# Currency Regimes and the Carry Trade *

**Olivier Accominotti**[†] **Jason Cen**[‡] **David Chambers**[§] **Ian W. Marsh**[¶]

This version: November 2017

**Abstract**

Carry trade returns vary across fixed and floating currency regimes. Over the last century, outsized carry returns occur exclusively in the floating regime, being zero in the fixed regime. The absence of skewness in floating carry returns rules out a skewness-based explanation for this result. Fixed-to-floating regime shifts deliver negative return shocks to the floating carry strategy, even when controlling for volatility risk. This result explains average excess returns to the floating and therefore the unconditional carry trades over the long-run. We rationalize these findings with a model allowing risk compensation in currency markets to depend on regime.

**Keywords:** Exchange rate regime, Carry trade

**JEL classification:** F31, G12

*First version: January, 2017. We thank Geert Bekaert, Giancarlo Corsetti, Elroy Dimson, Antti Ilmanen, Nikola Mirkov, Scott Murray, Carol Osler, Rich Payne, Raghu Rau, Lucio Sarno, Avanidhar Subrahmanyam, John Thanassoulis, Adrien Verdelhan, and seminar participants at Cambridge University, Cass Business School, Warwick Business School, and the Bank of England, and participants at EEA 2017, NFA 2017, the 2017 World Congress of Cliometrics and the 2017 INFINITI Conference on International Finance for helpful comments and suggestions. We are indebted to Cambridge University's Centre for Endowment Asset Management (CEAM), Cambridge Endowment for Research in Finance (CERF) and London School of Economics' Research Infrastructure and Investment Funds (RIIF) for financial support.

†London School of Economics and CEPR, Email: o.accominotti@lse.ac.uk

‡University of Essex, Email: j.cen@essex.ac.uk

§Cambridge Judge Business School, Email: d.chambers@jbs.cam.ac.uk

¶Cass Business School, Email: i.marsh@city.ac.uk

# 1. Introduction

Currency carry trades going long currencies with high interest rates and short currencies with low interest rates deliver outsized unconditional returns. This result is based on the post-Bretton Woods era (for example, Lustig, Roussanov, and Verdelhan (2011), and Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011a)) – a period dominated by floating currencies. Yet over the past century investors have experienced considerable variation in exchange rate regimes between fixed and floating both over time and across currencies. Our paper is the first to examine the impact of exchange rate regimes and regime shocks on carry trade returns.

Our empirical analysis exploits a new database of daily bid and offered exchange rates in spot and forward markets spanning the interval 1919-present. The year 1919 marks the dawn of modern currency trading with the emergence of a continuously traded forward market in London. Consistent with the post-Bretton Woods evidence, we find that the carry trade earns significant average returns over the whole sample period. Our estimated Sharpe ratio of between 0.5 and 0.6 is still substantial and only slightly lower than the 0.7 to 0.8 for the post-Bretton Woods sample. This finding of outsized carry returns across the whole period is robust to differing portfolio weights and to the inclusion of transaction costs. We further exploit our data to examine the dependence of carry trade returns on currency regimes by conditioning the return to the carry trade on the exchange rate regime of each currency pair at the beginning of each period.[1] We classify any currency pair into a floating (fixed) regime based on whether its exchange rate volatility is above (below) a certain threshold. Our choice of threshold derives from a simple statistical approach based on exchange rate volatility which is similar to Shambaugh (2004). Last, we examine the impact of regime shifts on carry trade returns.

[1] We apply the term *regime* to currency pairs. Thus, for example, the Swiss franc may be in a fixed regime against the euro but concurrently in a floating regime against the dollar. When referring to (near) system-wide exchange rate arrangements we use terms such as the Bretton Woods sample or era. Note that even during periods when floating (fixed) rates dominate, some currency pairs were in fixed (floating) regimes.

Our first finding is that carry trade returns vary with exchange rate regimes.[2] Average excess returns of the unconditional carry trade are entirely driven by returns to the carry strategy conditioned on the sample of currency pairs in the floating exchange rate regime. We term this strategy the *floating carry trade*. In comparison, the carry strategy conditioned on the sample of currency pairs in the fixed exchange rate regime (the *fixed carry trade*) generates zero returns on average. Moreover, the exchange rate of a floating currency pair tends to move according to a random walk without drift as the average spot return is close to zero and statistically insignificant. In contrast, the exchange rate of a fixed currency pair tends to move as predicted by the uncovered interest parity (UIP). Although the carry component of fixed carry trade returns is substantial at 2-3%, these gains are exactly offset by losses from spot rate depreciation when fixed exchange rate regimes collapse.

There are three other results related to our main finding regarding the regime-dependence of carry returns. First, we find that the skewness of returns to the floating and fixed carry trade strategies in our long sample differ from the consensus view regarding skewness in the literature. In the post-Bretton Woods period, outsized carry returns display negative skewness (Menkhoff, Sarno, Schmeling, and Schrimpf, 2012) and we confirm this result in our own sample. However, when we examine skewness of floating and fixed carry returns separately in our long sample, only the unprofitable fixed carry trade displays negative return skewness due to losses arising from the collapse of currency pegs. In contrast, the return skewness of the profitable floating carry trade is not significantly different from zero. Second, we further explore the indirect relationship between floating carry returns and the fixed regime. We find that the more that either currency in a floating pair is in a pegged relationship with other currencies, the worse is the performance of the floating carry trade strategy. Last, our results regarding the regime-dependence of carry returns hold not only for the base-neutral carry trade strategy but also for alternative specifications of the strategy employing different base currencies.

[2] Accominotti and Chambers (2016), Cen and Marsh (2016) and Doskov and Swinkels (2015) examine carry trade returns earned before the post-Bretton Woods era but do not address regime dependence of currency risk premia.

We run a range of empirical tests to check the robustness of our finding regarding the importance of regime-dependence for carry returns. To begin with, we show that regime-dependence is not subsumed by the dependence on volatility per se. Moreover, we find that the regime-dependence result holds when alternative volatility measures are used to classify regime. We verify the robustness of our results by experimenting with a sequence of volatility thresholds. Last, we ascertain that the variation of carry trade returns is not only related to the time-series but also the cross-section of exchange rate regimes across currency pairs.

Our second main finding is that the collapse of currency pegs has spill-over effects on floating currency pairs, thereby causing significant losses to carry traders. The January 2015 abandonment by the Swiss National Bank of its cap on the value of the franc against the euro is an example of such a collapse.[3] The breakdown of this particular fixed exchange rate coincides with poor carry trade returns when investment currencies such as the Australian and New Zealand dollars depreciate against the pound sterling, while funding currencies such as the Japanese yen and Swiss franc appreciate. Our regression analysis verifies that this example is representative of the relationship between fixed-to-floating regime changes and negative returns to the floating carry trade. Furthermore, the impact of regime shocks on carry trade returns is robust to using alternative regime-change indicators and to controlling for volatility risks. Finally, we find that major economic events that shaped the history of the international monetary system and exchange rate regimes are captured by our methodology. These events coincide with episodes of heightened economic and political uncertainty and investor flight-to-safety.

In the final section of the paper, we seek to explain our empirical results by extending the Lustig, Roussanov, and Verdelhan (2014) model to allow risk compensation in foreign exchange markets to depend on currency regimes. In our model, fixed currency pairs are characterized by relatively low volatility and significantly negative skewness, and floating currency pairs by relatively high volatility

[3]This cap is described as a one-sided restriction on the value of the franc. However, this restriction resulted in a low volatility regime where the franc was effectively fixed to the euro within a very narrow bound due to high demand for the Swiss currency.

and indeterminate sign of skewness. More specifically, the pricing kernel of a fixed-regime country is characterized by symmetric exposure to a global risk factor (and near-zero exposure to a local risk factor). As a result we show that fixed carry trade returns should be near-zero even though interest differentials are significantly positive. Conversely, the pricing kernel of a floating-regime country has asymmetric exposure to the global factor such that currencies with high interest rates command a larger risk premium. The model also incorporates asymmetric jump shocks into the pricing kernels for floating-regime countries. The empirical implication is that fixed-regime currencies switching to a floating regime negatively impact carry trade returns of floating currency pairs. In other words, the collapse of currency pegs results in negative shocks to carry trade returns even when the strategy is ex ante constructed using only floating currency pairs.

Our paper contributes to four sets of literature. First, we add to the risk-based explanations of outsized carry returns which suggest that countries differing in their interest rates have persistently asymmetric exposures to global shocks (e.g., Lustig, Roussanov, and Verdelhan (2011, 2014), and Menkhoff, Sarno, Schmeling, and Schrimpf (2012)). Such explanations are based on empirical analysis of the post-Bretton Woods era. The impact of regime variations on currency returns is underexplored. Our paper extends the literature by conditioning the standard carry trade strategy on both floating and fixed regimes over almost a century.

Second, we supplement an emerging literature aiming to understand the sustained profitability of the carry trade by analyzing the decomposition of carry trade returns (e.g., Koijen, Moskowitz, Pedersen, and Vrugt (2017) and Hassan and Mano (2014)). By relating the variation of carry trade returns to the time-series and cross-section of currency regimes, we provide a novel way to understand the outsized carry trade return puzzle in asset pricing.

Third, our paper contributes to the literature that explains carry trade returns in terms of crash risks, rare disasters or peso problems (e.g., Brunnermeier, Nagel, and Pedersen (2008), Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011a), Farhi and Gabaix (2016), Farhi, Fraiberger, Ranciere, and Verdelhan (2013), and Jurek (2014)). These empirical studies assume carry trade returns are exposed to some large unobserved negative shocks and estimate carry trade returns hedged by currency options in a relatively short sample. By contrast, in seeking to explain carry trade returns, our study makes explicit one type of large negative shock well represented in our long sample, namely, the fixed-to-floating regime shift in seeking to explain carry trade returns.

Fourth, we touch upon a literature relating carry trade returns to skewness. This strategy which goes long negatively skewed investment currencies and shorts positively skewed funding currencies may earn positive mean returns since investors dislike skewness (Brunnermeier et al. (2008), Osler (2012), and Rafferty (2010)). Our results challenge this characteristic-based explanation given that, in our long sample, the profitable floating carry trade is not significantly skewed but the unprofitable fixed carry trade is significantly skewed. This finding adds to the evidence questioning the skewness-based explanation uncovered in other studies (Bekaert and Panayotov (2015), and Burnside, Eichenbaum, and Rebelo (2011b)).

The remainder of the paper is organized as follows. Section 2 describes the data. Section 3 presents long-run evidence on carry trade returns. Section 4 examines the currency regime-dependence of carry trade returns. In Section 5, we provide evidence in favor of regime shocks as potentially explaining carry trade returns. Section 6 introduces a no-arbitrage model of regime-dependent exchange rates to rationalize our empirical results. Section 7 concludes.

## 2. Data

Our new foreign exchange dataset comprises daily bid and offered rates in spot and forward exchange markets from December, 1919 to July, 2017, covering 19 currencies of developed countries, namely Austria, Australia, Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United States, the United

Kingdom, and the Euro zone. We use this data to estimate carry trade returns at monthly frequency before and after transaction costs, and measure monthly volatility of exchange rates using daily data.

Our start date of 1919 reflects the establishment of a forward currency market in London for the first time, together with a modern spot market based on dealings by telegraphic transfer (Accominotti and Chambers, 2016). In addition, London emerged as the major global center of currency trading in this period (Atkin, 2005, pp. 40-41).

We collect bid and ask quotations of spot and forward exchange rates from the Financial Times Historical Archive for the period 1919-1975 [4] and WM/Reuters via Datastream for the period 1976-2017. We complement our dataset with other data sources including the Manchester Guardian, Einzig (1937), Keynes (1923), BBI, Hai, Mark, and Wu (1997), and the Bank of England.

Table I presents descriptive statistics of our sample, including the number of monthly observations, the mean and standard deviation of log excess returns ($rx$, % per annum), one-month forward discounts ($fd$, % per annum), appreciation rates ($-\Delta s$, % per annum), spot bid-ask spreads (BAS, basis points), and forward swap bid-ask spreads (BAF, basis points) for 18 exchange rates against the pound sterling (GBP) over the period 1919-2017. Over the full sample period (Panel A), mean excess returns are generally small. Furthermore, there exists a cross-sectional correlation between forward discount and expected spot return in that currencies traded with a forward discount (premium) against the GBP tend to depreciate (appreciate). We also report descriptive statistics for three subsamples: the interwar period (1919:12-1939:07) in Panel B, the World War II and Bretton Woods era (1939:08-1971:07) in Panel C, and the post-Bretton Woods era (1971:08-2017:07) in Panel D. Exchange rate volatility is generally lower for the WWII and Bretton Woods era when the fixed

[4]Spot and forward rates are the last quotes of the day until 1994 when the 4 pm London fix begins. In the interwar period, reported foreign exchange quotes are the buying and selling rates at the close of business (Miller, 1929, p. 137; Phillips, 1926, p. 58). Between September 1939 and December 1951 when the London market was effectively closed to interbank trading, spot and forward exchange rates are official quotations (Atkin, 2005, pp. 101-105). In December 1951, the forward market was liberalized with the end of official quotations for forward rates (Atkin, 2005, p. 102).

regime dominated than for the other two subsamples in which the floating regime prevailed.

Figure 1 graphs the coverage of our sample, which starts with 4 currencies and grows to 10 currencies by the early 1930s. These include the 9 currencies which were the most actively traded in the 1920s and 1930s cited by Einzig (1937, p. 104) plus the Canadian dollar (CAD). The 9 currencies are the Belgian franc, the Swiss franc, the German mark, the Spanish peseta, the French franc, the Pound sterling, the Italian lira, the Dutch guilder and the US dollar. The number then drops to 5 during World War II and begins to increase again after the war, reaching another peak in the post-Bretton Woods period with 18 currencies in the 1980s. The introduction of the euro in 1999 shrinks the sample to only the G10 currencies.[5]

Although trading volumes were not published until 1986, foreign exchange market activity was substantial before then. The Bank of England estimated daily foreign exchange turnover on the London market in the 1920s as equivalent to 30% of British GDP and 20% of world trade volume on an annual basis (Accominotti and Chambers, 2016). Trading activity then declined sharply during WWII and during the first decade of Bretton Woods. Thereafter, once current account convertibility was restored in the 1950s, currency speculation resumed and London reemerged as the leading global center of foreign exchange trading from the 1960s onwards (Atkin, 2005, p. 120).

## 3. Long-run evidence on the carry trade

In this section, using our long-run foreign exchange dataset, we examine the performance of the carry trade based on the following four definitions of the strategy:

- *Linear* weights a currency in proportion to its forward discount relative to the cross-sectional

[5] We exclude high inflation currencies: the German mark from June 1922 to October 1923 and the Portuguese escudo from April 1974 to December 1985.

average interest rate. The weight on currency $i$ at time $t$ is given by

$$w^{i,1}_{\text{Linear},t} = A_{\text{Linear},t}\left(fd^{i,1}_t - \overline{fd}^1_t\right) , \tag{1}$$

where $A_{\text{Linear},t}$ is an adjustment factor that controls the investment scale to ensure that long or short positions both sum to unity in absolute value.[6]

- *H1-L1* invests in the currency with the highest forward discount and shorts the currency with the lowest forward discount.

- $H_{25\%}$-$L_{25\%}$ takes a long position in currencies in the top quartile ranked by the forward discount and a short position in those in the bottom quartile. Currencies are equally weighted for the long position and the short position, respectively.

- *Rank-based* weights each currency in proportion to its rank in terms of its forward discount relative to the cross-sectional median rank.

We take advantage of the availability of bid-ask quotes in our data set to evaluate the effect of transaction costs on carry trade performance. To this end, we estimate the costs incurred in the trading of both the spot and forward exchanges. Our estimate of transaction costs in the spot market reduces the gross log excess return at time $t$ by

$$\tau_{\text{spot},t} = \sum_i \left| w^{i,1}_t - w^{i,1}_{t-1} \right| \text{BAS}^{i,1}_t , \tag{2}$$

where $\text{BAS}^{i,1}_t$ is the log bid-ask spread of the spot rate of currency $i$ against the reference currency. Note that the cost is determined by portfolio turnover, measured by $\left| w^{i,1}_t - w^{i,1}_{t-1} \right|$, and market liquidity, captured by the bid-ask spread. In addition, the net excess return realised at time $t$ (for

[6]The linear strategy in equation (1) is expressed in terms of currency pairs $i, 1$ where 1 represents the reference currency. In Appendix A we show that we can equivalently represent this weighting scheme in terms of general currency pairs $i, j$. This equivalence will be useful in later sections where we condition carry trade returns on the regime applicable to each currency pair $i, j$.

the period from $t-1$ to $t$) is impacted by transaction costs incurred at the beginning and the end of the period. However, we only include the spot market transaction costs incurred at the end of each period by assuming that the investor's initial wealth at the beginning of each period is after transaction costs incurred at the end of the previous period.[7] This choice has no impact on estimating the average return and evaluating long-term investment performance.

Similarly, our estimate of the cost in the forward swap transactions reduces the gross log excess return at time $t$ by

$$\tau_{fwd,t} = \sum_i \left| w_{t-1}^{i,1} \right| \mathrm{BAF}_{t-1}^{i,1}\,, \tag{3}$$

where $\mathrm{BAF}_t^{i,1}$ is the bid-ask spread of the log forward points of currency $i$ against the reference currency. Note that since the one-month forward swap transaction is always settled, assuming no default by either counterparty, the transaction cost is always incurred and is contracted at the beginning of each period.

Table II presents summary statistics for the carry trade over the whole sample period from 1919 to the present. The overall conclusion is that the carry trade generates positive returns across all four weighting schemes and also before and after transaction costs. The four carry trade strategies earn economically and statistically significant excess returns, ranging from 3.36% to 7.66% per annum, depending on the choice of portfolio weights and whether transaction costs are taken into account.

Although the choice of weighting scheme matters for the magnitude of average excess returns, the Sharpe ratio is more consistent across our four strategies – between 0.51 and 0.55 before transaction costs and between 0.36 and 0.38 after transaction costs. This result is driven by the fact that strategies with extreme weights, e.g., the *H1-L1* strategy, tend to deliver higher average returns but with more volatility and without actually improving the risk-return tradeoff.

[7] We take into account transaction costs incurred at the beginning and the end of the whole sample and those incurred when a currency drops out of the sample or when a currency (re-)appears in the sample.

The decomposition of the excess return into the spot return and the carry return is also informative. The profits of the carry trade tend to be entirely generated from the carry component while the component due to spot exchange rate changes is not only economically very small but also statistically insignificant, even though the sign is always negative. This evidence is consistent with Koijen, Moskowitz, Pedersen, and Vrugt (2017) who report based on a panel regression analysis that high-interest rate currencies neither depreciate, nor appreciate, on average. Furthermore, transaction costs matter for both return components. Transaction costs in the spot market reduce the average return by about 0.5% while transaction costs in the forward swaps, which are independent of the spot exchange, reduce the average return by about 1%. Last but not least, we find positive (1.5) but statistically insignificant skewness in our long sample of carry returns. This finding contrasts with that of negative skewness in the post-Bretton Woods period. We return to this subject below.

In the rest of the paper, we report carry trade returns employing the linear strategy.[8] Figure 2 graphs the cumulative log excess return to the linear carry trade strategy over the full sample period before and after transaction costs. The return to the carry trade exhibits substantial time-variation. Outperformance occurs in the 1920s and 1930s, and from the 1970s onwards. The intervening decades, when returns are substantially lower, coincides with the Bretton Woods era of fixed exchange rates. The next section examines the dependence of carry trade returns on currency regime in more detail.

## 4. Carry trade conditional on currency regimes

We next examine the performance of the carry trade conditional on the classification of exchange rate regime for each currency pair in our sample. At the beginning of each month within our full

[8] Returns based on the four weighting schemes are highly correlated. Our results are unaltered by the choice of alternative weighting schemes.

sample period, we first classify the exchange rate regime for each currency pair based on the ex ante volatility of its cross rate. Then we condition the carry trade strategy on each exchange rate regime and examine the performance of two regime-based carry trade strategies: the *floating carry trade* and the *fixed carry trade*.

## 4.1. Classification of exchange rate regimes

Our sample period of almost a century can be divided into three episodes: the interwar period, the Bretton Woods era and the post-Bretton Woods era.[9] The interwar period began with the removal of wartime capital controls in 1919 which forced European governments to float their currencies. By the end of 1927, all major currencies (except the Spanish peseta) had switched from floating to fixed exchange rates. This return to the gold standard proved short-lived as currency pegs were abandoned during the 1930s, particularly following the sterling crisis in September 1931. At the Bretton Woods conference in 1944, countries agreed to maintain fixed (but adjustable) exchange rates relative to the US dollar, which was itself convertible into gold. This was initially a success. However, first the pound sterling in the mid-1960s and then the US dollar in the late 1960s and early 1970s were subject to considerable speculation as their pegs became increasingly difficult to defend. By 1973, Bretton Woods was at an end and the major currencies of the world largely persevered with floating exchange rates thereafter. The major exception was the emergence of the euro in 1999. In each of these three episodes, there was substantial cross-country heterogeneity in the choice of currency regime. Very rarely did all countries adopt the same regime.

When considering exchange rate regime classification, one approach is to use the macroeconomics-based method of Reinhart and Rogoff (see Ilzetzki, Reinhart, and Rogoff, 2004). However, this approach simply describes whether the currency of a country is fixed or floating without reference to a certain anchor. Moreover, regime classification is not possible for all currency pairs following

[9] Eichengreen (1996) provides detailed analysis of the major developments in the international monetary system throughout the period of our study.

such an approach. Given these limitations, we opt for a de facto regime classification based on exchange rate volatility, similar to Shambaugh (2004). In our main analysis, we classify exchange rate regimes using cross rate volatility $\sigma_t^{i,j}$ measured as an exponentially moving average of spot returns for each currency pair $(i, j)$ at time $t$, i.e., $\sigma_t^{i,j} = 100 \times \sqrt{261} \times (1 - \rho) \sum_{u=0}^{t-1} \rho^u |\Delta s_{t-u}^{i,j}|$, where $\rho = 0.99$ is chosen such that the half-life of past exchange rate is about three months. We later check the robustness of our results using alternative volatility measures to classify exchange rate regimes.

It is worth highlighting the main advantages of our approach. First, volatility is measured without look-ahead bias and therefore can be estimated in real time. Second, we can classify the regime of any currency pair, subject to the availability of exchange rate data. Third, our volatility-based classification captures the effective regime either when currencies are locked in a multilateral fashion, or when there are occasional interventions that create a wedge between the official exchange rate status and actual exchange rate movements.

Based on the ex ante volatility measure, we classify each currency pair $(i, j)$ at time $t$ into two regimes $z$ defined as

$$z = \begin{cases} \text{Fixed}, & \text{if } \sigma_t^{i,j} < V \\ \text{Floating}, & \text{if } \sigma_t^{i,j} \geq V \,, \end{cases} \tag{4}$$

where $V$ is the volatility threshold. For our main analysis, we choose $V = 4\%$. This choice of volatility threshold demonstrates consistency with the generally accepted classification of regimes. For example, in the first instance, the G10 exchange rates against the U.S. dollar in the post Euro period are correctly classified as floating, since the minimum volatility estimates in this subsample lie slightly above 4%. However, if we chose a lower volatility threshold, say 2% per annum, currencies in the European Exchange Rate Mechanism (ERM) would be incorrectly classified as floating in the early 1980s.

Figure 3 graphs the time-series of the fraction of currency pairs classified into fixed and floating exchange rate regimes based on a 4% threshold. The floating (fixed) regime fraction consists of all currency pairs with a volatility above (below) this threshold. The distribution of regimes is somewhat concentrated over time. The floating regime dominates in the post-Bretton Woods period and the fixed regime does so in the Bretton Woods period and in World War II. The interwar period, consistent with the historical narrative, displays more regime heterogeneity.

### 4.2. Regime-dependent carry trade performance

We now condition the return to the linear carry trade strategy on ex ante exchange rate regimes. This is equivalent to a double portfolio sorting which treats the currency regime as a cross-sectional currency characteristic in addition to the interest rate differential.

Because currency regime is a characteristic variable applicable to all currency pairs, we start by representing the carry trade strategy by a portfolio of all currency pairs. Formally, let the log excess return to the carry trade be

$$rx_{t+1}^{\mathrm{CT}} = \sum_{i,j} w_t^{i,j}\, rx_{t+1}^{i,j} \tag{5}$$

where the weight on each currency pair is denoted as

$$w_t^{i,j} = A_t\, fd_t^{i,j} = A_t \left( fd_t^{i,1} - fd_t^{j,1} \right) \tag{6}$$

with $A_t$ being an adjustment factor that alters the scale of investment. In Appendix A, we show that this representation is equivalent to the linear carry trade strategy in terms of exchange rates against a given reference currency indexed by '1' presented in Section 3.

Next, the return to the carry trade can be decomposed into two regime-dependent strategies, i.e., the *fixed carry trade* and the *floating carry trade* as

$$rx_{t+1}^{\text{CT}} = \omega_t^{\text{Fixed}} rx_{t+1}^{\text{Fixed}} + \omega_t^{\text{Float}} rx_{t+1}^{\text{Float}} \tag{7}$$

where

$$\begin{aligned} rx_{t+1}^{z} &= \frac{1}{\omega_t^z} \sum_{i,j} w_t^{i,j}\, rx_{t+1}^{i,j}\, \mathbf{I}_t^{i,j}(z) \\ \omega_t^z &= \frac{\sum_{i,j} \mathbf{I}_t^{i,j}(z)}{\sum_{i,j} 1}, \end{aligned} \tag{8}$$

and $\mathbf{I}_t^{i,j}(z)$ is a dummy variable indicating whether currency pair $(i, j)$ at time $t$ is in regime $z \in \{\text{Fixed, Float}\}$, and $\mathbf{I}^{i,i}(z) \equiv 0$ for $\forall\ z$. This decomposition provides an interpretation of the carry trade as a strategy that dynamically allocates portfolio weights on each regime style $z$ based on the the fraction $\omega_t^z$ in the investment universe. Note that when a certain regime, say the fixed regime, is absent from the investment universe, i.e, $\omega_t^{\text{Fixed}} = 0$, and $\omega_t^{\text{Float}} = 1$, the fixed-regime excess return corresponds to a missing value, and therefore carry trade returns are totally driven by the floating regime, i.e., $rx_{t+1}^{\text{CT}} = rx_{t+1}^{\text{Float}}$.

Table III presents summary statistics of returns to the fixed and floating carry trade strategies. The profitability of the carry trade is solely attributable to the returns of floating currency pairs. The average gross excess return to the floating carry trade is 9.46% per annum, and the Sharpe ratio is 0.61 on an annualized basis. By contrast, the fixed carry trade delivers insignificant excess return of 0.72% per annum on average and an insignificant Sharpe ratio of only 0.11.[10]

The importance of regime for the performance of the carry trade strategy remains true when transaction costs are taken into account. The fixed carry trade generates losses of 55 basis points a year with the Sharpe ratio being -0.08. The floating carry trade, on the other hand, earns a

[10] Our results regarding the performance of the fixed carry trade hold when we exclude the period from September 1939 to December 1951 when the London interbank market was effectively closed and only official currency quotations are quoted in the financial press.

significantly positive excess return of 7.19% per annum on average with a significantly positive Sharpe ratio of 0.47.

We next consider the cross-sectional correlation between interest rate differentials and exchange rate changes by decomposing excess returns into the carry and spot return components. The high interest rate currency of a fixed currency pair eventually tends to depreciate significantly relative to the low interest rate currency when the currency peg collapses. Furthermore, after transaction costs, the gains from the interest rate differential (+2.35% p.a.) are offset by capital losses from future spot exchange rate changes (-2.90% p.a.) in the month when the peg collapses. This finding suggests that the uncovered interest parity (UIP) holds for the fixed carry trade. By contrast, after transaction costs the exchange rate of a floating currency pair with positive interest rate differentials (7.25% p.a.) does not change significantly (-0.06% p.a.). This finding suggests that the UIP is violated for floating currency pairs.

In addition, our findings regarding the skewness of returns to the floating and fixed carry trade strategies in our long sample differ from the consensus view regarding skewness in the literature. In the post-Bretton Woods period, outsized carry returns display negative skewness and the former are viewed as compensation for investors bearing negative return skewness (Menkhoff, Sarno, Schmeling, and Schrimpf, 2012). Whilst we obtain a similar result for negative skewness of unconditional carry trade returns for the post-Bretton Woods period (unreported), skewness for the whole sample period is not statistically significantly different from zero (Table II). However, when we examine skewness of fixed and floating carry returns separately, we see a different picture (Table III). The unprofitable fixed carry trade after transaction costs displays negative return skewness (-16.66), due to losses arising from the collapse of currency pegs. In contrast, the return skewness of the profitable floating carry trade after transaction costs is not significantly different from zero (0.30). Hence, this result casts some doubt on the skewness-based explanation for outsized carry trade returns.

## 4.3. Indirect effect of fixed exchange rates on the carry trade

The evidence presented so far suggests a direct relationship between currency regimes and carry trade returns in so far as outsized carry trade returns seem to be concentrated in the floating regime. We next examine how the fixed regime indirectly affects floating carry trade performance.

To this end, we measure the extent to which each floating currency pair is interconnected with the fixed regime currencies. We sort floating currency pairs into three groups. The first group, *Low Mix*, includes floating currency pairs with neither currency in the pair pegged to any other currency. The second group, *Med Mix*, includes floating currency pairs with either currency in the pair pegged to less than half of the remaining currencies. The third group, *High Mix*, includes floating currency pairs with both currencies in the pair pegged to more than half of the remaining currencies.

Table IV reports the excess returns, their decomposition, their second and third moments and the Sharpe ratio for each of these three sorts both before and after transaction costs. The Sharpe ratio of the floating carry trade before (after) transaction costs decreases from 0.66 (0.51) for the Low Mix group to 0.39 (0.20) for the High Mix group. Hence, we conclude that the more that either currency in a floating pair is in a pegged relationship with other currencies, the lower is the performance of the floating carry trade strategy.

## 4.4. Base carry trade strategy

So far we have shown that the correlation between interest rate differentials and expected returns is not unconditional but depends on exchange rate regimes by examining the standard dollar-neutral carry trade. Lustig, Roussanov, and Verdelhan (2014) develops a new carry trade strategy that exploits the time-varying interest rate differential of a base currency (e.g., the US dollar) relative to a basket of foreign currencies. They conclude that the base carry trade earns significant average excess return but exhibits different risk-return properties from the dollar-neutral carry trade.

Accordingly, we test whether our finding of regime-dependence holds for different base currencies. Our results are summarized in Table V. Only the floating base carry trade delivers outsized returns while the fixed base carry trade is not profitable, regardless of whether the base currency is the US dollar (Panel A), the pound sterling (Panel B) or the Deutsche mark (or Euro from 1999 onwards) (Panel C).[11]

## 4.5. Robustness

### 4.5.1. Distinguishing regime from volatility

Given that we classify exchange rate regimes based on cross rate volatility, it could be that carry trade returns are dependent on volatility per se rather than on regimes classified by a given volatility threshold. To clearly distinguish between these two types of dependence, we condition the carry trade strategy on a range of volatility thresholds. We sort currency pairs into six groups based on a range of volatilities: 2%, 4%, 8%, 10% and 12%. A linear carry trade strategy is constructed within each volatility group. Note that the first two groups, i.e., currency pairs with volatilities below 2% and between 2% and 4%, correspond to the fixed regime and the remaining four groups correspond to the floating regime, as defined in the previous section.

Although the expected return to the carry trade increases with the volatility of underlying exchange rates, the risk-adjusted return measured by the Sharpe ratio does not exhibit the same monotonicity. Once a currency pair enters into the floating regime, i.e., above the 4% threshold, the Sharpe ratio does not increase with volatility both before and after transaction costs (Table VI). Therefore, our evidence rejects the hypothesis that risk-adjusted carry returns are dependent on volatility per se.

[11]Consistent with Lustig et al. (2014), we find that return to the base carry trade arises from both interest rate differentials and exchange rate changes, in contrast to the standard base-neutral carry trade which generates profits entirely from the carry component.

#### 4.5.2. Alternative volatility-based regime classifications

We now verify the robustness of our results using alternative regime classifications. Table VII summarizes descriptive statistics of returns to the fixed and floating carry trades, respectively, using the exact methodology in Shambaugh (2004) which measures volatility as the absolute difference between the highest and the lowest exchange rate over the past year (Panel A) and in Menkhoff et al. (2012) which measures volatility as the mean absolute daily return within each month (Panel B). In both cases, we apply the same 4% volatility threshold and find our results hold. The annualized floating carry returns using the Shambaugh (2004) and Menkhoff et al. (2012) methods are 5.93% and 8.98% respectively, whereas the fixed carry returns are effectively zero.

#### 4.5.3. Varying the volatility threshold

Our volatility-based regime classification contains two inputs: the volatility measure and the threshold. We now verify that our results are robust to a range of volatility thresholds up to 10%. Figure 4 graphs the Sharpe ratio of the fixed and floating carry trades, respectively, both before and after transaction costs and includes the 5th and the 95th percentiles. A threshold of a little higher than 6% is required to produce a significantly positive Sharpe ratio for the fixed carry trade before transaction costs, and one of 10% after transaction costs. However, classifying a currency pair as fixed when its volatility is 6%, let alone 10%, would be inconsistent with the observed de jure regime classification during our sample period. In contrast, varying the volatility threshold does not have a significant effect on the Sharpe ratio of the floating carry trade.

#### 4.5.4. The time-series and cross-section of regime-dependence

Previously we noted that the fraction of currency pairs in the floating regime is higher in the 1920s and 1930s and in the post-Bretton Woods era and correspondingly lower in the Bretton Woods period and World War II (Figure 3). When viewed alongside the striking time-variation in carry trade performance graphed in Figure 2, we might conclude that the regime-dependence documented above is a pure time-series phenomenon. This view would be incorrect. Here, we verify that the variation of carry trade returns is indeed present in both the time-series and the cross section of exchange rate regimes.

We first note that in spite of the concentration of exchange rate regimes across time, both regimes are present in all three sub-periods. Around a half of all currency pairs are classified into the two regimes on average across the full sample period. The mean fractions are 0.42 for the fixed regime and 0.58 for the floating regime. Although, the fraction of each regime varies substantially across different subsample periods, both regimes are always represented in the cross-section. Moreover, there exist long time series of carry trade returns for both regimes: out of the 1171 months in our whole sample, there are 1123 months with non-missing observations for the fixed regime and 925 months with non-missing observations for the floating regime. We exploit this feature of our data to test the robustness of our finding regarding the regime-dependence of carry trade returns.

For each of our three subsamples, namely, the interwar period, the WWII and Bretton Woods period, and the post Bretton Woods period, we compute the performance of the fixed and floating carry trades. In all three subsamples, floating carry trade returns, both before and after transaction costs remain outsized and fixed carry returns are zero (Table VIII).[12]

As an alternative approach, we model the time dimension of currency regimes by classifying each month according to whether there are more fixed currency pairs than floating ones or vice versa. The results are summarized in Table IX. Before and after transaction costs, both the excess return (9.99% and 6.57%) and the Sharpe ratio (0.53 and 0.35) of the floating carry trade remain positive even in those months where the fraction of fixed currency pairs is more than half of all currency

[12]We see that the Sharpe ratio of the floating carry trade after transaction costs is much lower in the WWII and Bretton Woods period than in any other period. This is because transaction costs were especially high during the WWII and Bretton Woods period.

pairs in the sample.

## 5. Regime shocks and carry trade returns

Next, we examine the impact of exchange rate regime switches on carry trade returns. Our aim is to study regime shocks as potential risk factors that might explain why the carry trade earns outsized returns. Our focus is on realized spot returns since the carry return component is pre-determined. Since we have previously shown that carry trade profits are entirely accounted for by the floating carry trade, we examine realized spot returns to the floating carry trade.

Before turning to formal estimation, we first present an example of the impact of regime changes on currencies. On January 15, 2015, the Swiss National Bank (SNB) suddenly announced that it would no longer support the cap on the franc's value against the euro, which sent the global financial markets into chaos. The very immediate impact of this announcement was that the Swiss franc soared as much as 30% against the euro within a day. This event features a global flight-to-safety phenomenon, particularly in the currency universe of our sample. As Figure 5 portrays, investment currencies such as the Australian dollar and the New Zealand dollar, typically included in the carry trade as investment currencies, depreciated dramatically relative to safe haven currencies such as the Swiss franc and the Japanese yen which are typical funding currencies. Interestingly, the U.S. dollar, another safe haven currency, also experienced a large appreciation.

We now examine the impact of regime shocks on carry trade returns by estimating the following time-series regression:

$$-\Delta s_t^z = \alpha + \beta\, D_{t,\,\text{Fixed}\to\text{Float}} + \gamma\, D_{t,\,\text{Float}\to\text{Fixed}} + \varepsilon_t\,, \tag{9}$$

where $\Delta s_t^z$ is the realized spot return (after transaction costs) to regime-$z$ ($z \in \{\text{Float, Fixed}\}$) carry trade. $D_{t,\,\text{Fixed}\to\text{Float}}$ is a dummy variable indicating that from time $t-1$ to $t$ one or more currency pairs switch from the fixed regime to the floating regime. Similarly, $D_{t,\,\text{Float}\to\text{Fixed}}$ is a dummy variable indicating that from time $t-1$ to $t$ one or more currency pairs switch from the floating regime to the fixed regime.

Table X, Panel A shows that the switch of one or more currency pairs from a fixed to a floating regime is associated with a monthly loss of 123 basis points to the floating carry trade, sizable when compared with its monthly mean return of 60 basis points. The fixed carry trade is *directly* impacted with a monthly loss of 75 basis points, given that the regime shock is triggered by the collapse of one or more currency pairs in the fixed carry trade portfolio. By contrast, a switch to the fixed regime does not have a significant effect on either floating or fixed carry trade returns.

While both the case study and our regression results suggest that a fixed-to-floating regime switch corresponds to a bad state for carry traders, it remains unclear whether a more system-wide regime switch would have stronger impact. To address this issue, we estimate the following regression:

$$-\Delta s_t^z = \alpha + \beta\, P_{t,\,\text{Fixed}\to\text{Float}} + \gamma\, P_{t,\,\text{Float}\to\text{Fixed}} + \varepsilon_t\,, \tag{10}$$

where $P_{t,\,\text{Fixed}\to\text{Float}}$ measures the fraction of currency pairs switching from the fixed regime to the floating regime from time $t-1$ to $t$. Similarly, $P_{t,\,\text{Float}\to\text{Fixed}}$ measures the fraction of currency pairs switching from the floating regime to the fixed regime from time $t-1$ to $t$.

Panel B of Table X provides evidence that the more fixed exchange rates turn to floating, the worse is the outcome for carry traders. Indeed, even though the losses from the floating carry trade do not include losses arising from the collapse of pegged currencies, they are at least as large as those from the fixed carry trade. Again, there is no statistically significant effect for the floating-to-fixed regime switch.

To further validate our results, we perform the following analysis. First, we modify the regime change indicator to exclude regime shifts triggered by only very small volatility changes that pass the threshold (e.g., volatility changes from 3.9% to 4.1%). Table XI summarizes the results for regressions using these modified regime change indicators. Volatility has to increase by at least 1% to qualify for a fixed-to-floating switch in Panel A and by at least 2% in Panel B. In both cases, the fixed-to-floating regime shock negatively impacts carry trade returns. Since our sample of fixed-to-floating regime switches includes an extreme carry trade return of -44.9% in July to August 1931, we check our regression results excluding this outlier (Panel C). Again, carry trade returns remain negatively correlated with fixed-to-floating switches.

Next, we test whether fixed-to-floating regime shocks continue to negatively impact carry trade returns when we control for exposure to volatility risks (Table XII). We model the volatility of the US equity market (Panel A) and of floating currency pairs in the foreign exchange market (Panel B). The results show that whilst the floating carry trade returns are negatively correlated with volatility risks, the fixed carry trade returns are not exposed to volatility risks. This evidence is consistent with our results in the previous section. The unprofitable fixed carry trade is not exposed to volatility risks and therefore earns no risk premium. In contrast, the profitable floating carry trade has significantly negative exposure to volatility risks, earning a positive risk premium.

Our findings confirm the impact of regime shocks on carry trade returns on average. Table XIII presents summary statistics of floating carry trade returns during fixed-to-floating regime changes. Out of a total of 207 months in which fixed-to-floating regime changes occur, there are 125 months with negative returns. The sample average of these negative monthly returns is -282 basis point, larger in absolute value than that of the 82 positive monthly returns (183 basis points). Floating carry trade monthly returns during fixed-to-floating switches are strongly negatively skewed, with the 10-th percentile of -515 basis points and the 90-th percentile of 189 basis points.

Our de facto regime classification of fixed-to-floating regime shifts also correlates with events that shaped the history of the international financial system and the foreign exchange markets as documented in the secondary sources (Eichengreen (1996), Aldcroft and Oliver (1998), James

(2012), and Reinhart and Rogoff (2011)). Among the 25 largest monthly losses to the floating carry trade arising from a fixed-to-floating regime shift, all but five months coincide with such historical events (Table XIV). These events include: the collapse of the gold exchange standard system in the 1930s (the July 1931 German crisis and the US April 1933 devaluation); the collapse of the managed floating regimes in Europe at the outbreak of the Second World War; the European Monetary System crisis of 1992-1993 (Black Wednesday and the widening of the Exchange Rate Mechanism band); as well as the climax of the European debt crisis in May 2010 (when Greece asked for financial support from the International Monetary Fund and European Union). Each of these episodes was characterized by large negative returns to the floating carry trade and was associated with high uncertainty on global foreign exchange markets and investor flight to safe haven currencies (Eichengreen (1996)).

To summarize, fixed-to-floating regime shifts identify a negatively skewed systematic component of the returns to the profitable floating carry trade. These regime shifts coincide with important events of the international financial system that can be interpreted as "bad times" for investors. The floating carry trade incurs considerable losses in such "bad times" and therefore is expected to earn outsized returns on average. This interpretation, however, does not contradict our finding of zero skewness of floating carry returns in the previous section. In our long sample, the floating carry trade experiences large positive returns as high interest rate currencies depreciate relative to low interest rate currencies before the corresponding exchange rates are stabilized.[13] These positive returns add positive skewness to floating carry returns. Hence, skewness is not an appropriate statistic with which to characterize the risk of the floating and therefore the unconditional carry trades.

[13] For instance, from July to August of 1926, the French franc and the Belgian franc appreciated by 19% and 9%, respectively, against the US dollar prior to their return to the interwar gold standard. These appreciations contribute to a positive monthly excess return of 20% to the floating carry trade. Although this event does not correspond to floating-to-fixed regime switches for the French and Belgian currencies, the exchange rate behavior of these two currencies is driven by their aim of returning to the interwar gold standard.

# 6. A no-arbitrage model of regime-dependent exchange rates

In this section, we present a no-arbitrage model of exchange rates to rationalize our empirical results documented above. We start by introducing the setup of the model, and then we summarize the predictions that are consistent with our results.

## 6.1. Model setup

We extend the reduced-form no-arbitrage model in Lustig, Roussanov, and Verdelhan (2014) (LRV hereafter) by allowing currency regime and regime shifts to impact each country's pricing kernel dynamics. First, we allow the nominal pricing kernel of each country $i$ at time $t$, $\Lambda_t^i(\xi_t^i)$, to depend on its exchange rate regime $\xi_t^i \in \{0,1\}$.[14] When $\xi_t^i = 0$, country $i$ pegs its currency to that of some target country by restricting the volatility of the corresponding exchange rate within a narrow range. Otherwise, when $\xi_t^i = 1$, country $i$ allows its currency to float freely. For simplicity, we assume that the target country is unique and without loss of generality, indexed as $i = 0$.[15] The regime variable $\xi_t^i$, governed by a Markov chain, is independent across countries. The regime transitions occur infrequently with probabilities denoted by $Pr\left(\xi_{t+1}^i = 1 \middle| \xi_t^i = 0\right) = \lambda_t$, and $Pr\left(\xi_{t+1}^i = 0 \middle| \xi_t^i = 1\right) = \mu_t$. Formally, the pricing kernel of country $i = 1, 2, \cdots, N-1$ follows two regime-dependent laws of motion:

$$-\log \frac{\Lambda_{t+1}^i(1)}{\Lambda_t^i(1)} = \alpha + \chi z_t^i + \tau z_t^w + \sqrt{\gamma\, z_t^i}\, u_{t+1}^i + \sqrt{\kappa\, z_t^i}\, u_{t+1}^g + \sqrt{\delta^i\, z_t^w}\, u_{t+1}^w - J_{t+1}^i\,, \tag{11}$$

$$-\log \frac{\Lambda_{t+1}^i(0)}{\Lambda_t^i(0)} = \alpha + \chi z_t^i + \tau z_t^w + \sqrt{\gamma^0 z_t^i}\, u_{t+1}^i + \sqrt{\kappa^0 z_t^i}\, u_{t+1}^g + \sqrt{\delta^0 z_t^w}\, u_{t+1}^w - J_{t+1}^0\,, \tag{12}$$

[14] See Verdelhan (2015), and Sarno, Schneider, and Wagner (2012), among others, for models of nominal exchange rates based on nominal pricing kernels or stochastic discount factors.

[15] In general, the concept of fixed versus floating regimes is associated with currency pairs rather than countries. In our model with a unique and invariant target country currency $i = 0$, we can associate regimes with countries or currencies.

and the pricing kernel of the target country ($i=0$) follows

$$-\log \frac{\Lambda^0_{t+1}}{\Lambda^0_t} = \alpha + \chi z^0_t + \tau z^w_t + \sqrt{\gamma^0 z^0_t}\, u^0_{t+1} + \sqrt{\kappa^0 z^0_t}\, u^g_{t+1} + \sqrt{\delta^0 z^w_t}\, u^w_{t+1} - J^0_{t+1}\,, \tag{13}$$

where $u^i$ is a country-specific shock, and $u^g$ and $u^w$ are two global shocks. All three types of shocks are Gaussian with zero mean and unit variance and they are independent of each other and over time. The risk prices associated with country-specific shocks and the first global shock are driven only by the country-specific state variable $z^i$ for each country $i$, while the risk price for the second global shock depends on the global state variable $z^w$ which is common to all countries. The country-specific and global state variables are governed by square-root processes:

$$z^i_{t+1} = (1-\phi)\theta + \phi z^i_t - \sigma\sqrt{z^i_t}\, u^i_{t+1}\,, \tag{14}$$

$$z^w_{t+1} = (1-\phi^w)\theta^w + \phi^w z^w_t - \sigma^w\sqrt{z^w_t}\, u^w_{t+1}\,. \tag{15}$$

Our second extension to the LRV model is the inclusion of jump components in the pricing kernels, which are specified as compound Poisson jump processes:

$$J^i_{t+1} \equiv J(\nu_{t+1}, \zeta^i_{t+1}) = \sum_{k=1}^{\nu_{t+1}} \zeta^i_{t+1,k}\,, \tag{16}$$

where $\nu_{t+1}$ is the number of countries experiencing fixed-to-floating switches from $t$ to $t+1$, and $\zeta^i_{t+1,k}$ is the size of the $k$-th jump. We assume that $\nu_{t+1}$ follows a Poisson process with intensity $\lambda_t$ (the fixed-to-floating transition probability) and the size $\zeta^i_{t+1}$ is drawn from a time-invariant Gamma distribution $\Gamma(1, \sqrt{\eta^i})$.[16]

Equations (11) and (13) imply that the pricing kernels of fixed-regime countries (including the target country) exhibit no permanent heterogeneity with respect to any shocks. The heterogeneous

[16]The Gamma distribution is parameterized by its shape (set to be 1) and its scale $\sqrt{\eta^i}$. Therefore, the mean is $\sqrt{\eta^i}$ and the variance is $\eta^i$.

exposures to the country-specific shock $u^i$ and the global shock $u^g$ are only transitory. The global shock $u^w$ and the jump shock are both equally priced in all fixed-regime countries. On the other hand, Eq. (12), implies that floating-regime countries feature permanent heterogeneity in their exposures to the global shock $u^w$ and the jump shock $J^i$. However, the heterogeneity in exposures to the country-specific shock $u^i$ and the global shock $u^g$ is transitory. Importantly, the parameters associated with risk exposures are regime-dependent. Therefore, when country $i$ switches from the fixed regime to the floating regime, its exposures to shocks also experience permanent changes. In particular, the heterogeneity in jump risk exposures generates a spill-over effect on the exchange rates of floating-regime countries when fixed-to-floating regime shifts occur. Furthermore, we impose the following parameter restrictions:

$$\frac{2}{\gamma^0+\kappa^0} > \frac{1}{\chi} > \frac{1}{\gamma+\kappa} + \frac{1}{\gamma^0+\kappa^0}\,, \tag{17}$$

$$\gamma \gg \gamma^0\,,\ \kappa \gg \kappa^0\,. \tag{18}$$

The restriction in (17) extends the parameter restriction in Lustig et al. (2014) and is necessary to reproduce the failure (success) of the UIP for floating (fixed) currency pairs.[17] In addition, we introduce new conditions in (18), under which the precautionary savings component of a fixed-regime country's short-term interest rate is dominated by the global state variable $z^w$ rather than by the country-specific state variable $z^i$. We discuss the implications of these conditions in the next two sections.

## 6.2. Volatility implications

Consistent with the de facto classification of exchange rate regimes in our empirical analysis, our model implies that the fixed regime can be characterized by relatively low volatility and the floating

[17] Lustig et al. (2014) show that the condition $\chi < \frac{\gamma+\kappa}{2}$, implies the violation of uncovered interest parity (UIP).

regime by relatively high volatility.[18] Accordingly, the conditional variance of the exchange rate of a fixed currency pair $(i, j)$ is

$$Var_t \left[ \Delta s^{ij}_{t+1} \,\middle|\, \xi^i_t = \xi^j_t = 0 \right] = \frac{1}{2}\gamma^0 (z^i_t + z^j_t) + \frac{1}{2}\kappa^0 \left( \sqrt{z^i_t} - \sqrt{z^j_t} \right)^2 + \sum_{k=i,j} [s^{k0}_t(1) - s^{k0}_t(0)]^2 \lambda_t \,. \quad (19)$$

Intuitively, under the conditions in (18), a fixed currency pair is established when both countries in the pair are identically exposed to the global shock $u^w$ and substantially reduce their temporary exposures to their respective country specific shocks and the global shock $u^g$, so that the exchange rate between the two currencies is stabilized. As a result, the conditional variance of a fixed currency pair is mainly driven by the collapse of the peg: the smaller the transition probability $\lambda_t$, the smaller is the variance.

Correspondingly, the conditional variance of the exchange rate of a pure floating currency pair is

$$Var_t \left[ \Delta s^{ij}_{t+1} \,\middle|\, \xi^i_t = \xi^j_t = 1 \right] = \frac{1}{2}\gamma (z^i_t + z^j_t) + \frac{1}{2}\kappa \left( \sqrt{z^i_t} - \sqrt{z^j_t} \right)^2 + \frac{1}{2} \left( \sqrt{\delta^i} - \sqrt{\delta^j} \right)^2 z^w_t \quad (20)$$

$$+ \left[ (\sqrt{\eta^i} - \sqrt{\eta^j})^2 + \eta^i + \eta^j \right] \lambda_t + \sum_{k=i,j} [s^{k0}_t(0) - s^{k0}_t(1)]^2 \mu_t \,. \quad (21)$$

Its magnitude is jointly determined by country-specific risk prices, and heterogeneity of temporary and permanent risk exposures to global shocks including the fixed-to-floating regime shocks. Additionally, the likelihood that one of two floating countries pegs its currency to the target country also adds to the conditional variance.

[18] Higher order terms of state variables are excluded in all equations because they are at least an order of magnitude smaller than linear terms.

### 6.3. Model predictions

We now summarize the model's predictions for the regime-dependence of currency risk premia and skewness and for the impact of fixed-to-floating shocks on floating exchange rates.

#### 6.3.1. Currency risk premia

Our model implies that risk compensation in currency markets varies with currency regimes. The outsized unconditional return to the carry trade is almost exclusively accounted for by floating currency pairs $(i, j)$, in which either country $i$ or country $j$ (or both) allows its currency to float freely against some target currency. In contrast, carry trades based on fixed currency pairs generate nearly zero expected returns.

To see this, we show that the expected return associated with a pure floating currency pair (investing in a money market account denominated in floating currency $i$ and borrowing floating currency $j$) is

$$E_t \left[ rx_{t+1}^{ij} \,\middle|\, \xi_t^i = 1, \xi_t^j = 1 \right] = \frac{1}{2}(\delta^j - \delta^i) z_t^w + (\eta^j - \eta^i)\lambda_t + \frac{1}{2}(\gamma + \kappa)(z_t^j - z_t^i)\,, \tag{22}$$

and the interest rate differential between currencies $i$ and $j$ is

$$\begin{aligned} r_t^i(1) - r_t^j(1) = \frac{1}{2}(\delta^j - \delta^i) z_t^w + \left[ (\sqrt{\eta^j} - \sqrt{\eta^i}) + (\eta^j - \eta^i) \right] \lambda_t + \left[ \chi - \frac{1}{2}(\gamma + \kappa) \right] (z_t^i - z_t^j) \\ + [s_t^{ij}(0) - s_t^{ij}(1)]\mu_t\,. \end{aligned} \tag{23}$$

Focusing on the permanent heterogeneity in risk prices, we find a positive cross-sectional correlation between interest rate differentials and currency risk premia (consistent with the prediction in LRV): the larger the dispersion of risk exposures between the floating country and the target country, $\delta^j > \delta^i$ and $\eta^j > \eta^i$, the higher are the interest rate differential and expected return. This cross-sectional correlation contributes to the profitability of base-neutral carry trade strategies.

Turning to the temporary heterogeneity in risk prices, we find a positive time-series correlation between interest rate differentials and currency risk premia (consistent with the failure of the UIP) since the second inequality in (17) implies $\chi < \frac{1}{2}(\gamma+\kappa)$. This time-series correlation contributes to the profitability of base carry trade strategies.

Similarly, the expected return associated with a mixed floating pair $(i, j)$ (investing in a money market account denominated in floating currency $i$ and borrowing a fixed currency $j$) is

$$E_t\left[rx_{t+1}^{ij}\,\middle|\,\xi_t^i = 1, \xi_t^j = 0\right] = \frac{1}{2}(\delta^0 - \delta^i)z_t^w + (\eta^0 - \eta^i)\lambda_t + \frac{1}{2}(\gamma^0 + \kappa^0)z_t^j - \frac{1}{2}(\gamma + \kappa)z_t^i\,. \tag{24}$$

The interest rate differential between currencies $i$ and $j$ is

$$\begin{aligned} r_t^i(1) - r_t^j(0) = {} & \frac{1}{2}(\delta^0 - \delta^i)z_t^w + \left[(\sqrt{\eta^0} - \sqrt{\eta^i}) + (\eta^0 - \eta^i)\right]\lambda_t + \left[\chi - \frac{1}{2}(\gamma+\kappa)\right]z_t^i - \left[\chi - \frac{1}{2}(\gamma^0+\kappa^0)\right]z_t^j \\ & + [s_t^{i0}(0) - s_t^{i0}(1)]\mu_t - [s_t^{j0}(1) - s_t^{j0}(0)]\lambda_t\,. \end{aligned} \tag{25}$$

Again from the permanent heterogeneity in risk exposures, we find positive cross-sectional correlation between interest rate differentials and currency risk premia (consistent with the prediction in LRV): the larger the dispersion of risk exposures between the floating country and the fixed country, $\delta^0 > \delta^i$ and $\eta^0 > \eta^i$, the higher are expected returns to the carry trade. In particular, this mixed floating pair $(i, j)$ delivers lower expected returns than a pure floating pair $(i, k)$ if the low interest rate country with a floating currency $k$ has larger permanent exposures to global shocks, i.e., $\delta^k > \delta^0$ and $\eta^k > \eta^0$.

From the temporary heterogeneity in risk prices, we find a positive time-series correlation between interest rate differentials and currency risk premia (consistent with the failure of the UIP) given the second inequality in (17).

In contrast, the expected return associated with a fixed currency pair $(i, j)$ is

$$E_t \left[ rx_{t+1}^{ij} \,\middle|\, \xi_t^i = 0, \xi_t^j = 0 \right] = \frac{1}{2}(\gamma^0 + \kappa^0)(z_t^j - z_t^i) \,, \tag{26}$$

The corresponding interest rate differential is

$$r_t^i(0) - r_t^j(0) = \left[ \chi - \frac{1}{2}(\gamma^0 + \kappa^0) \right] (z_t^j - z_t^i) + [s_t^{ij}(1) - s_t^{ij}(0)]\lambda_t \,. \tag{27}$$

Permanent heterogeneity in risk exposures of fixed currency pairs has a negligible impact on currency risk premia and interest rate differentials. In addition, interest rate differentials associated with fixed currency pairs are mainly driven by a devaluation premium. Hence, the base-neutral carry trade strategy based on fixed currency pairs is not profitable. Furthermore, the first inequality in (17) that $\chi > \frac{1}{2}(\gamma^0 + \kappa^0)$ implies a negative but near-zero time-series correlation between interest rate differentials and currency risk premia, leading to unprofitable base carry trade strategies. This near-zero time-series correlation is consistent with the UIP.

#### 6.3.2. Skewness

We now show how conditional skewness varies with exchange rate regimes. We first note that our model introduces non-Gaussianity to exchange rates via two channels: i) the idiosyncratic regime shock that corresponds to the likelihood of a fixed currency pair starting to float or a floating currency pair starting to peg, and is represented by the regime-dependence of each country's pricing kernel, $\Lambda_t^i(\xi_t^i)$; and ii) the systematic regime shock that corresponds to the impact on floating currencies of fixed-to-floating regime shifts in the fixed currency universe, and is represented by the jump component in pricing kernels, $J_t^i$.

The conditional skewness of a pure floating currency pair, driven by both the idiosyncratic and systematic regime shocks, is

$$Skew_t\left[rx^{ij}_{t+1}\,\middle|\,\xi^i_t=\xi^j_t=1\right]=\frac{\left[s^{ij}_t(1)-s^{ij}_t(0)\right]^3\mu_t-\left[(\sqrt{\eta^j}-\sqrt{\eta^i})^3+2\sqrt{\eta^j\eta^i}(\sqrt{\eta^j}-\sqrt{\eta^i})\right]\lambda_t}{\left\{Var_t[\Delta s^{ij}_{t+1}\,\middle|\,\xi^i_t=\xi^j_t=1]\right\}^{\frac{3}{2}}}. \tag{28}$$

When $\eta^j>\eta^i$ such that the interest rate differential is positive, the systematic regime shock tends to reduce the skewness of floating currencies. However, high interest rate currencies tend to depreciate (appreciate) against low interest rate currencies if their regime switches from fixed (floating) to floating (fixed) such that $s^{ij}_t(1)-s^{ij}_t(0)>0$, and therefore the idiosyncratic regime shock tends to increase the skewness. Overall, the sign of the skewness for floating currencies is indeterminate. Furthermore, the skewness tends to be of small magnitude because the variance is relatively large (Eq. (20)).

In contrast, the skewness of a fixed currency pair is

$$Skew_t\left[rx^{ij}_{t+1}\,\middle|\,\xi^i_t=\xi^j_t=0\right]=\frac{-\left[s^{ij}_t(1)-s^{ij}_t(0)\right]^3\lambda_t}{\left\{Var_t[\Delta s^{ij}_{t+1}\,\middle|\,\xi^i_t=\xi^j_t=0]\right\}^{\frac{3}{2}}}, \tag{29}$$

which is negative. The skewness of a fixed currency pair is only influenced by the idiosyncratic regime shock because countries with pegged currencies have symmetric exposure to the systematic regime shock. Moreover, the skewness tends to be of large magnitude because the variance is relatively small (Eq. (19)).

#### 6.3.3. Impact of regime shocks

Our model implies that fixed regime currencies switching to a floating regime negatively impact carry trade returns of floating currency pairs. In other words, the collapse of currency pegs results in negative shocks to carry trade returns even when the strategy is ex ante constructed using floating currency pairs.

For simplicity, we consider the case in which neither currency in the floating pair changes regime from time $t$ to $t+1$. Conditional on the realizations of fixed-to-floating regime switches, i.e. $\nu_{t+1} = 1$, the average impact on the depreciation of currency $i$ against currency $j$ is

$$\Delta E_{t+1}\left[-\Delta s_{t+1}^{ij}\,\middle|\,\nu_{t+1}=1\right] = \begin{cases} (\sqrt{\eta^i} - \sqrt{\eta^j})(1-\lambda_t) < 0, & \text{if } \xi_t^i = \xi_{t+1}^i = 1,\, \xi_t^j = \xi_{t+1}^j = 1\,, \\ (\sqrt{\eta^i} - \sqrt{\eta^0})(1-\lambda_t) < 0, & \text{if } \xi_t^i = \xi_{t+1}^i = 1,\, \xi_t^j = \xi_{t+1}^j = 0\,. \end{cases} \tag{30}$$

Note that when $\eta^j > \eta^0 > \eta^i$, high-interest rate currencies depreciate relative to low-interest rate currencies, and hence fixed-to-floating switches induce a negative shock to carry trade returns. In contrast, in the absence of heterogeneity in exposures to the regime shocks, i.e., $\eta^i = \eta^j$, there would be no impact of fixed-to-floating regime shocks on the returns of floating currency pairs.

To summarize, the addition of regime-dependence and regime shocks to the LRV model gives us predictions which are fully consistent with our empirical results documented in sections 4 and 5 above.

## 7. Conclusion

In this paper, we document the long run performance of the carry trade using a new foreign exchange dataset covering the history of established currency trading from 1919 to the present. Using this database we first confirm that the carry trade generates robustly significant long run performance. This evidence is invariant across different weighting schemes for the carry trade strategy and after transaction costs are deducted.

Our key contribution to the literature is to examine how the risk and return of the carry trade are related to currency regimes over this long run sample period. We report two main findings.

First, we find carry trade returns are related to both the time-series and cross-sectional variation of exchange rate regimes. The superior carry trade performance is attributable exclusively to floating currency pairs. The average annualized gross excess return is 9.46% per annum and the Sharpe ratio is 0.61. In contrast, the fixed carry trade is not profitable. Although not as large as in the case of the floating carry trade, there is still a statistically significant carry component of 2-3% to the fixed carry trade. However, this is fully offset by the exchange rate depreciation arising from currency peg collapses. As a result of the latter, fixed carry returns are negatively skewed. Importantly, the skewness of outsized floating carry returns is insignificantly different from zero in our long sample. This result contradicts the conclusion drawn from the analysis of the post-Bretton Woods era that outsized carry returns represent compensation to investors for bearing negative skewness.

Second, exchange rate regime shifts offer a potential channel to explain the positive mean return to the carry trade. While a floating to fixed regime change does not affect carry returns, the collapse of a currency peg spills over onto floating currency pairs resulting in negative shocks to monthly carry trade returns of -123 basis points. Regime changes are sometimes clustered and we also conclude that the more fixed exchange rates switch to floating, the worse the return to carry trading (even if the investment universe comprises only ex ante floating rates). We find that a large proportion of the largest monthly losses to the floating carry trade strategy coincide with events in the financial and currency markets which are characterized by heightened uncertainty and are well documented in the secondary literature.

Finally, we extend the Lustig, Roussanov, and Verdelhan (2014) model such that it allows risk compensation in foreign exchange markets to depend on currency regimes in ways consistent with our empirical results. Currencies in a fixed regime are characterized by a symmetric exposure to a global risk factor and near-zero exposure to a local factor and as such earn very low carry returns.

Floating regime currencies have asymmetric exposure to the global factor and high interest rate currencies command a larger risk premium. Asymmetric jump processes in the pricing kernels allow regime shocks to affect currency returns. Consequently, the collapse of currency pegs results in negative shocks to carry returns even when the strategy is constructed using only ex ante floating currency pairs.

## REFERENCES


Accominotti, Olivier, and David Chambers, 2016, If you're so smart: John Maynard Keynes and currency speculation in the interwar years, *Journal of Economic History* 76, 342–386.

Aldcroft, Derek H., and Michael J. Oliver, 1998, *Exchange Rate Regimes in the Twentieth Century* (Edward Elgar).

Atkin, John, 2005, *The Foreign Exchange Market of London* (New York: Routledge).

Bekaert, Geert, and George Panayotov, 2015, Good carry, bad carry, Columbia Business School Research Paper No. 15-53.

Brunnermeier, Markus K., Stefan Nagel, and Lasse Heje Pedersen, 2008, Carry trade and currency crashes, *NBER Macroeconomics Annual* 23, 313–347.

Burnside, Craig, Martin Eichenbaum, Isaac Kleshchelski, and Sergio Rebelo, 2011a, Do peso problems explain the returns to the carry trade?, *Review of Financial Studies* 24, 853–891.

Burnside, Craig, Martin Eichenbaum, and Sergio Rebelo, 2011b, Carry trade and momentum in currency markets, *Annual Review of Financial Economics* 3.

Cen, Jason, and Ian W. Marsh, 2016, Foreign exchange trading strategies and rare events, Working Paper, Cass Business School.

Doskov, Nikolay, and Laurens Swinkels, 2015, Empirical evidence on the currency carry trade, 1900-2012, *Journal of International Money and Finance* 51, 370–389.

Eichengreen, Barry, 1996, *Globalizing Capital: A History of the International Monetary System* (Princeton: Princeton University Press).

Einzig, Paul, 1937, *The Theory of Forward Exchange* (MacMillan and Co., Limited, London).

Farhi, Emmanuel, Samuel Fraiberger, Romain Ranciere, and Adrien Verdelhan, 2013, Crash risk in currency markets, Working Paper, Harvard University.

Farhi, Emmanuel, and Xavier Gabaix, 2016, Rare disasters and exchange rates, *The Quarterly Journal of Economics* 131, 1–52.

Hai, Weike, Nelson C. Mark, and Yangru Wu, 1997, Understanding spot and forward exchange rate regressions, *Journal of Applied Econometrics* 12, 715–734.

Hassan, Tarek A, and Rui C. Mano, 2014, Forward and spot exchange rates in a multi-currency world, Technical report, National Bureau of Economic Research.

Ilzetzki, Ethan O., Carmen M. Reinhart, and Kenneth Rogoff, 2004, Exchange rate arrangements into the 21st century: Will the anchor currency hold?, Unpublished.

James, Harold, 2012, *Making the European Monetary Union* (Harvard University Press).

Jurek, Jakub W, 2014, Crash-neutral currency carry trades, *Journal of Financial Economics* 113, 325–347.

Keynes, John M., 1923, *A Tract on Monetary Reform* (London: Macmillan).

Koijen, Ralph S., Tobias J. Moskowitz, Lasse Heje Pedersen, and Evert B. Vrugt, 2017, Carry, *Journal of Financial Economics* (forthcoming).

Lustig, Hanno, Nikolai Roussanov, and Adrien Verdelhan, 2011, Common risk factors in currency markets, *Review of Financial Studies* 24, 3731–3777.

Lustig, Hanno, Nikolai Roussanov, and Adrien Verdelhan, 2014, Countercyclical currency risk premia, *Journal of Financial Economics* 111, 527–553.

Menkhoff, Lukas, Lucio Sarno, Maik Schmeling, and Andreas Schrimpf, 2012, Carry trades and global foreign exchange volatility, *Journal of Finance* 67, 681–718.

Miller, Hugh F. R., 1929, *The Foreign Exchange Market: A Practical Treatise on Post-war Foreign Exchange*, second edition (London: E. Arnold).

Osler, Carol L., 2012, Market microstructure and the profitability of currency trading, *Annual Review of Finance and Economics* 4, 469–495.

Phillips, H. W., 1926, *Modern Foreign Exchange and Foreign Banking* (Macdonald and Evans).

Rafferty, Barry, 2010, The returns to currency speculation and global currency realignment risk, Working Paper, Duke University.

Reinhart, Carmen M., and Kenneth S. Rogoff, 2011, From financial crash to debt crisis, *American Economic Review* 101, 1676–1706.

Sarno, Lucio, Paul Schneider, and Christian Wagner, 2012, Properties of foreign exchange risk premiums, *Journal of Financial Economics* 105, 279–310.

Shambaugh, Jay, 2004, The effects of fixed exchange rates on monetary policy, *Quarterly Journal of Economcis* 119, 301–352.

Verdelhan, Adrien, 2015, The share of systematic risk in bilateral exchange rates, *Journal of Finance* forthcoming.

## Appendix A. Equivalent representations of carry trade strategies

To help motivate our methodology of classifying exchange rate regimes and conditioning the carry trade on currency regimes with regard to currency pairs, we start with an alternative representation of the linear carry trade strategy, which is equivalent to the linear strategy presented in Section 3.

Formally, let the log excess return to the carry trade be

$$rx_{t+1} = \sum_{i,j} w_t^{i,j} \, rx_{t+1}^{i,j} \, , \tag{A1}$$

where the weight on each individual currency pair is denoted as $w_t^{i,j} = A_t \, fd_t^{i,j} = A_t \left( fd_t^{i,1} - fd_t^{j,1} \right)$ and where $A_t$ is an adjustment factor that alters the scale of investment.

We first verify that this new policy rule is indeed equivalent to the linear policy rule in terms of exchange rates against a given reference currency, indexed by "1", without loss of generality, as follows:

$$\begin{aligned} rx_{t+1} &= \sum_{i,j} w_t^{i,j} \, rx_{t+1}^{i,1} - \sum_{i,j} w_t^{i,j} \, rx_{t+1}^{j,1} \\ &= \sum_i \left( \sum_j w_t^{i,j} \right) rx_{t+1}^{i,1} + \sum_j \left( \sum_i w_t^{j,i} \right) rx_{t+1}^{j,1} \\ &= \sum_i \left( 2 \sum_j w_t^{i,j} \right) rx_{t+1}^{i,1} \, . \end{aligned}$$

Substituting in the definition of the linear weights regarding currency pairs, we obtain

$$rx_{t+1} = \sum_i \left( \sum_j 2 \, A_t (fd_t^{i,1} - fd_t^{j,1}) \right) rx_{t+1}^{i,1}$$

$$= \sum_i 2\, A_t N_t \left( fd_t^{i,1} - \overline{fd}_t^{1} \right) rx_{t+1}^{i,1}$$

$$\equiv \sum_i w_{\mathrm{Linear},t}^{i,1}\, rx_{t+1}^{i,1} \,,$$

where $N_t$ is the number of currencies available in the investment universe at time $t$. The linear strategy in terms of currency pairs is equivalent to the linear strategy in terms of currencies against a fixed reference currency as long as the scaling factors are defined as

$$A_t \equiv \frac{1}{2\, N_t} A_{\mathrm{Linear},t} \,. \tag{A2}$$

Similarly, we show below that the regime-dependent carry trade strategies can be implemented by an effective weighting scheme using only exchange rates against GBP:

$$\begin{aligned} rx_{t+1}^{z} &= \frac{1}{\omega_t^z} \sum_i \sum_j w_t^{i,j}\, rx_{t+1}^{i,j}\, \mathbf{I}_t^{i,j}(z) \\ &= \frac{1}{\omega_t^z} \sum_i \left( \sum_j w_t^{i,j} \mathbf{I}_t^{i,j}(z) \right) rx_{t+1}^{i,1} + \frac{1}{\omega_t^z} \sum_j \left( \sum_i w_t^{j,i} \mathbf{I}_t^{j,i}(z) \right) rx_{t+1}^{j,1} \\ &= \frac{2}{\omega_t^z} \sum_i \left( \sum_j w_t^{i,j} \mathbf{I}_t^{i,j}(z) \right) rx_{t+1}^{i,1} \\ &\equiv \sum_i w_{\mathrm{Eff},t}^{i,1}(z)\, rx_{t+1}^{i,1} \,, \end{aligned} \tag{A3}$$

where

$$w_{\mathrm{Eff},t}^{i,1}(z) = \frac{2}{\omega_t^z} \sum_j w_t^{i,j} \mathbf{I}_t^{i,j}(z) \,. \tag{A4}$$

When estimating regime-dependent carry trade returns, we need to take into account transaction costs. In section 3, we estimated the impact of transaction costs assuming linear strategy with a given reference currency. Of course, the equivalence of our new representation of the carry trade based on all currency pairs to the linear strategy representation with a given reference currency may not hold when transaction costs are taken into account. This is because the choice of the reference currency matters for the bid-ask spread and additionally because turnover rates will differ between these two representations. However, bid-ask spreads are not needed and we can implement the regime-dependent carry trade using exchange rates against GBP, recognizing the following relation:

$$rx^{z}_{t+1} = \sum_{i} w^{i,1}_{\mathrm{Eff},t}(z)\, rx^{i,1}_{t+1}\,, \tag{A5}$$

where

$$w^{i,1}_{\mathrm{Eff},t}(z) \equiv \frac{2}{\omega^{z}_{t}} \sum_{j} w^{i,j}_{t} \mathbf{I}^{i,j}_{t}(z)\,. \tag{A6}$$

Since the carry trade strategy conditioned on all regime-$z$ currency pairs can be implemented by the effective portfolio weights $w^{i,1}_{\mathrm{Eff},t}(z)$ using exchange rates against GBP, transaction costs associated with this effective weighting scheme are measured as

$$\tau_{\mathrm{spot},t}(z) = \sum_{i} \left| w^{i,1}_{\mathrm{Eff},t}(z) - w^{i,1}_{\mathrm{Eff},t-1}(z) \right| \,\mathrm{BAS}^{i,1}_{t}\,, \tag{A7}$$

for the spot market, and

$$\tau_{\mathrm{fwd},t}(z) = \sum_{i} \left| w^{i,1}_{\mathrm{Eff},t-1}(z) \right| \,\mathrm{BAF}^{i,1}_{t-1}\,, \tag{A8}$$

for the forward market.

## Figures and Tables

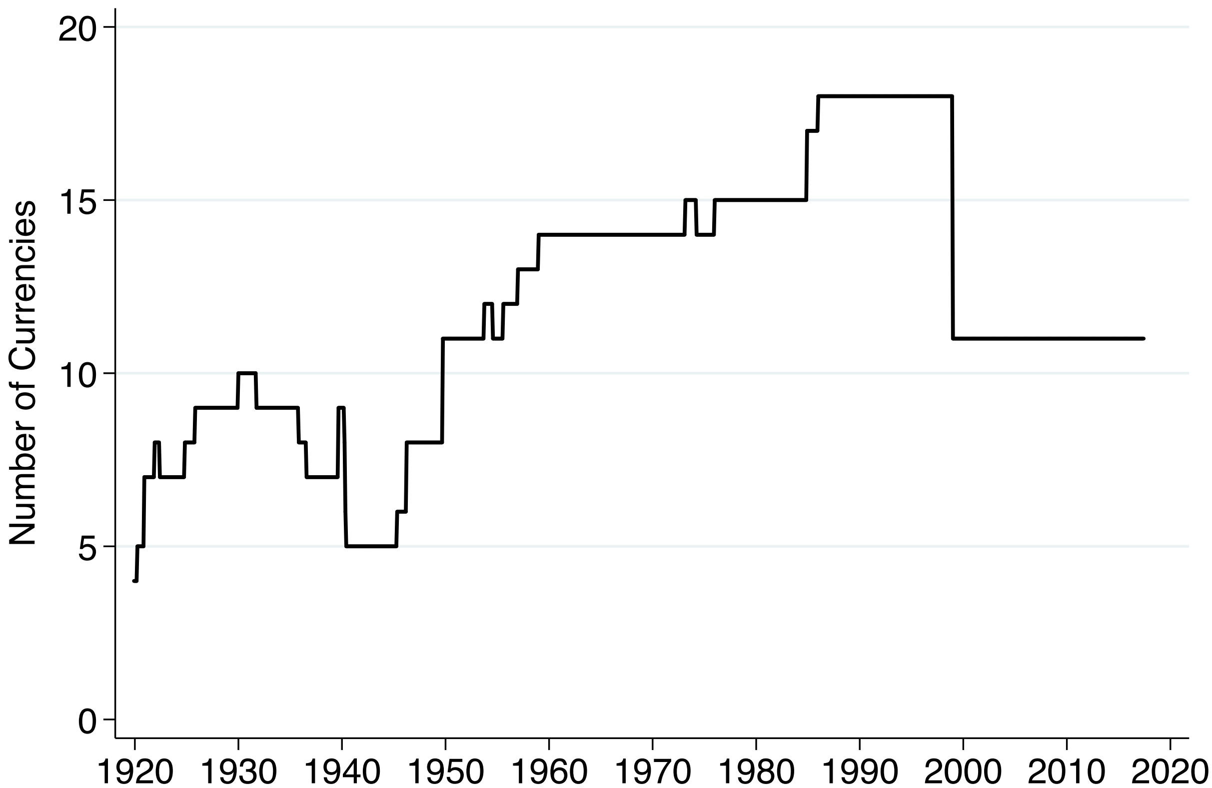



**Figure 1. Sample coverage.** This figure graphs the number of currencies in the investment universe that are used to construct the carry trade strategy over the period December, 1919 to July, 2017. Time is indexed as of the portfolio formation date.

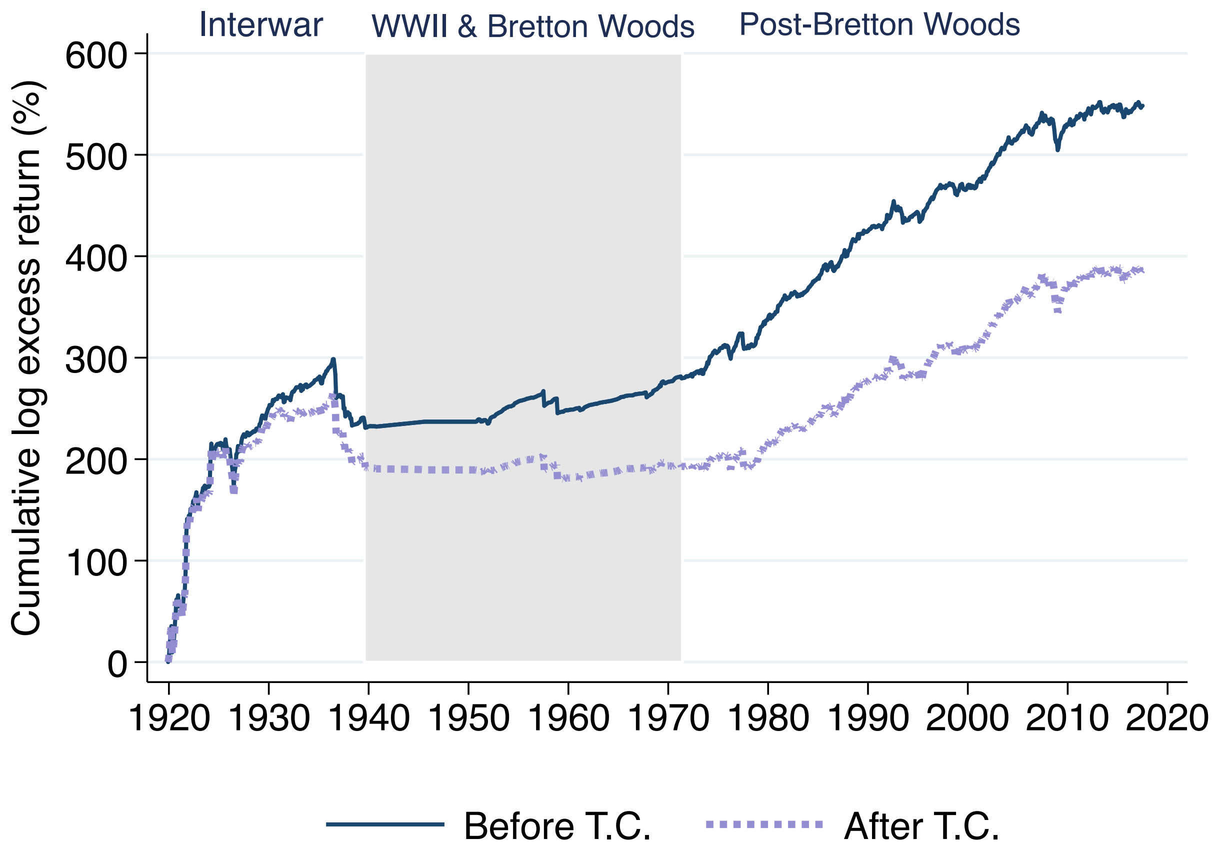



**Figure 2. Long-run carry trade returns.** This figure graphs the cumulative log excess return to the carry trade strategy from December, 1919 to July, 2017. The solid line indicates the return before transaction costs (T. C.) and the dashed line indicates the return after transaction costs.

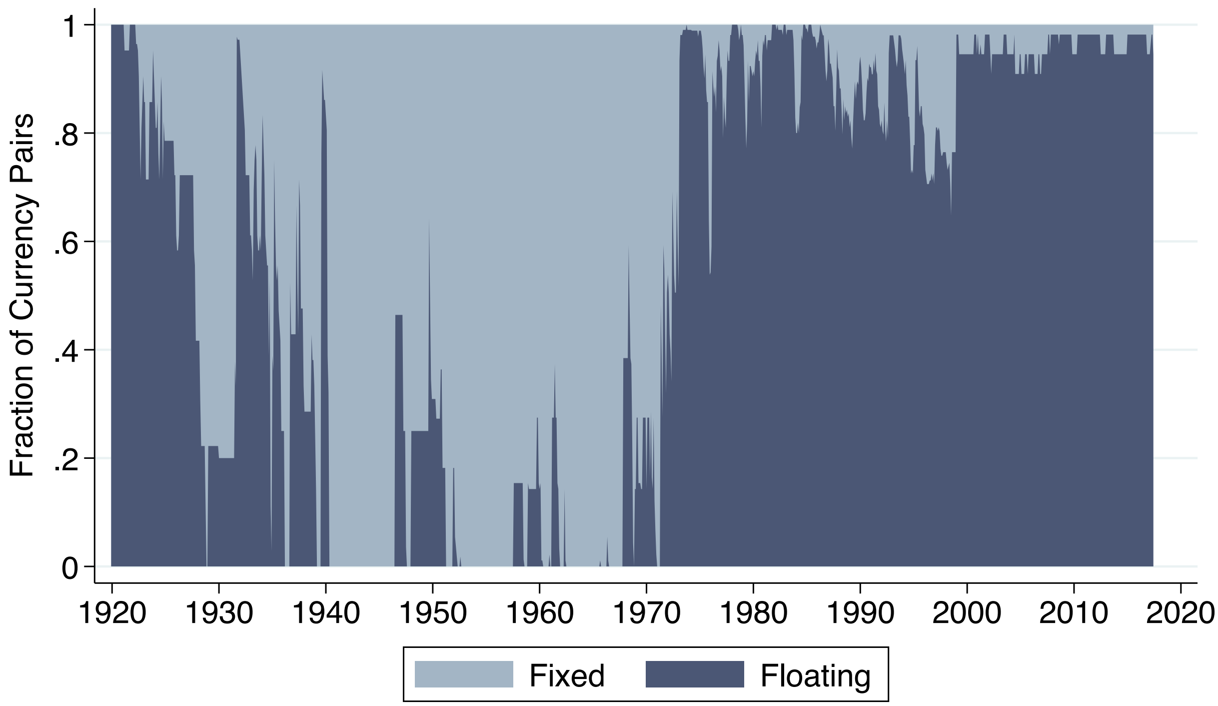
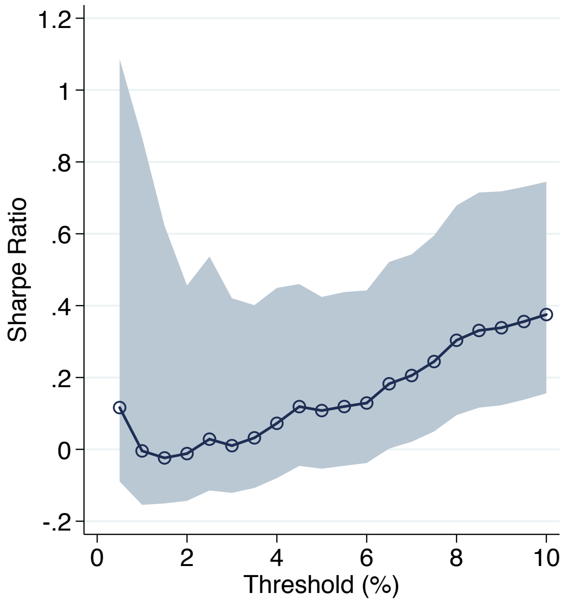
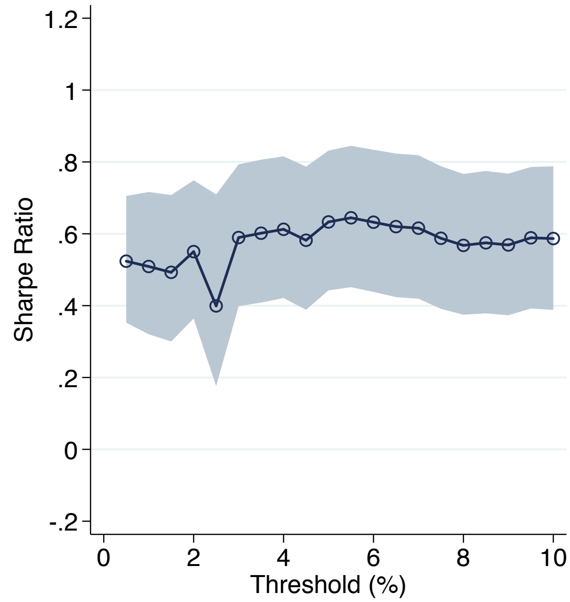


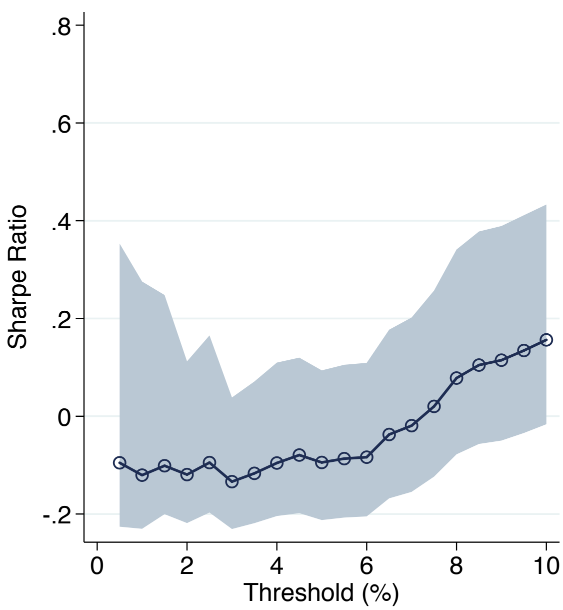

**Figure 3. Fraction of currency pairs in each of the Fixed and Floating exchange rate regimes.** This figure describes the fraction of currency pairs in the investment universe that are classified in each exchange rate regime based on a volatility threshold of 4% per annum over the period December, 1919 to July, 2017.



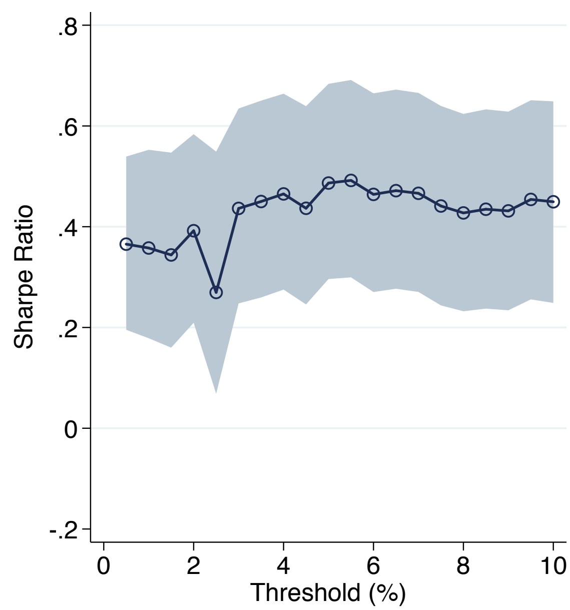

**(a)** Fixed regime, before transaction costs




**(b)** Floating regime, before transaction costs




**(c)** Fixed regime, after transaction costs




**(d)** Floating regime, after transaction costs

**Figure 4. Sharpe ratios of fixed and floating carry trades across different volatility thresholds.** This figure summarizes the Sharpe ratios (including the 5th and the 95th percentiles), before and after transaction costs, corresponding to the fixed regime (Panels (a) and (b)) and floating regime (Panels (c) and (d)) respectively, using a range of volatility thresholds to classify exchange rate regimes over the period December, 1919 to July, 2017.

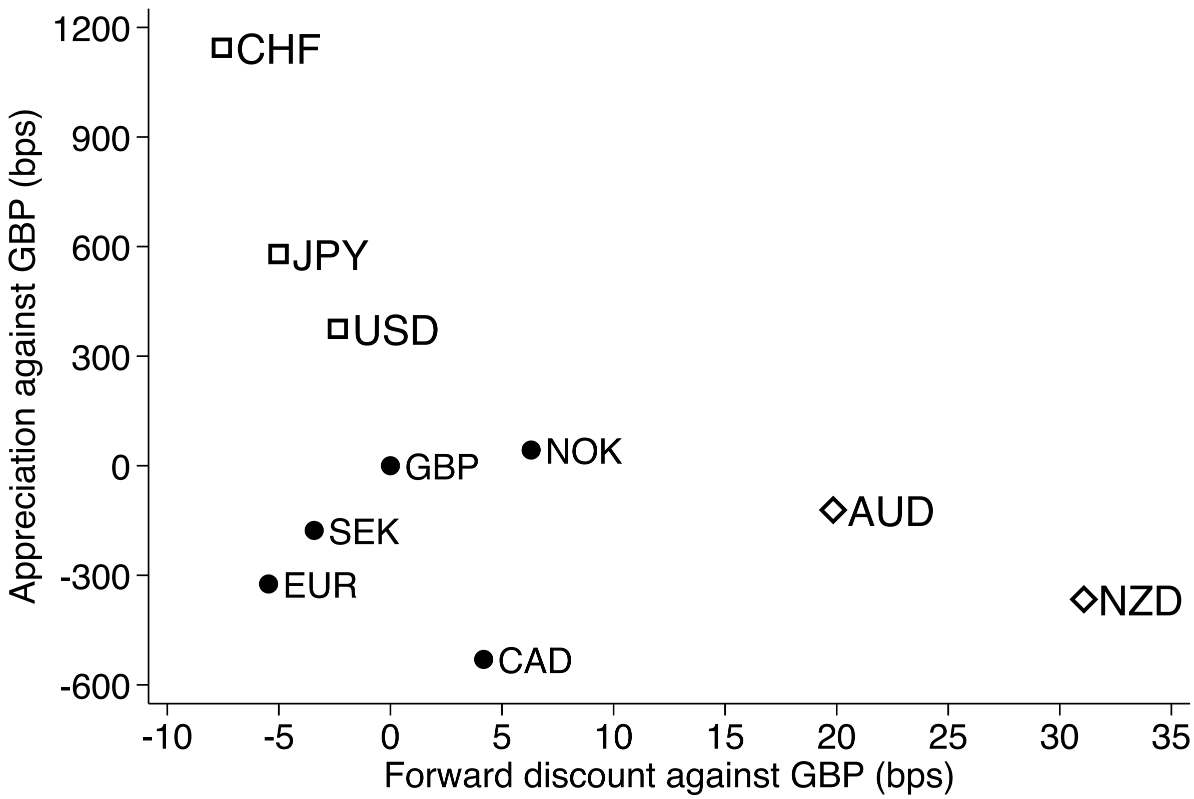



**Figure 5. Case study: Switzerland abandons euro cap** This figure is a scatter plot of the realized spot return against the forward discount of the G10 currencies against the pound sterling (GBP) in January 2015. In that month, the Swiss National Bank announced that it could no longer support the cap on the value of the Swiss franc against the euro.

**Table I**
**Sample Descriptive Statistics**

This table summarizes the number of monthly observations, the mean and standard deviation of log excess returns ($rx$, % per annum), one-month forward discounts ($fd$, % per annum), appreciation rate ($-\Delta s$, % per annum), spot bid-ask spreads (BAS, basis points), and forward swap bid-ask spreads (BAF, basis points) for 18 exchange rates against the pound sterling (GBP) over the period from December, 1919 to July, 2017. Panel A reports descriptive statistics for the full sample period, Panel B for the interwar period (1919:12-1939:07), Panel C for the World War II and Bretton Woods era (1939:08-1971:07), and Panel D for the post Bretton Woods era (1971:08-2017:07).

Panel A: Full sample

| | | $rx$ (%pa) | | $fd$ (%pa) | | $-\Delta s$ (%pa) | | BAS (bps) | | BAF (bps) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | obs | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Australia | 391 | 0.79 | 12.76 | 1.29 | 0.67 | -0.5 | 12.66 | 10 | 5 | 3 | 5 |
| Austria | 504 | -0.05 | 8.02 | -3.14 | 0.95 | 3.09 | 7.96 | 20 | 25 | 25 | 30 |
| Belgium | 877 | -0.38 | 11.01 | -0.88 | 1.22 | 0.50 | 10.95 | 13 | 13 | 11 | 11 |
| Canada | 1050 | 0.38 | 8.69 | -0.87 | 0.58 | 1.25 | 8.60 | 14 | 23 | 6 | 5 |
| Denmark | 813 | 0.99 | 7.46 | -0.26 | 0.83 | 1.25 | 7.35 | 7 | 6 | 10 | 12 |
| Euro | 222 | 0.34 | 8.39 | -1.07 | 0.26 | 1.40 | 8.38 | 6 | 2 | 1 | 1 |
| France | 879 | -1.75 | 14.44 | 1.17 | 2.12 | -2.92 | 14.66 | 9 | 8 | 10 | 10 |
| Germany | 652 | -3.93 | 15.5 | -3.15 | 1.04 | -0.78 | 15.40 | 15 | 21 | 8 | 11 |
| Italy | 712 | 0.57 | 11.76 | 1.69 | 1.60 | -1.12 | 11.52 | 10 | 12 | 14 | 17 |
| Japan | 532 | -0.46 | 12.41 | -3.86 | 1.46 | 3.40 | 12.36 | 22 | 18 | 4 | 4 |
| Netherlands | 866 | 0.34 | 7.52 | -1.89 | 0.95 | 2.23 | 7.45 | 14 | 15 | 9 | 8 |
| NewZealand | 391 | 3.38 | 12.54 | 2.38 | 1.14 | 0.99 | 12.53 | 15 | 11 | 6 | 12 |
| Norway | 820 | 0.74 | 7.50 | -0.21 | 0.87 | 0.95 | 7.43 | 9 | 9 | 9 | 11 |
| Portugal | 397 | 1.05 | 6.58 | 0.7 | 1.26 | 0.35 | 6.60 | 31 | 24 | 30 | 33 |
| Spain | 405 | 1.44 | 12.02 | 4.02 | 1.99 | -2.58 | 11.98 | 16 | 12 | 20 | 23 |
| Sweden | 934 | 0.12 | 7.39 | -0.46 | 0.86 | 0.58 | 7.36 | 14 | 16 | 9 | 10 |
| Switzerland | 1147 | 0.20 | 9.55 | -2.76 | 1.05 | 2.96 | 9.49 | 17 | 20 | 8 | 11 |
| USA | 1171 | -0.15 | 9.09 | -1.22 | 0.68 | 1.07 | 9.04 | 7 | 7 | 5 | 6 |

**Table I**
**Sample Descriptive Statistics (cont.)**

Panel B: Interwar period (1919:12-1939:07)

| | | $rx$ (%pa) | | $fd$ (%pa) | | $-\Delta s$ (%pa) | | BAS (bps) | | BAF (bps) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | obs | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Belgium | 224 | -3.19 | 17.50 | 1.06 | 1.74 | -4.24 | 17.47 | 11 | 17 | 7 | 11 |
| Canada | 115 | 1.58 | 7.12 | 0.37 | 0.26 | 1.21 | 7.15 | 14 | 19 | 7 | 3 |
| France | 236 | -3.33 | 20.37 | 4.04 | 3.39 | -7.37 | 20.92 | 9 | 7 | 7 | 8 |
| Germany | 109 | -20.39 | 33.37 | -0.09 | 1.03 | -20.30 | 32.98 | 19 | 38 | 7 | 7 |
| Italy | 191 | 0.95 | 18.86 | 2.12 | 2.11 | -1.18 | 18.54 | 20 | 19 | 14 | 19 |
| Netherlands | 224 | 2.74 | 8.78 | 0.90 | 1.00 | 1.84 | 8.77 | 10 | 18 | 6 | 7 |
| Spain | 129 | 1.59 | 16.10 | 3.34 | 2.13 | -1.75 | 15.85 | 19 | 17 | 21 | 22 |
| Switzerland | 212 | 1.26 | 11.21 | 0.49 | 1.08 | 0.77 | 11.21 | 11 | 20 | 6 | 10 |
| USA | 236 | -0.3 | 9.49 | 0.37 | 0.47 | -0.67 | 9.56 | 6 | 7 | 2 | 2 |

Panel C: WWII and Bretton Woods era (1939:08-1971:07)

| | | $rx$ (%pa) | | $fd$ (%pa) | | $-\Delta s$ (%pa) | | BAS (bps) | | BAF (bps) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | obs | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Austria | 175 | -0.17 | 3.87 | -1.5 | 0.57 | 1.33 | 3.87 | 7 | 4 | 26 | 22 |
| Belgium | 324 | 0.35 | 5.43 | -1.32 | 0.64 | 1.67 | 5.37 | 9 | 12 | 10 | 9 |
| Canada | 384 | 0.95 | 6.05 | -0.82 | 0.44 | 1.77 | 6.00 | 24 | 33 | 9 | 5 |
| Denmark | 262 | 0.28 | 1.62 | -0.02 | 0.48 | 0.30 | 1.56 | 4 | 6 | 15 | 14 |
| France | 314 | -3.07 | 13.57 | 0.93 | 1.20 | -3.99 | 13.65 | 7 | 8 | 14 | 12 |
| Germany | 214 | -0.41 | 3.99 | -2.31 | 0.80 | 1.90 | 3.99 | 3 | 4 | 5 | 3 |
| Italy | 192 | -0.20 | 3.63 | -1.09 | 0.75 | 0.89 | 3.53 | 3 | 1 | 11 | 13 |
| Netherlands | 313 | -0.57 | 3.31 | -1.69 | 0.56 | 1.12 | 3.27 | 9 | 14 | 9 | 7 |
| Norway | 269 | 0.15 | 3.05 | -0.55 | 0.33 | 0.70 | 3.04 | 6 | 14 | 13 | 13 |
| Portugal | 209 | 1.18 | 4.32 | -0.33 | 0.69 | 1.52 | 4.27 | 22 | 12 | 32 | 29 |
| Sweden | 383 | 0.14 | 3.76 | -0.80 | 0.41 | 0.94 | 3.74 | 18 | 24 | 12 | 8 |
| Switzerland | 384 | 0.23 | 7.04 | -1.82 | 0.57 | 2.05 | 7.01 | 17 | 23 | 10 | 7 |
| USA | 384 | 0.49 | 7.03 | -1.26 | 0.41 | 1.74 | 7.00 | 11 | 9 | 10 | 7 |

**Table I**
**Sample Descriptive Statistics (cont.)**

Panel D: Post-Bretton Woods era (1971:08-2017:07)

| | | $rx$ (%pa) | | $fd$ (%pa) | | $-\Delta s$ (%pa) | | BAS (bps) | | BAF (bps) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Country | obs | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Australia | 391 | 0.79 | 12.76 | 1.29 | 0.67 | -0.50 | 12.66 | 10 | 5 | 3 | 5 |
| Austria | 329 | 0.01 | 9.52 | -4.02 | 1.01 | 4.02 | 9.44 | 27 | 29 | 24 | 34 |
| Belgium | 329 | 0.82 | 9.26 | -1.77 | 1.12 | 2.59 | 9.09 | 17 | 7 | 14 | 11 |
| Canada | 551 | -0.26 | 10.38 | -1.16 | 0.68 | 0.89 | 10.26 | 7 | 5 | 3 | 5 |
| Denmark | 551 | 1.32 | 9.00 | -0.37 | 0.95 | 1.70 | 8.87 | 8 | 5 | 8 | 9 |
| Euro | 222 | 0.34 | 8.39 | -1.07 | 0.26 | 1.40 | 8.38 | 6 | 2 | 1 | 1 |
| France | 329 | 0.65 | 9.20 | -0.65 | 1.27 | 1.30 | 9.01 | 11 | 7 | 9 | 10 |
| Germany | 329 | -0.77 | 9.53 | -4.71 | 0.93 | 3.94 | 9.45 | 21 | 16 | 11 | 14 |
| Italy | 329 | 0.81 | 9.27 | 3.07 | 1.45 | -2.26 | 8.99 | 9 | 6 | 17 | 16 |
| Japan | 532 | -0.46 | 12.41 | -3.86 | 1.46 | 3.40 | 12.36 | 22 | 18 | 4 | 4 |
| Netherlands | 329 | -0.42 | 9.27 | -3.98 | 0.78 | 3.56 | 9.14 | 22 | 9 | 11 | 8 |
| NewZealand | 391 | 3.38 | 12.54 | 2.38 | 1.14 | 0.99 | 12.53 | 15 | 11 | 6 | 12 |
| Norway | 551 | 1.03 | 8.90 | -0.04 | 1.03 | 1.07 | 8.82 | 11 | 5 | 7 | 9 |
| Portugal | 188 | 0.90 | 8.42 | 1.84 | 1.61 | -0.94 | 8.47 | 40 | 30 | 27 | 36 |
| Spain | 276 | 1.37 | 9.57 | 4.35 | 1.91 | -2.97 | 9.69 | 14 | 8 | 20 | 24 |
| Sweden | 551 | 0.12 | 9.10 | -0.22 | 1.07 | 0.34 | 9.07 | 11 | 4 | 7 | 10 |
| Switzerland | 551 | -0.23 | 10.36 | -4.67 | 0.97 | 4.43 | 10.25 | 20 | 17 | 8 | 14 |
| USA | 551 | -0.52 | 10.14 | -1.87 | 0.79 | 1.35 | 10.03 | 5 | 5 | 2 | 2 |

**Table II**

**Long-run performance of the carry trade before and after transaction costs.**

This table presents descriptive statistics for the annualized return to the carry trade strategies based on different weighting schemes including: (i) *Linear* weights a currency in proportion to its forward discount relative to the cross-sectional average interest rate; (ii) *H1-L1* invests in the currency with the highest forward discount and shorts the currency with the lowest forward discount; (iii) $H_{25\%}$-$L_{25\%}$ takes a long position in currencies in the top quartile ranked by the forward discount and a short position in those in the bottom quartile; and (iv) *Rank* weights each currency in proportion to its rank in terms of its forward discount relative to the cross-sectional median rank. For each policy rule, we report the excess return, carry return, spot return, standard deviation, skewness, and the Sharpe ratio, both before and after transaction costs, as well as correlation with returns to the linearly weighted strategy. Standard errors, obtained by bootstrapping under the assumption of i.i.d. returns, are shown in parentheses. The sample runs from December 1919 to July, 2017.

| | Before Transaction Costs | | | | | | After Transaction Costs | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Corr |
| *Linear* | 5.61 | 6.43 | -0.81 | 10.74 | 1.54 | 0.52 | 3.96 | 5.28 | -1.32 | 10.74 | 1.49 | 0.37 | |
| | (1.29) | (0.34) | (1.33) | (0.97) | (1.60) | (0.10) | (1.29) | (0.30) | (1.34) | (0.97) | (1.59) | (0.10) | |
| *H1-L1* | 7.66 | 8.78 | -1.12 | 15.04 | 0.67 | 0.51 | 5.39 | 7.44 | -2.05 | 15.06 | 0.64 | 0.36 | 0.89 |
| | (1.73) | (0.45) | (1.77) | (0.98) | (0.89) | (0.10) | (1.73) | (0.40) | (1.77) | (0.98) | (0.89) | (0.10) | (0.01) |
| $H_{25\%}$-$L_{25\%}$ | 5.06 | 5.49 | -0.43 | 9.33 | 1.05 | 0.54 | 3.58 | 4.42 | -0.85 | 9.36 | 1.03 | 0.38 | 0.91 |
| | (1.07) | (0.27) | (1.09) | (0.63) | (0.83) | (0.10) | (1.08) | (0.24) | (1.09) | (0.63) | (0.83) | (0.10) | (0.01) |
| *Rank* | 4.84 | 5.18 | -0.34 | 8.73 | 0.81 | 0.55 | 3.36 | 4.13 | -0.77 | 8.76 | 0.79 | 0.38 | 0.94 |
| | (1.04) | (0.25) | (1.06) | (0.65) | (1.08) | (0.10) | (1.05) | (0.22) | (1.06) | (0.65) | (1.07) | (0.10) | (0.01) |

## Table III
**Performance of the carry trade conditional on exchange rate regimes.**

This table presents descriptive statistics for the annualized return to the carry trade strategies conditional on two exchange rate regimes. A currency pair is classified as in a fixed regime if its ex ante volatility is below 4% per annum and in a floating regime otherwise. For each regime, we report the excess return, carry return, spot return, standard deviation and the Sharpe ratio. Standard errors, obtained by bootstrapping under the assumption of i.i.d. returns, are shown in parentheses. The sample runs from December 1919 to July, 2017.

| | | Before Transaction Costs | | | | | | After Transaction Costs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. |
| Fixed | 1123 | 0.72 | 3.14 | -2.42 | 6.66 | -16.71 | 0.11 | -0.55 | 2.35 | -2.90 | 6.68 | -16.66 | -0.08 |
| | | (0.69) | (0.27) | (0.89) | (1.93) | (4.69) | (0.16) | (0.69) | (0.26) | (0.90) | (1.93) | (4.52) | (0.10) |
| Float | 925 | 9.46 | 8.70 | 0.76 | 15.47 | 0.48 | 0.61 | 7.19 | 7.25 | -0.06 | 15.46 | 0.30 | 0.47 |
| | | (1.75) | (0.40) | (1.76) | (1.24) | (1.13) | (0.12) | (1.76) | (0.35) | (1.76) | (1.26) | (1.20) | (0.12) |

**Table IV**
**Indirect impact of exchange rate regimes on carry trade performance.**

This table summarizes how the performance of the carry trade strategy conditional on the floating regime varies with the extent to which either currency in each floating pair is fixed to some other currency. We categorize floating currency pairs into three subgroups: (i) a *Low Mix* floating pair indicates that neither currency in the pair is fixed to any other currencies; (ii) a *Med Mix* floating pair indicates that either currency in the pair is fixed to less than half of the remaining currencies; and (iii) *High Mix* indicates that either currency in the pair is fixed to more than half of the remaining currencies. For each group, we report the annualized excess return, carry return, spot return, standard deviation and the Sharpe ratio. Standard errors, obtained by bootstrapping under the assumption of i.i.d. returns, are shown in parentheses. The sample runs from December 1919 to July, 2017.

| | | Before Transaction Costs | | | | | | After Transaction Costs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. |
| High Mix | 307 | 6.92 | 9.20 | -2.28 | 17.57 | -1.32 | 0.39 | 3.52 | 7.21 | -3.68 | 17.52 | -1.69 | 0.20 |
| | | (3.45) | (1.04) | (3.48) | (2.21) | (1.30) | (0.22) | (3.44) | (0.93) | (3.48) | (2.33) | (1.40) | (0.21) |
| Med Mix | 621 | 7.25 | 7.17 | 0.08 | 12.14 | 1.31 | 0.60 | 4.71 | 6.10 | -1.39 | 12.25 | 1.10 | 0.38 |
| | | (1.68) | (0.41) | (1.66) | (1.04) | (0.94) | (0.13) | (1.71) | (0.38) | (1.70) | (1.05) | (0.96) | (0.14) |
| Low Mix | 735 | 10.74 | 9.28 | 1.46 | 16.25 | 1.92 | 0.66 | 8.25 | 7.88 | 0.37 | 16.18 | 1.90 | 0.51 |
| | | (2.07) | (0.39) | (2.03) | (1.57) | (1.26) | (0.12) | (2.06) | (0.33) | (2.03) | (1.56) | (1.27) | (0.12) |

**Table V**

**Regime-dependent returns to the base carry trade strategies.**

This table presents descriptive statistics for the performance of the carry trade strategies conditional on fixed and floating exchange rate regimes for three base currencies, USD (Panel A), GBP (Panel B), and DEM (EUR) (Panel C). A currency pair is classified as in the fixed regime if its ex ante volatility is below 4% per annum and in the floating regime otherwise. For each regime, we report the annualized excess return, carry return, spot return, standard deviation and the Sharpe ratio. Standard errors, obtained by bootstrapping under the assumption of i.i.d. returns, are shown in parentheses. The sample runs from December 1919 to July 2017.

| | | Before Transaction Costs | | | | | | After Transaction Costs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. |
| Panel A: Average forward discount against USD | | | | | | | | | | | | | |
| Fixed | 704 | 0.75 | 1.22 | -0.47 | 3.58 | -4.86 | 0.21 | -0.42 | 0.40 | -0.82 | 3.66 | -4.90 | -0.11 |
| | | (0.46) | (0.09) | (0.48) | (0.50) | (1.50) | (0.15) | (0.47) | (0.09) | (0.49) | (0.50) | (1.43) | (0.12) |
| Float | 907 | 4.51 | 2.31 | 2.21 | 10.82 | 0.12 | 0.42 | 3.56 | 1.64 | 1.92 | 10.84 | 0.10 | 0.33 |
| | | (1.23) | (0.11) | (1.23) | (0.58) | (0.60) | (0.12) | (1.23) | (0.10) | (1.23) | (0.58) | (0.59) | (0.11) |
| Panel B: Average forward discount against GBP | | | | | | | | | | | | | |
| Fixed | 597 | -0.49 | 1.14 | -1.62 | 5.03 | -5.61 | -0.10 | -1.19 | 0.62 | -1.81 | 5.11 | -6.03 | -0.23 |
| | | (0.71) | (0.11) | (0.74) | (0.91) | (2.65) | (0.14) | (0.72) | (0.11) | (0.75) | (0.95) | (2.68) | (0.12) |
| Float | 905 | 3.58 | 2.05 | 1.53 | 10.21 | 0.94 | 0.35 | 2.87 | 1.53 | 1.34 | 10.20 | 0.91 | 0.28 |
| | | (1.16) | (0.10) | (1.15) | (0.69) | (0.81) | (0.11) | (1.16) | (0.09) | (1.15) | (0.69) | (0.81) | (0.11) |
| Panel C: Average forward discount against DEM (EUR) | | | | | | | | | | | | | |
| Fixed | 753 | 0.64 | 1.45 | -0.81 | 2.67 | 1.56 | 0.24 | -0.67 | 0.72 | -1.39 | 2.50 | -1.98 | -0.27 |
| | | (0.34) | (0.07) | (0.34) | (0.40) | (3.18) | (0.13) | (0.32) | (0.06) | (0.32) | (0.28) | (1.74) | (0.12) |
| Float | 733 | 5.90 | 3.11 | 2.79 | 13.54 | 3.75 | 0.44 | 4.66 | 2.20 | 2.47 | 13.56 | 3.69 | 0.34 |
| | | (1.74) | (0.12) | (1.73) | (1.69) | (1.60) | (0.11) | (1.74) | (0.10) | (1.73) | (1.69) | (1.62) | (0.11) |

**Table VI**

**Carry trade performance conditional on exchange rate volatility.**

This table summarizes how the performance of the carry trade varies with ex ante exchange rate volatility. All currency pairs are sorted into 6 categories by the cross rate volatility measured at the beginning of each month. The first two categories, i.e., volatility lower than 2% ([0, 2]) and volatility between 2% and 4% ([2, 4]), comprise currency pairs in the fixed regime. The remaining categories comprise floating currency pairs. For each volatility category, we report the annualized excess return, carry return, spot return, standard deviation and the Sharpe ratio. Standard errors, obtained by bootstrapping under the assumption of i.i.d. returns, are shown in parentheses. The sample runs from December 1919 to July, 2017.

| | | Before Transaction Costs | | | | | | After Transaction Costs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volatility | T | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. |
| [0, 2] | 923 | 0.07 | 2.14 | -2.07 | 7.00 | -21.64 | 0.01 | -0.83 | 1.54 | -2.36 | 7.01 | -21.66 | -0.12 |
| | | (0.80) | (0.31) | (1.06) | (2.80) | (6.07) | (0.19) | (0.80) | (0.30) | (1.06) | (2.80) | (5.82) | (0.10) |
| [2, 4] | 750 | 1.87 | 4.71 | -2.84 | 8.12 | -10.65 | 0.23 | -0.47 | 3.47 | -3.94 | 8.16 | -10.90 | -0.06 |
| | | (1.03) | (0.39) | (1.26) | (1.97) | (3.43) | (0.20) | (1.03) | (0.36) | (1.26) | (1.99) | (3.21) | (0.13) |
| [4, 6] | 811 | 5.32 | 6.70 | -1.38 | 8.35 | 0.19 | 0.64 | 3.03 | 5.44 | -2.41 | 8.30 | -0.20 | 0.37 |
| | | (1.01) | (0.39) | (0.95) | (0.78) | (1.38) | (0.13) | (1.01) | (0.34) | (0.96) | (0.77) | (1.34) | (0.13) |
| [6, 8] | 667 | 6.67 | 7.87 | -1.21 | 10.75 | -1.79 | 0.62 | 3.54 | 6.51 | -2.97 | 10.62 | -2.05 | 0.33 |
| | | (1.44) | (0.48) | (1.40) | (1.06) | (1.38) | (0.17) | (1.42) | (0.41) | (1.41) | (1.07) | (1.39) | (0.15) |
| [8, 12] | 629 | 8.10 | 8.46 | -0.36 | 16.54 | -2.00 | 0.49 | 4.43 | 7.03 | -2.60 | 16.52 | -2.16 | 0.27 |
| | | (2.29) | (0.45) | (2.25) | (1.64) | (1.17) | (0.16) | (2.28) | (0.38) | (2.27) | (1.67) | (1.18) | (0.15) |
| $> 12$ | 695 | 13.66 | 11.91 | 1.74 | 25.55 | 0.20 | 0.53 | 10.03 | 10.21 | -0.18 | 25.52 | 0.10 | 0.39 |
| | | (3.37) | (0.62) | (3.41) | (1.80) | (0.75) | (0.14) | (3.37) | (0.56) | (3.41) | (1.81) | (0.77) | (0.13) |

**Table VII**
**Regime-dependent carry trade returns based on alternative classifications of exchange rate regimes.**

This table presents descriptive statistics for the performance of the carry trade strategies conditional on fixed and floating exchange rate regimes based on alternative classifications, i.e., Shambaugh (2004) which measures volatility as the absolute difference between the highest and lowest exchange rate over the past year (Panel A) and Menkhoff et al. (2012) which measures volatility as the mean absolute daily return within each month (Panel B). A currency pair is classified as in the fixed regime if its ex ante volatility is below 4% per annum and in the floating regime otherwise. For each regime, we report the annualized excess return, carry return, spot return, standard deviation and the Sharpe ratio. Standard errors, obtained by bootstrapping under the assumption of i.i.d. returns, are shown in parentheses. The sample runs from December 1919 to July, 2017.

| | | Before Transaction Costs | | | | | | After Transaction Costs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. |
| Panel A: Shambaugh (2004) | | | | | | | | | | | | | |
| Fixed | 1105 | 0.87 | 2.82 | -1.95 | 5.64 | -15.89 | 0.15 | -0.43 | 1.98 | -2.41 | 5.68 | -15.85 | -0.08 |
| | | (0.59) | (0.22) | (0.73) | (1.60) | (4.84) | (0.17) | (0.59) | (0.21) | (0.73) | (1.60) | (4.54) | (0.10) |
| Float | 1004 | 8.23 | 8.47 | -0.23 | 15.53 | -0.43 | 0.53 | 5.93 | 6.96 | -1.03 | 15.48 | -0.82 | 0.38 |
| | | (1.68) | (0.37) | (1.70) | (1.31) | (1.25) | (0.12) | (1.68) | (0.33) | (1.70) | (1.35) | (1.33) | (0.12) |
| Panel B: Menkhoff et al. (2012) | | | | | | | | | | | | | |
| Fixed | 1157 | 1.39 | 4.48 | -3.09 | 6.33 | -11.21 | 0.22 | -0.48 | 3.47 | -3.95 | 6.36 | -11.17 | -0.07 |
| | | (0.64) | (0.23) | (0.78) | (1.35) | (3.82) | (0.15) | (0.64) | (0.22) | (0.78) | (1.34) | (3.71) | (0.10) |
| Float | 737 | 11.69 | 9.58 | 2.11 | 18.01 | 0.86 | 0.65 | 8.98 | 8.18 | 0.80 | 17.90 | 0.65 | 0.50 |
| | | (2.31) | (0.43) | (2.31) | (1.50) | (1.05) | (0.13) | (2.30) | (0.39) | (2.31) | (1.52) | (1.12) | (0.13) |

**Table VIII**

**Regime-dependent carry trade returns over sub-periods**

This table presents descriptive statistics for the performance of the carry trade strategies conditional on fixed and floating exchange rate regimes for each of the three sub-periods, i.e., the interwar period (Panel A), World War II and the Bretton Woods period (Panel B), and the post Bretton Woods period (Panel C). A currency pair is classified as in the fixed regime if its ex ante volatility is below 4% per annum and in the floating regime otherwise. For each regime, we report the annualized excess return, carry return, spot return, standard deviation and the Sharpe ratio. Standard errors, obtained by bootstrapping under the assumption of i.i.d. returns, are shown in parentheses. The sample runs from December 1919 to July, 2017.

| | | Before Transaction Costs | | | | | | After Transaction Costs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. |
| Panel A: Interwar Period (1919:12-1939:7) | | | | | | | | | | | | | |
| Fixed | 214 | -1.29 | 5.74 | -7.03 | 13.41 | -10.03 | -0.10 | -2.62 | 4.98 | -7.60 | 13.44 | -10.00 | -0.20 |
| | | (3.14) | (1.27) | (4.26) | (5.13) | (2.89) | (0.32) | (3.15) | (1.25) | (4.26) | (5.12) | (2.79) | (0.25) |
| Float | 223 | 19.79 | 10.55 | 9.24 | 27.52 | 0.07 | 0.72 | 17.10 | 9.03 | 8.07 | 27.56 | -0.02 | 0.62 |
| | | (6.33) | (0.97) | (6.46) | (2.73) | (0.76) | (0.24) | (6.34) | (0.90) | (6.45) | (2.80) | (0.80) | (0.24) |
| Panel B: World War II and the Bretton Woods period (1939:8-1971:7) | | | | | | | | | | | | | |
| Fixed | 384 | 1.27 | 2.70 | -1.43 | 4.00 | -10.79 | 0.32 | -0.19 | 1.55 | -1.75 | 4.02 | -11.08 | -0.05 |
| | | (0.70) | (0.17) | (0.75) | (1.25) | (3.41) | (0.46) | (0.70) | (0.13) | (0.75) | (1.28) | (3.34) | (0.25) |
| Float | 151 | 5.54 | 7.42 | -1.88 | 9.24 | 1.81 | 0.60 | 1.90 | 5.04 | -3.14 | 8.88 | 0.82 | 0.21 |
| | | (2.60) | (1.71) | (1.79) | (1.91) | (2.23) | (0.28) | (2.49) | (1.49) | (1.84) | (1.82) | (2.38) | (0.28) |
| Panel C: Post Bretton Woods period (1971:8-2017:6) | | | | | | | | | | | | | |
| Fixed | 525 | 1.14 | 2.41 | -1.27 | 3.14 | -3.87 | 0.36 | 0.03 | 1.86 | -1.83 | 3.20 | -4.82 | 0.01 |
| | | (0.47) | (0.18) | (0.50) | (0.47) | (1.81) | (0.20) | (0.48) | (0.15) | (0.51) | (0.51) | (1.79) | (0.16) |
| Float | 551 | 6.35 | 8.30 | -1.95 | 8.27 | -0.87 | 0.77 | 4.63 | 7.14 | -2.51 | 8.30 | -0.89 | 0.56 |
| | | (1.23) | (0.26) | (1.24) | (0.38) | (0.21) | (0.17) | (1.23) | (0.22) | (1.24) | (0.39) | (0.22) | (0.16) |

**Table IX**

**Variation of regime-dependent carry trade returns with the fraction of fixed currency pairs.**

This table presents descriptive statistics for the performance of the carry trade strategies conditional on fixed and floating exchange rate regimes for each of the two subsamples defined by whether the fraction of fixed currency pairs in a month is above 0.5 (Panel A) or below 0.5 (Panel B). A currency pair is classified as in the fixed regime if its ex ante volatility is below 4% per annum and in the floating regime otherwise. For each regime, we report the annualized excess return, spot return, carry return, standard deviation and the Sharpe ratio. Standard errors, obtained by bootstrapping under the assumption of i.i.d. returns, are shown in parentheses. The sample runs from December 1919 to July, 2017.

| | | Before Transaction Costs | | | | | | After Transaction Costs | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. | Ex.Ret | Carry | Spot | St.Dev | Skew | S.R. |
| Panel A: Fraction of fixed currency pairs $> 0.5$ | | | | | | | | | | | | | |
| Fixed | 474 | 0.55 | 3.46 | -2.91 | 5.52 | -8.92 | 0.10 | -0.82 | 2.38 | -3.20 | 5.57 | -8.97 | -0.15 |
| | | (0.87) | (0.31) | (1.06) | (1.28) | (1.65) | (0.22) | (0.88) | (0.29) | (1.06) | (1.29) | (1.62) | (0.15) |
| Float | 228 | 9.99 | 9.67 | 0.32 | 18.97 | -1.33 | 0.53 | 6.57 | 7.50 | -0.93 | 18.89 | -1.67 | 0.35 |
| | | (4.42) | (1.38) | (4.47) | (2.74) | (1.46) | (0.27) | (4.40) | (1.25) | (4.46) | (2.88) | (1.54) | (0.26) |
| Panel B: Fraction of fixed currency pairs $< 0.5$ | | | | | | | | | | | | | |
| Fixed | 649 | 0.85 | 2.92 | -2.07 | 7.38 | -18.52 | 0.11 | -0.36 | 2.33 | -2.69 | 7.39 | -18.53 | -0.05 |
| | | (1.01) | (0.40) | (1.34) | (3.04) | (7.23) | (0.28) | (1.01) | (0.39) | (1.34) | (3.04) | (6.86) | (0.17) |
| Float | 697 | 9.28 | 8.38 | 0.90 | 14.16 | 1.86 | 0.66 | 7.39 | 7.17 | 0.22 | 14.17 | 1.82 | 0.52 |
| | | (1.86) | (0.27) | (1.85) | (1.31) | (1.12) | (0.12) | (1.87) | (0.23) | (1.85) | (1.30) | (1.12) | (0.12) |

**Table X**

**Impact of exchange rate regime changes on carry trade returns.**

This table presents results for the impact of regime changes on monthly returns to the carry trade (basis points). We examine the covariation between shocks to exchange rate regimes and shocks to the carry trade return by running time-series regressions of the realized spot returns for the floating and fixed carry trades respectively on variables indicating exchange rate regime changes in the investment universe. We model regime changes, both fixed to floating and vice versa, by dummy variables (Panel A) and the fraction of currency pairs experiencing regime shifts (Panel B). Statistical significance is indicated by * , ** , and ***, for the level of 10%, 5%, and 1%, respectively. The sample runs from December 1919 to July, 2017.

| | Float | | | Fixed | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| **Panel A: Dummy variables for regime changes** | | | | | | |
| *Constant* | 26 | 1 | 26 | -9 | -20** | -7 |
| $D_{\text{Fixed}\rightarrow\text{Float}}$ | -123*** | | -123*** | -76*** | | -75*** |
| $D_{\text{Float}\rightarrow\text{Fixed}}$ | | -5 | 1 | | -13 | -6 |
| **Panel B: Fraction of currency pairs experiencing regime changes** | | | | | | |
| *Constant* | 15 | 0 | 18 | -12 | -24*** | -11 |
| $P_{\text{Fixed}\rightarrow\text{Float}}$ | -204*** | | -209*** | -184*** | | -186*** |
| $P_{\text{Float}\rightarrow\text{Fixed}}$ | | -26 | -50 | | -10 | -27 |

**Table XI**
**Robustness tests of the impact of exchange rate regime changes.**

This table presents results for the impact of regime changes on monthly returns to the carry trade (basis points) using modified regime change indicators. We examine the covariation between shocks to exchange rate regimes and shocks to the carry trade return by running time-series regressions of the realized spot returns for the floating and fixed carry trades respectively on different definitions of the dummy variables indicating exchange rate regime changes in the investment universe. In Panel A volatility must increase by at least 1% to qualify for a regime change and in Panel B by at least 2%. In Panel C, we exclude an extreme carry return outlier for July to August, 1931. Statistical significance is indicated by $*$ , $**$ , and $***$, for the level of 10%, 5%, and 1%, respectively. The sample runs from December 1919 to July, 2017.

| | Float | | | Fixed | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| | **Panel A: $\Delta\sigma_t^{i,j} > 1$ to qualify for Fixed-Floating switch** | | | | | |
| *Constant* | 22 | 0 | 25 | -9 | -20** | -5 |
| $D_{\text{Fixed}\rightarrow\text{Float}}$ | -204*** | | -205*** | -142*** | | -142*** |
| $D_{\text{Float}\rightarrow\text{Fixed}}$ | | -5 | -8 | | -13 | -12 |
| | **Panel B: $\Delta\sigma_t^{i,j} > 2$ to qualify for Fixed-Floating switch** | | | | | |
| *Constant* | 19 | 1 | 23 | -9 | -20** | -5 |
| $D_{\text{Fixed}\rightarrow\text{Float}}$ | -241*** | | -242*** | -179*** | | -180*** |
| $D_{\text{Float}\rightarrow\text{Fixed}}$ | | -5 | -12 | | -13 | -16 |
| | **Panel C: Excluding the return from 1931:7 to 1931:8** | | | | | |
| *Constant* | 26** | 9 | 29 | -9 | -20** | -8 |
| $D_{\text{Fixed}\rightarrow\text{Float}}$ | -101*** | | -101*** | -76*** | | -76*** |
| $D_{\text{Float}\rightarrow\text{Fixed}}$ | | -13 | -8 | | -13 | -6 |

**Table XII**
**Impact of fixed-to-floating regime shifts controlling for volatility risk.**

This table presents results for the impact of regime changes on monthly returns to the carry trade (basis points) controlling for volatility risks in the US equity market and in the foreign exchange market of floating currency pairs. We examine the covariation between shocks to exchange rate regimes and shocks to the carry trade return by running time-series regressions of the realized spot returns for the floating and fixed carry trades respectively on variables indicating exchange rate regime changes in the investment universe. In Panel A, we control for changes in US equity market volatility. In Panel B, we control for changes in average floating exchange rate volatility. Statistical significance is indicated by * , ** , and ***, for the level of 10%, 5%, and 1%, respectively. The sample runs from December 1919 to July, 2017.

Panel A: Control for changes in US equity market volatility

| | Float | | | Fixed | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| $Constant$ | -1 | 26 | 19 | -24*** | -9 | -12 |
| $dEQVol$ | -3* | -3* | -3* | 0 | 0 | 0 |
| $D_{\text{Fixed}\to\text{Float}}$ | | -121*** | | | -76*** | |
| $P_{\text{Fixed}\to\text{Float}}$ | | | -197** | | | -185*** |

Panel B: Control for changes in average floating exchange rate volatility

| | Float | | | Fixed | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (1) | (2) | (3) |
| $Constant$ | -4 | 22 | 10 | -16*** | 0 | -1 |
| $dFXVol$ | -10** | -8 | -9* | -1 | 0 | 0 |
| $D_{\text{Fixed}\to\text{Float}}$ | | -113*** | | | -64*** | |
| $P_{\text{Fixed}\to\text{Float}}$ | | | -185** | | | -168*** |

## Table XIII
**Descriptive statistics of floating carry trade monthly returns during fixed-to-floating regime switches.**

$T$, $T(+)$, and $T(-)$ are the total number of monthly returns, the number of positive monthly returns and the number of negative monthly returns. Mean, Mean(+), and Mean($-$) represent the sample averages of monthly returns, positive monthly returns, and negative monthly returns, respectively, during fixed-to-floating regime switches.

| T | T(+) | T(-) | Median (bps) | SD (bps) | Skew | Ex.Kurt |
|---|---|---|---|---|---|---|
| 207 | 82 | 125 | -26 | 468 | -3.76 | 38 |

| Mean (bps) | Mean(+)(bps) | Mean(-)(bps) | Min (bps) | P10 (bps) | P90 (bps) | Max (bps) |
|---|---|---|---|---|---|---|
| -96 | 183 | -282 | -4490 | -515 | 189 | 1923 |

**Table XIV**

**Fixed-to-floating regime changes associated with the largest monthly losses of the floating carry trade.**

This table lists the 25 monthly losses to the floating carry trade arising from a fixed-to-floating regime shift. All but five of these 25 months coincide with events that shaped the history of the international financial system and of exchange rate regimes as documented in the secondary sources (Eichengreen (1996), Aldcroft and Oliver (1998), James (2012), and Reinhart and Rogoff (2011)).

| month $t+1$ | Return (bps) | Example of collapsed pegs | Main historical event |
|---|---|---|---|
| 1931m07 | -4490 | DEM/USD | The collapse of the gold standard system in the 1930s: July 1931 German Crisis |
| 1977m07 | -1415 | ESP/FRF | —— |
| 1922m11 | -1098 | CHF/USD | Pressure on CHF, followed by a referendum on the introduction of a capital levy |
| 1926m04 | -988 | ESP/DEM | Speculation on ESP in the hope of stablization at the prewar gold parity |
| 1926m05 | -987 | ESP/USD | Speculation on ESP in the hope of stablization at the prewar gold parity |
| 1939m09 | -965 | BEF/USD | The collapse of the managed floating regimes in Europe at the outbreak of WWII |
| 1993m07 | -957 | BEF/DEM | The European Monetary System crisis of 1992-1993: the widening ERM band |
| 1995m03 | -901 | PTE/DEM | Spain and Portugal exchange rate realignment |
| 1987m10 | -865 | ESP/NLG | 1987 Stock Market Crash spill-over to the foreign exchange markets |
| 1935m03 | -759 | BEF/FRF | Belgium suspended the gold standard |
| 1977m08 | -739 | FRF/USD | Sweden suspended agreement with Snake: DEM/SEK volatility increased from 7% to 21% |
| 2008m09 | -739 | SEK/EUR | Nadir of the 2008 GFC (The bankruptcy of Lehman Brothers) |
| 2007m08 | -721 | CHF/EUR | SNB and ECB responded to money market tension at the beginning of the GFC |
| 1924m07 | -720 | CHF/USD | CHF and GBP started appreciating against USD before returning to the gold standard |
| 1992m09 | -628 | GBP/DEM | The European Monetary System crisis of 1992-1993: Black Wednesday |
| 1933m04 | -607 | USD/FRF | The collapse of the gold standard in the 1930s: the US April 1933 devaluation |
| 1989m02 | -599 | ITL/CHF | —— |
| 2010m05 | -566 | CHF/EUR | The climax of the European debt crisis: Greece asked for financial support from IMF |
| 1980m04 | -531 | NOK/SEK | —— |
| 2015m01 | -519 | CHF/EUR | SNB abandoned euro cap |
| 1973m06 | -515 | DEM/NLG | Snake realignment: DEM revalued by 5.5% |
| 1976m04 | -496 | ATS/NOK | —— |
| 2007m11 | -494 | CHF/EUR | SNB,ECB, FED introduced swap lines following dollar liquidity shortages among EU banks |
| 1992m01 | -470 | ATS/BEF | —— |
| 1976m03 | -457 | FRF/DEM | France withdrew from Snake again following its first withdrawal in Jan 1974 |