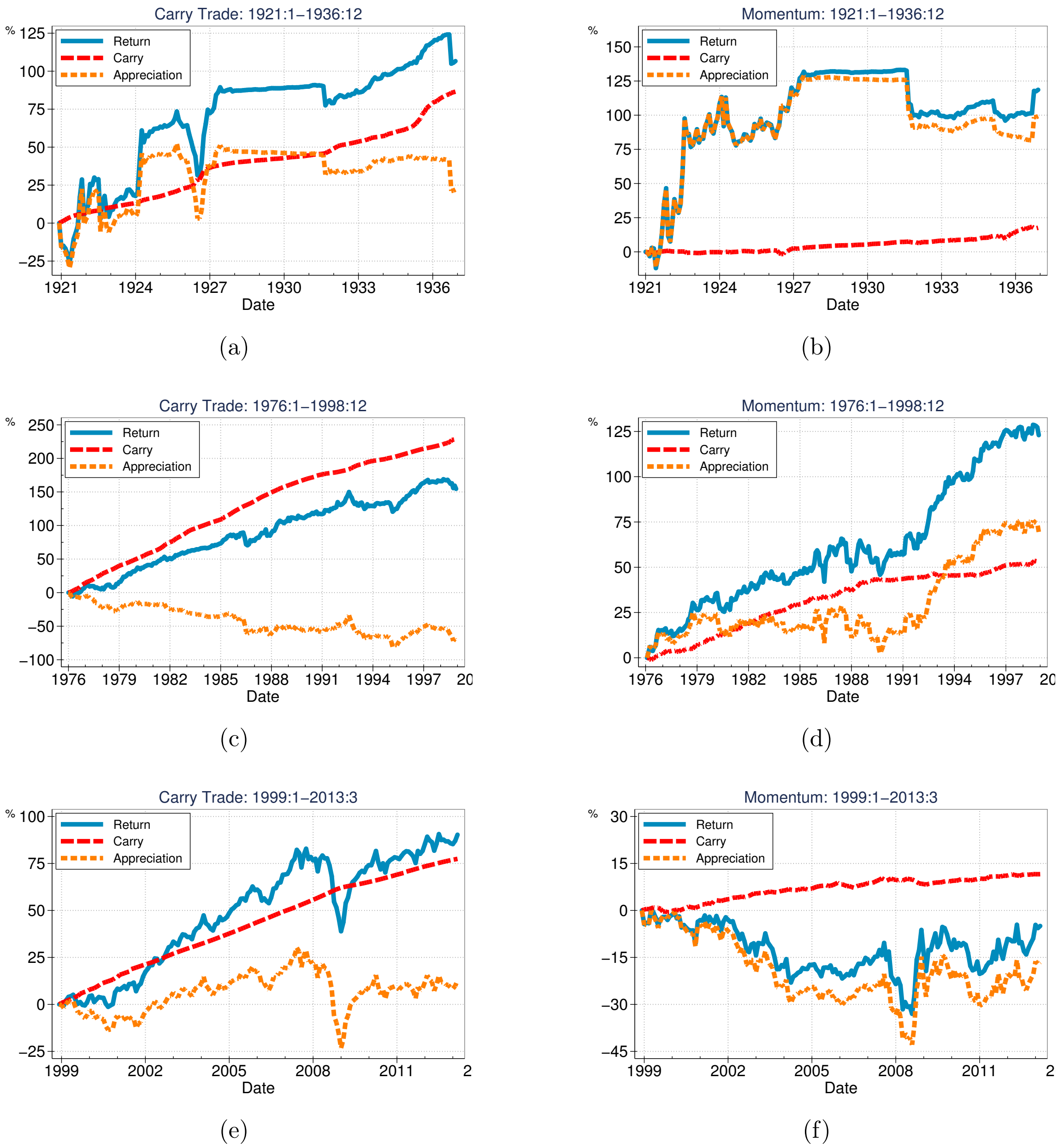
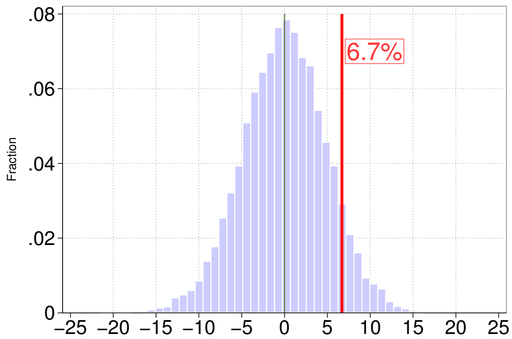
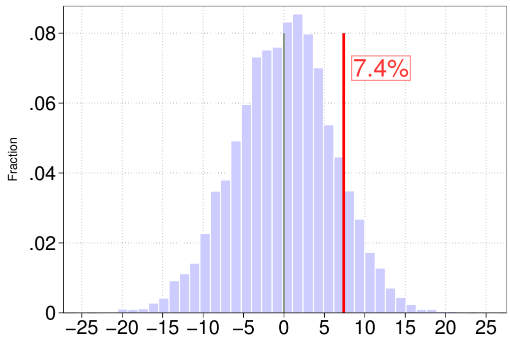


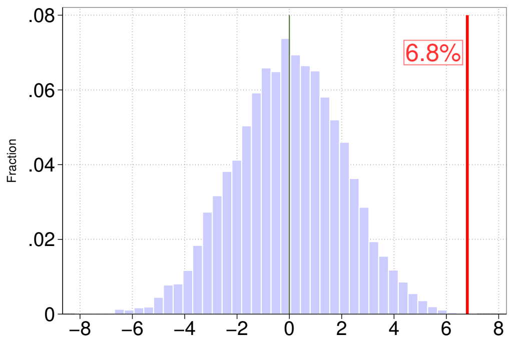
Figure 3: Cumulative Returns of the Carry and Momentum Strategies.
This figure shows the simple cumulative excess returns of the long-short carry strategy and the long-short momentum strategy, along with the simple interest cumulations and simple cumulative exchange rate returns.



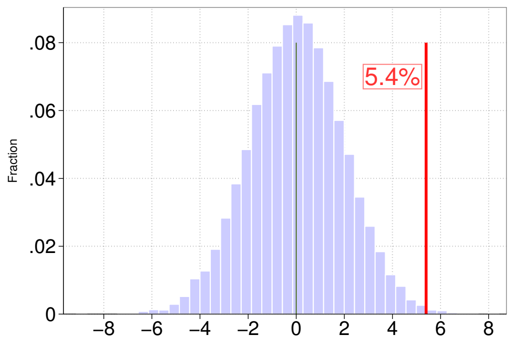
(a) Carry: 1921:1-1936:12



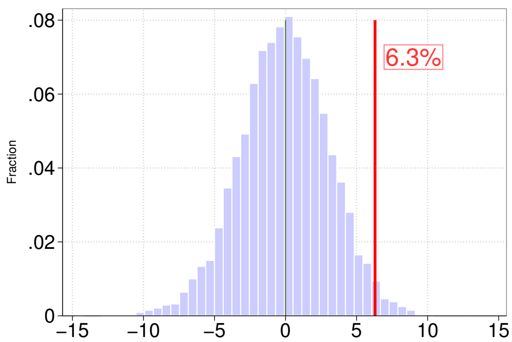
(b) MOM:1921:1-1936:12



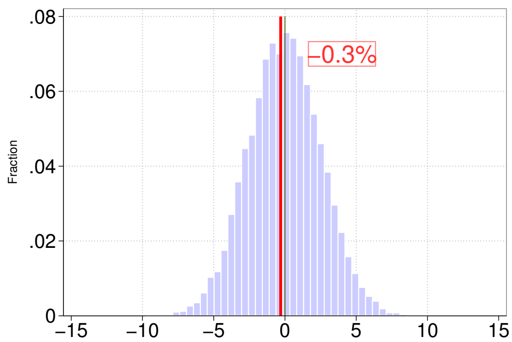
(c) Carry: 1976:1-1998:12



(d) MOM: 1976:1-1998:12

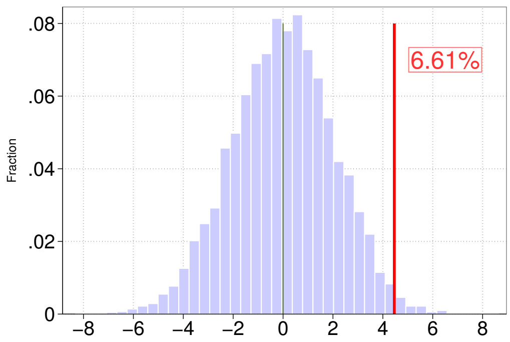


(e) Carry: 1999:1-2013:3

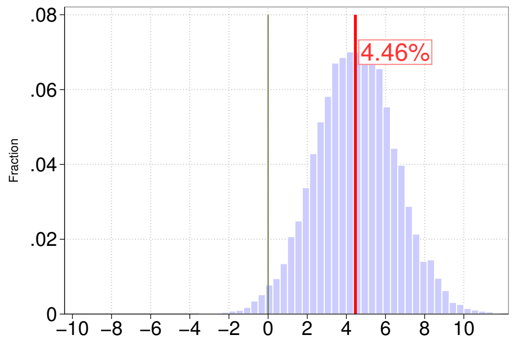


(f) MOM: 1999:1-2013:3

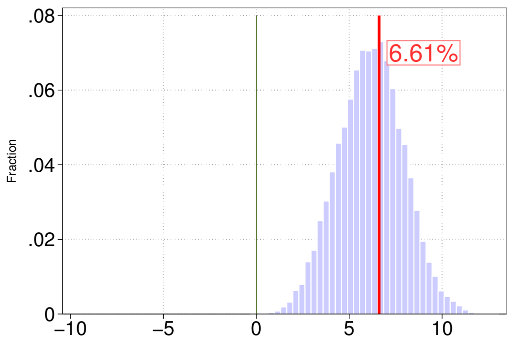
Figure 4: Distribution for the Average Excess Return given zero true mean.



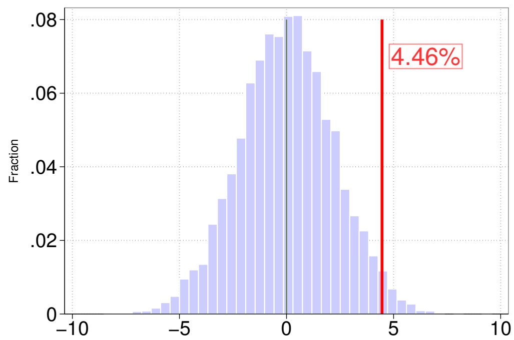
(a) Distr($\overline{Z}^{carry}$) under H_0 : $\overline{Z}^{carry} = 0$



(b) Distr($\overline{Z}^{mom}$) under H_0 : $\overline{Z}^{carry} = 0$

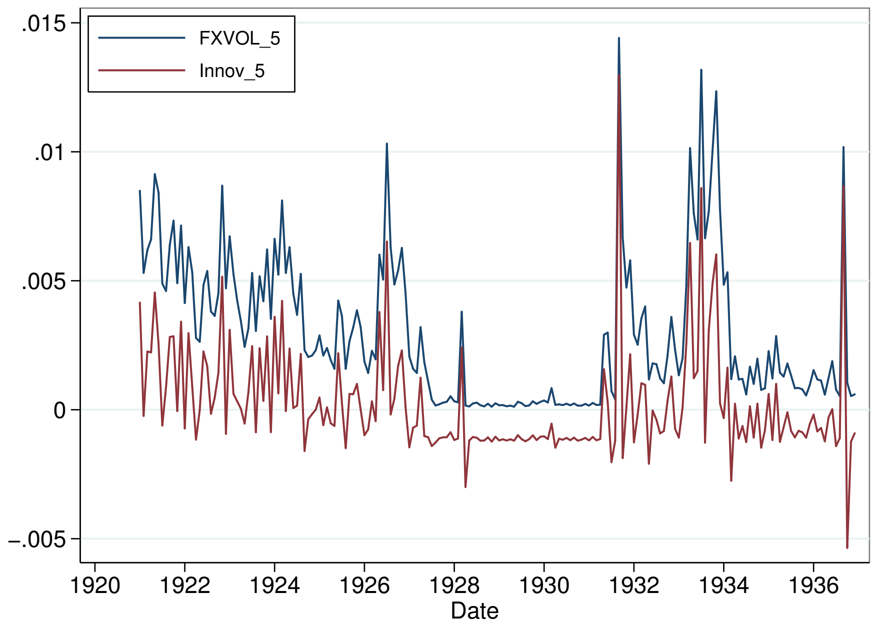


(c) Distr($\overline{Z}^{carry}$) under H_0 : $\overline{Z}^{mom} = 0$

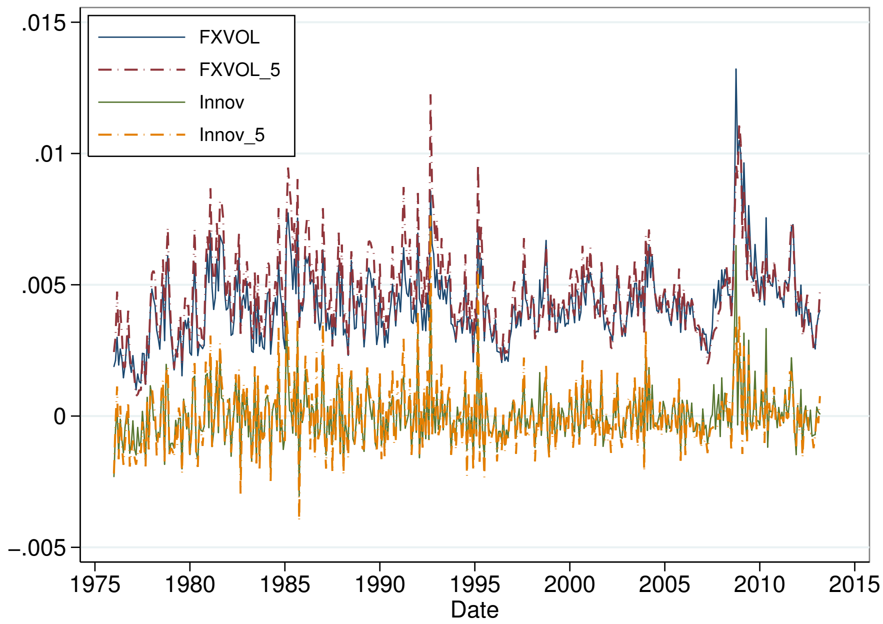


(d) Distr($\overline{Z}^{mom}$) under H_0 : $\overline{Z}^{mom} = 0$

Figure 5: Full-sample implied Distribution for the Average Excess Return given zero true mean of either carry trade or momentum.



(a) Interwar Sample



(b) Modern Sample

Figure 6: Global FX Volatility and its Innovations.
This upper panel shows the Global FX volatility measure using daily exchange rate returns of only five major currencies (CHF, DEM, GBP, FRF, ITL) and its innovations implied by an AR(1) model. The lower panel contrasts the Global FX volatility measure using daily exchange rate returns of only five major currencies (CHF, DEM, GBP, FRF, ITL) and that using daily exchange rate returns of all developed countries.

Appendices

A Additional Tables and Figures

In this section, we present tables and figures that aim to complement the point outlined in the paper.

Table A.1 shows that although our interwar data contains a smaller number of currencies than the modern data, the size of each portfolios are similar. In detail, each currency portfolios are more likely to include two to three currencies.

Figure A.1 illustrates that the composition of currency portfolios in each sample period. We can see that in the interwar sample, the carry strategy tends to long the Italian lira, the French franc, and the German mark while short the Swiss franc and the Belgium franc.

Figure A.2 as a companion to Table 5 demonstrate how the maximum empirical likelihood procedure attempts to re-weight the sample observations in order to restrict the mean to be zero. Due to the concentration of extreme exchange rate movements in the interwar period, the empirical likelihood maximization shifts the distribution of realized payoff to the less extent to the left for the interwar sample than for the modern samples.

Finally, we evaluate the significance of volatility risk premium on the basis of rare disaster distribution with zero mean excess return to the carry or momentum strategy respectively. Specifically, we generate 10,000 artificial sample of excess returns by resampling each payoff based on empirical likelihood estimates separately. For each artificial sample, we reproduce estimation of the volatility risk premium using the artificial time series data. In this way, we obtain the empirical distribution of volatility risk premium under the null that the corresponding payoff is generated from a rare disaster distribution with mean of zero.

The results, presented in Table A.2, indicate that if the return to the carry trade (momentum) strategy were generated by a rare disaster distribution with mean of zero, then it would be very unlikely that empiricists will be able to obtains a volatility risk premium at least as large as what is actually obtained.

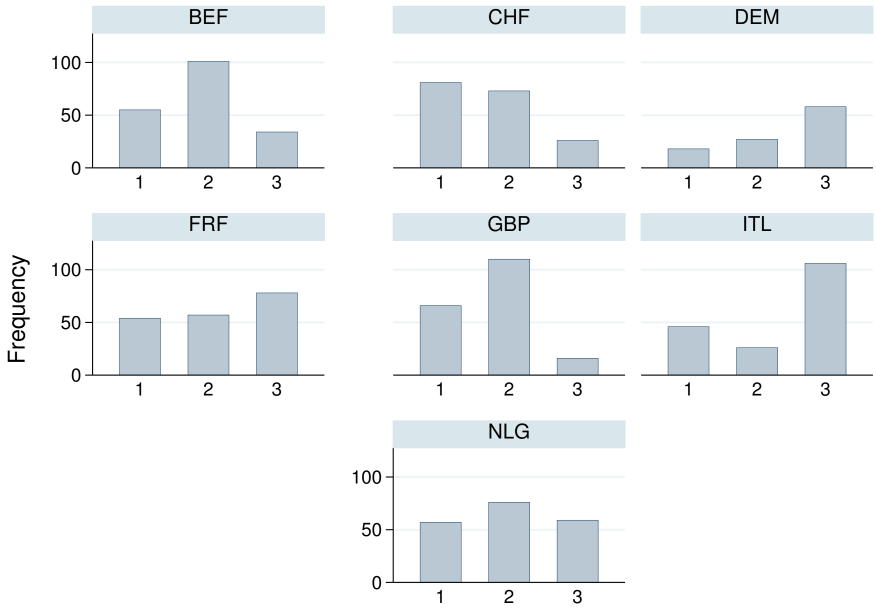
Table A.1: The Number of Currencies in Each Portfolio.
This table tabulates the frequency of the number of currencies in each portfolio in terms of # of observations (months). The first column shows the number of currencies and other columns show the frequency in each subsample. Panel a: the interwar sample from 1921:1-1936:12. Panel b: the post Bretton Woods sample from 1976:1-1998:12. Panel c: the post euro sample from 1999:1-2013:3. The table illustrates that in the interwar sample and the post euro sample, each portfolio typically contains two currencies and in the post Bretton, each portfolio is typically allocated with three currencies.

	Carry					Momentum				
Portfolio	1L	2	3M	4	5H	1L	2	3M	4	5H
# of currency					a. 1921:1-1936:12					
1	7		12		7	4		12		5
2	185		86		185	187		89		186
3	0		90		0	0		90		0
4	0		4		0	0		0		0
Total			192					191		
# of currency					b. 1976:1-1998:12					
1	0	1	1	106	0	0	0	0	107	0
2	0	105	27	168	0	0	107	29	167	0
3	273	168	247	0	275	274	167	245	0	274
4	1	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0	0	0	0	0	0
Total			275					274		
# of currency					c. 1999:1-2013:3					
1	0	0	4	1	0	0	0	0	2	0
2	171	167	167	170	171	171	171	171	169	171
3	0	4	0	0	0	0	0	0	0	0
Total			171					171		

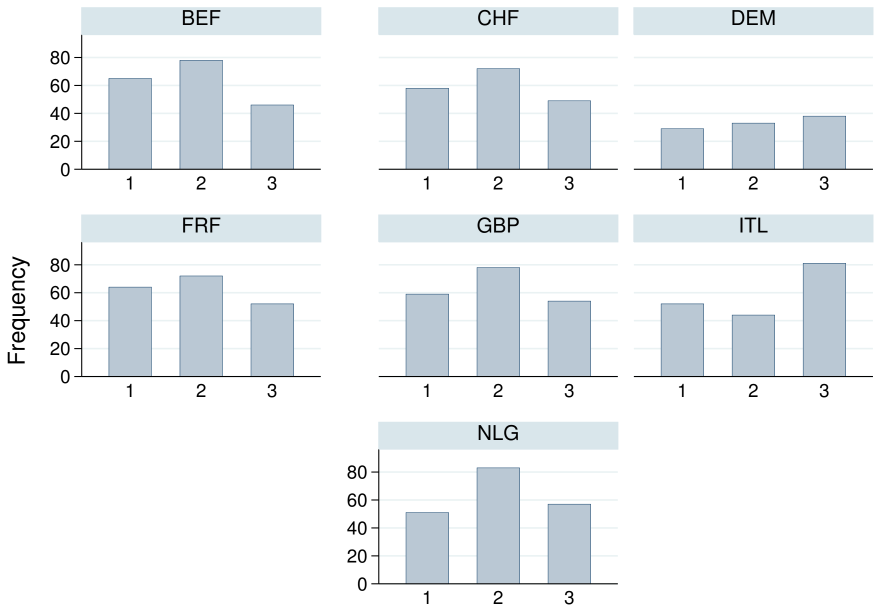
Table A.2: Distribution of **FX Volatility Risk Premium** Implied from Empirical Likelihoods.

This table reports key statistics of the distribution of FX Volatility risk premium estimated using the cross section of the carry trade portfolios or momentum portfolios based on empirical likelihood estimates under the null hypothesis that the true mean return to the carry trade or momentum HML strategy is zero. The distribution of volatility risk premium are obtained by resampling the actual data with replacement to generate bootstrap sample of the same size as the actual sample and compute the volatility risk premium in each bootstrap sample via the Fama-MacBeth procedure. The numbers reported in this table include the actual sample volatility risk premium, and the mean, median, 2.5% percentile, 97.5% percentile of the, the probability that the volatility risk premium is no smaller than of the actual sample volatility risk premium, and the probability that the volatility risk premium is no larger than zero, according to the distribution of the volatility risk premium. Panel a1 presents the distribution for volatility risk premium estimated using carry trade portfolios based on empirical likelihood such that mean carry trade return is zero; Panel a2 presents the distribution for volatility risk premium estimated using carry trade portfolios based on the same EL as in Panel a1. Separately, Panel b1 presents the distribution for volatility risk premium estimated using carry trade portfolios based on empirical likelihood such that mean momentum return is zero while Panel b2 presents the distribution for volatility risk premium estimated using momentum portfolios based on the same EL as in Panel b1. In each panel, we report results for each of the three subsamples and the full sample.

	Data	EL implied distribution for volatility risk premium						Data	EL implied distribution for volatility risk premium					
	$\overline{rp}$	Mean	Med	2.5%	97.5%	$P[\geq \overline{rp}]$	$P[\leq 0]$	$\overline{rp}$	Mean	Med	2.5%	97.5%	$P[\geq \overline{rp}]$	$P[\leq 0]$
		a1. $Distr(\overline{rp}^{carry})$ implied from $\overline{Z}^{carry} = 0$							a2. $Distr(\overline{rp}^{mom.})$ implied from $\overline{Z}^{carry} = 0$					
1921:1-1936:12	5.49	-0.28	-0.14	-8.33	7.48	6.33	52.06	4.61	3.08	2.43	-4.54	13.77	29.45	20.69
1976:1-1998:12	5.78	0.41	0.45	-3.34	3.97	0.14	40.02	0.41	0.70	0.31	-0.97	3.97	46.49	31.66
1999:1-2013:3	3.92	-1.08	-1.09	-6.29	3.89	2.45	65.84	-0.56	1.43	1.22	-3.16	6.84	78.21	30.46
Full sample	**6.29**	**-0.16**	**-0.10**	**-4.10**	**3.47**	**0.03**	**52.13**	**3.45**	**3.20**	**3.05**	**-0.43**	**7.95**	**42.46**	**5.48**
		b1. $Distr(\overline{rp}^{carry})$ implied from $\overline{Z}^{mom} = 0$							b2. $Distr(\overline{rp}^{mom.})$ implied from $\overline{Z}^{mom.} = 0$					
1921:1-1936:12	6.73	4.09	3.70	-2.37	12.61	24.68	13.51	4.61	0.35	0.36	-8.82	9.61	14.11	44.90
1976:1-1998:12	5.80	4.29	4.30	0.76	7.91	20.28	0.49	0.41	-0.63	-0.51	-3.50	1.93	16.68	70.86
1999:1-2013:3	3.92	3.17	3.12	-1.29	7.96	36.95	9.29	-0.56	0.39	0.10	-3.39	5.07	69.07	46.06
Full sample	**6.46**	**5.05**	**5.18**	**0.65**	**8.61**	**23.47**	**0.90**	**3.45**	**0.47**	**0.47**	**-3.13**	**4.04**	**4.85**	**38.98**

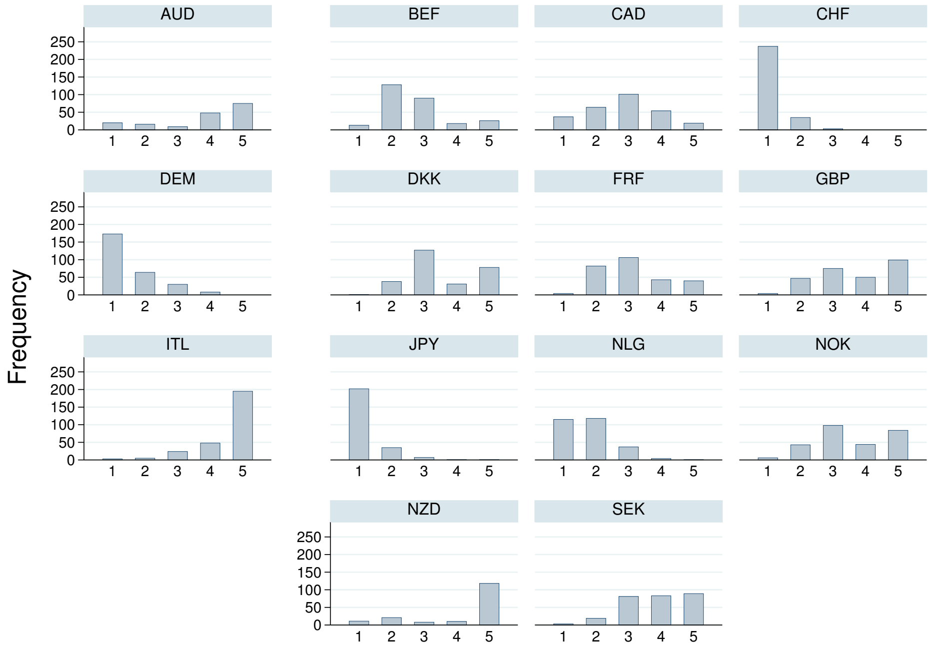


(a) Carry: 1921:1-1936:12

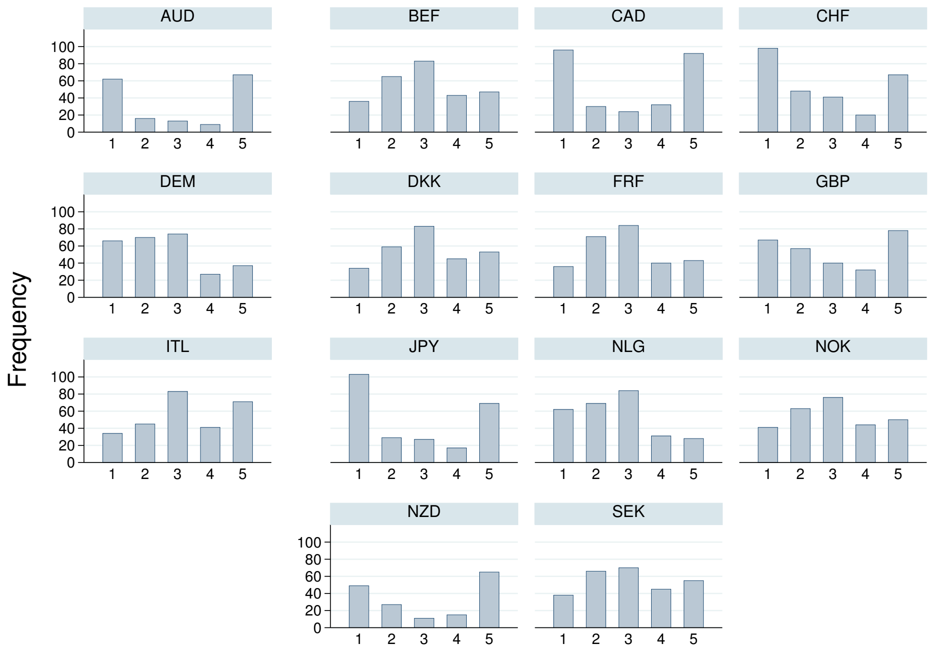


(b) MOM: 1921:1-1936:12

Figure A.1: This figure plots the frequency of each currency being sorted in each portfolio. Panel (a): Carry trade portfolios in the interwar sample; Panel (b) Currency momentum portfolios in the interwar sample...**Continued on the next page**...

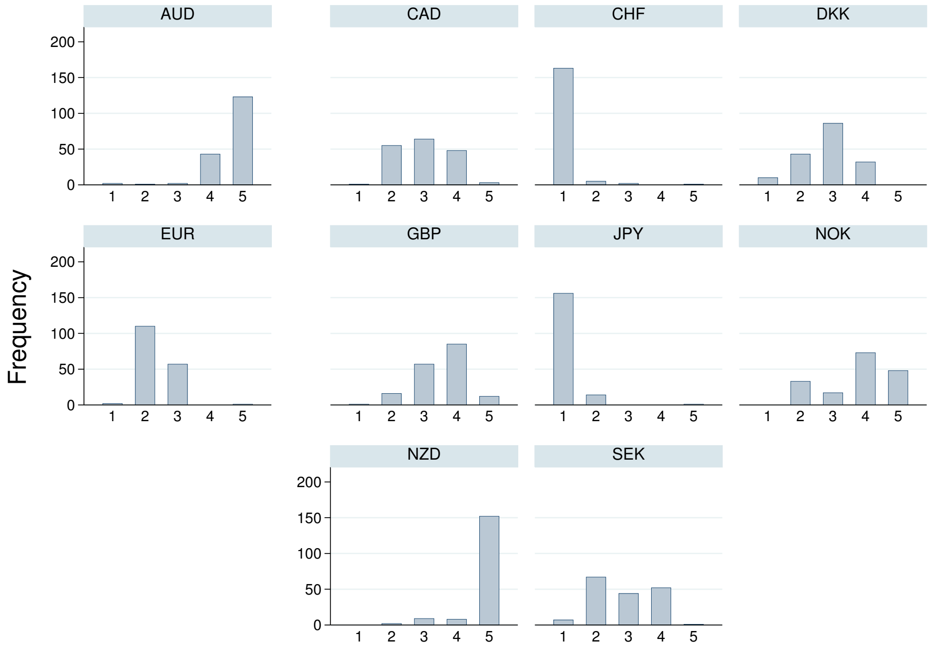


(c) Carry: 1976:1-1998:12

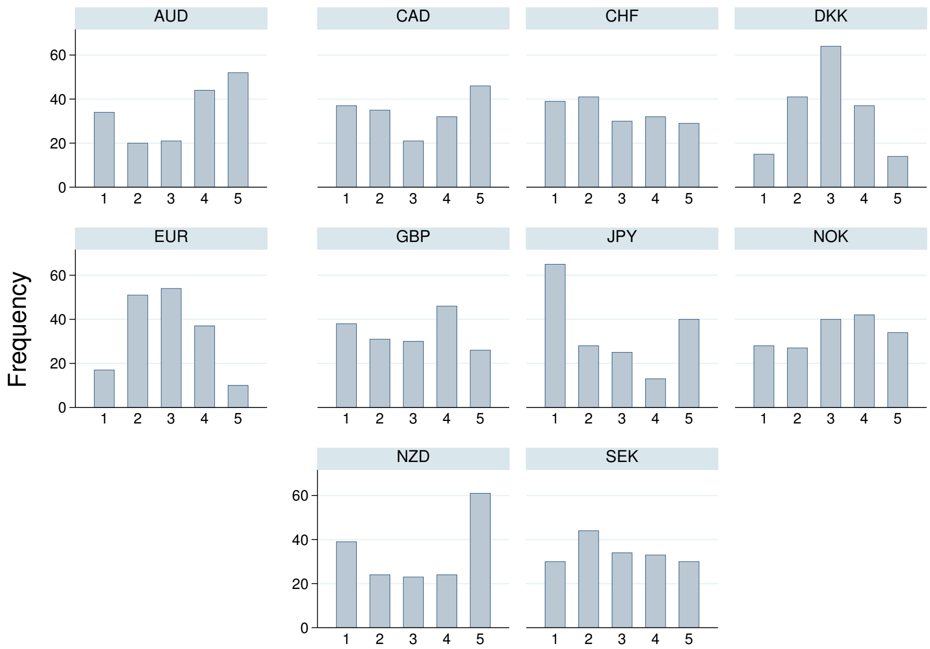


(d) MOM: 1976:1-1998:12

Figure A.1: ...**Continued from the previous page**...Panel (c): Carry trade portfolios in the post Bretton Woods sample; Panel (d) Currency momentum portfolios in the post Bretton Woods sample...**Continued on the next page**...

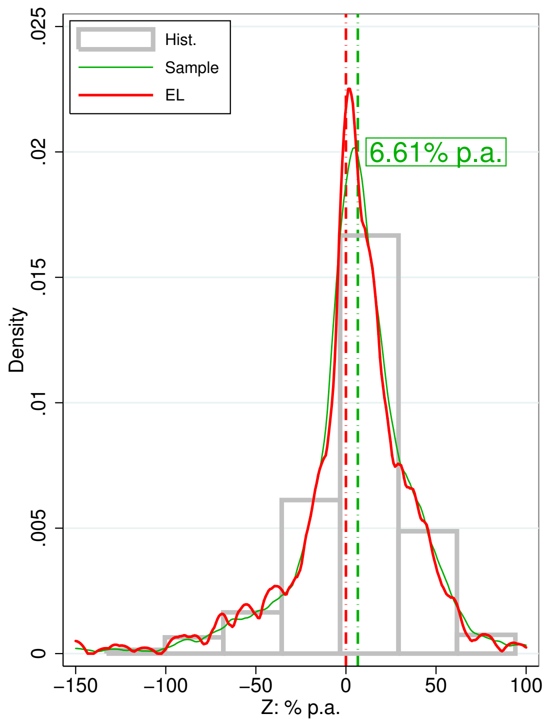


(e) Carry: 1999:1-2013:3

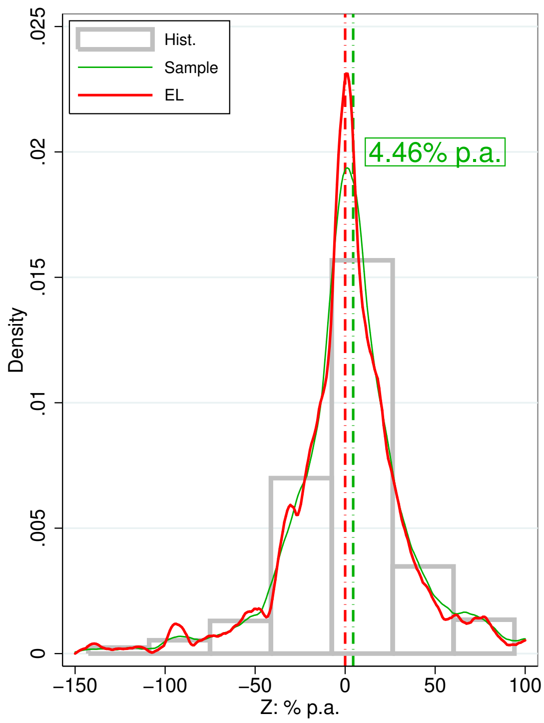


(f) MOM: I1999:1-2013:3

Figure A.1: ...**Continued from the previous page**...Panel (e): Carry trade portfolios in the post euro sample; Panel (f) Currency momentum portfolios in the post euro sample.

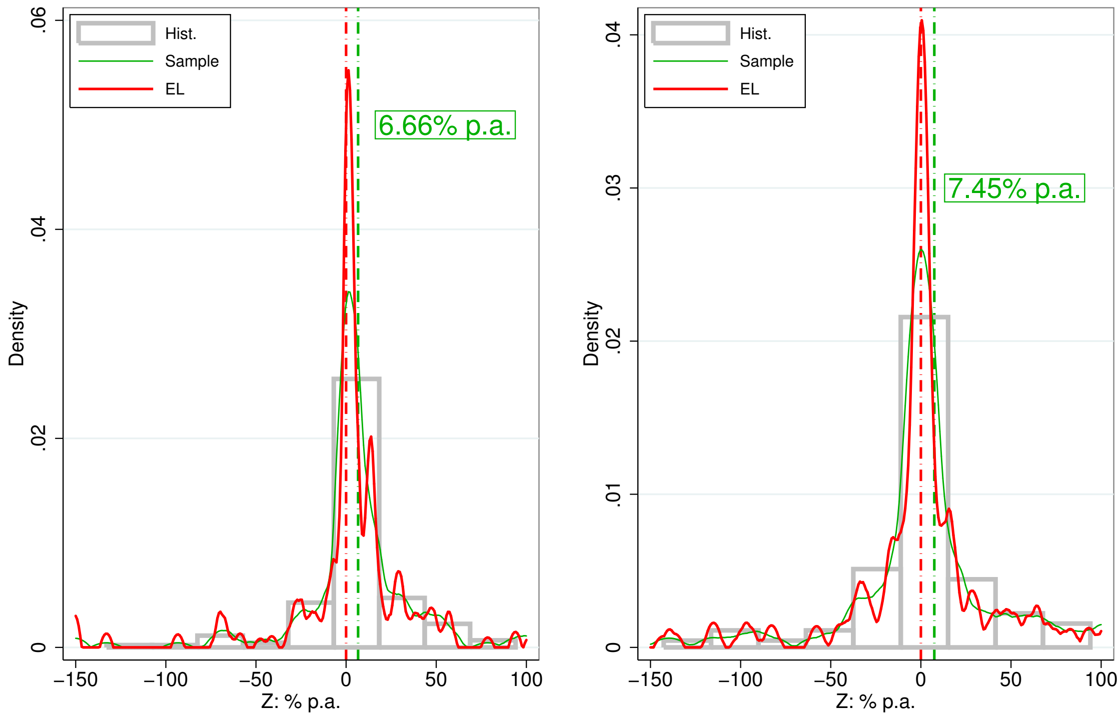


(a) Carry: full sample



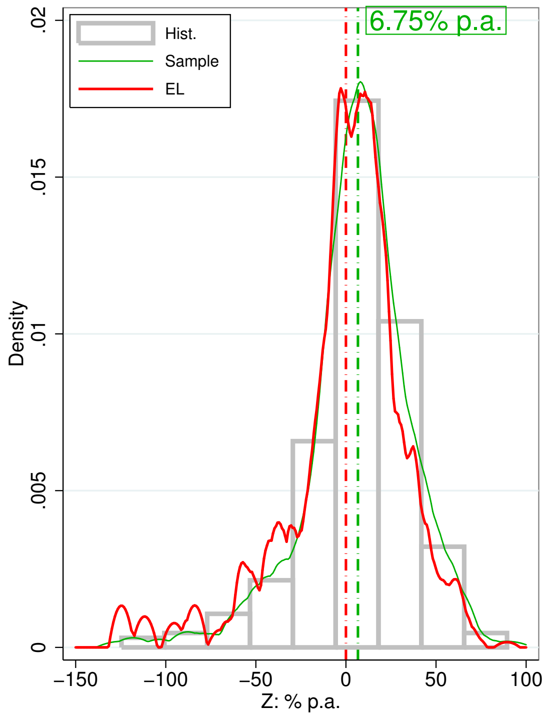
(b) MOM: full sample

Figure A.2: EL-implied and Sample-based Distributions for the **Realized Excess Return**. The solid red line plots the pdf of the rare disaster distribution with mean zero based on EL estimates. The solid green line plots the kernel density fitted to the actual sample. The gray bar chart plots the actual sample histogram. Additionally, the vertical red line marks the mean excess return based on the EL-implied rare disaster distribution which is zero under the null. and the vertical green line marks the actual sample mean excess return. Panel (a) and (b) plot the distributions based on interwar sample data from 1921:1-1936:12 for the realized excess returns to the carry trade and the currency momentum strategy respectively...**Continued on the next page**...

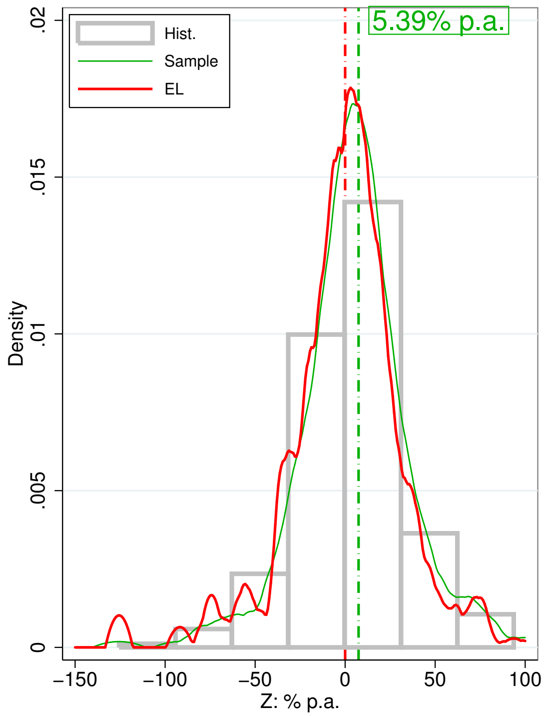


(c) Carry: 1921:1-1936:12 (d) MOM: 1921:1-1936:12

Figure A.2: ...**Continued from the previous page**...Panel (c) and (d) plot the EL-implied and Sample-based Distributions for Realized Excess Returns using the post Bretton Woods sample from 1976:1-1998:12, for the realized excess returns to the carry trade and the currency momentum strategy respectively...**Continued on the next page**...

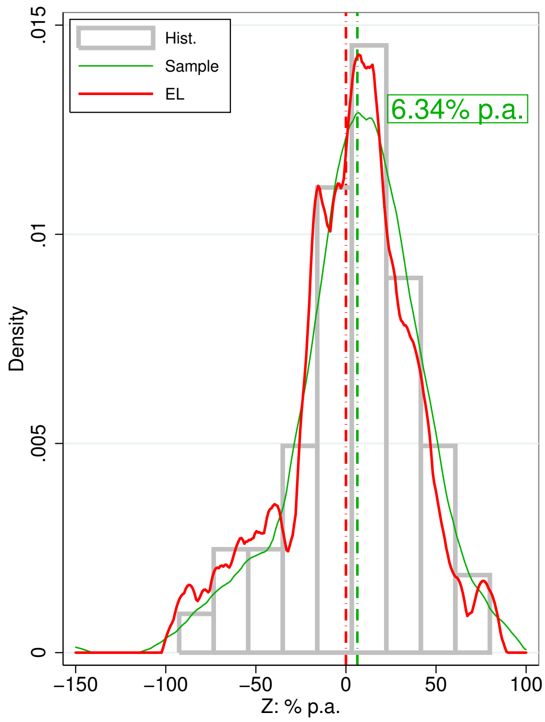


(e) Carry: 1976:1-1998:12

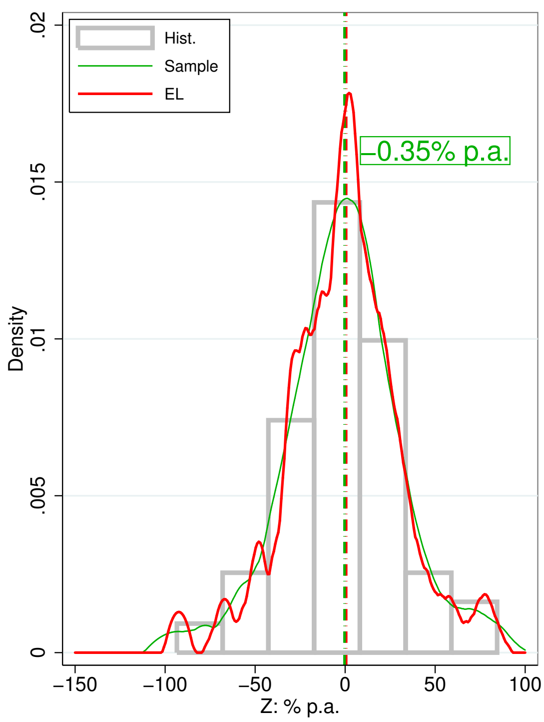


(f) MOM: 1976:1-1998:12

Figure A.2: ...**Continued from the previous page**...Panel (e) and (f) plot the EL-implied and Sample-based Distributions for Realized Excess Returns using the post Bretton Woods sample from 1976:1-1998:12, for the realized excess returns to the carry trade and the currency momentum strategy respectively...**Continued on the next page**...



(g) Carry: 1999:1-2013:3



(h) MOM: 1999:1-12013:3

Figure A.2: ...**Continued from the previous page**...Panel (g) and (h) plot the EL-implied and Sample-based Distributions for Realized Excess Returns using the post euro sample from 1999:1-2013:3, for the realized excess returns to the carry trade and the currency momentum strategy respectively.