Asset Management: Advanced Investments

Currencies

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Overview

Overview

Measuring Returns on FX Investments

- The return in domestic currency of an investment in an asset denominated in foreign currency has **two components**:
  1. the **return on the investment** expressed in foreign currency; and
  2. the **return on the foreign currency** expressed in domestic currency.

- Let $R^*_{t,k}$ denote the return on the foreign currency asset measured **in foreign currency** between t and $t+k$, and $r^*_{t,k} = \ln(1 + R^*_{t,k})$ the corresponding continuously compounded return.

- Let S_t denote the spot exchange rate expressed as the number of units of domestic currency per unit of foreign currency, e.g. 1.1 CHF per EUR, and s_t its logarithm.

- Thus, an increase in S_t and s_t means that the domestic currency (CHF) is depreciating – one unit of the foreign currency buys more units of the domestic currency.

Measuring Returns on FX Investments

- Suppose you take one unit of the domestic currency, change it in foreign currency, and invest the resulting amount $1/S_t$ in the foreign currency asset.

- After k periods, the value of your investment (i.e. the **gross return**) measured **in domestic currency** is

$$V_{t+k} = 1 + R_{t,k} = \frac{S_{t+k}(1 + R^*_{t,k})}{S_t} = (1 + R^{FX}_{t,k})(1 + R^*_{t,k}) \ . \qquad (1)$$

- The corresponding **log return** is

$$r_{t,k} = s_{t+k} - s_t + r^*_{t,k} = r^{FX}_{t,k} + r^*_{t,k} \ . \qquad (2)$$

- One often considers the **excess log return** compared to that of an alternative asset, say that on the domestic riskless asset $i_{t,k}$:

$$rx_{t,k} = s_{t+k} - s_t + r^*_{t,k} - i_{t,k} \ . \qquad (3)$$

Overview

Covered Interest Rate Parity (CIP)

- Assume you are a domestic investor considering investing in a foreign money or bond market.
- Let $I_{t,k}$ denote the k-period **cumulative** discrete interest (with compounding) earned on the domestic currency at time t and $i_{t,k} = \ln(1 + I_{t,k})$ the equivalent continuously compounded interest.
- Let $I^*_{t,k}$ denote the k-period **cumulative** discrete interest (with compounding) earned on the foreign currency at time t and $i^*_{t,k} = \ln(1 + I^*_{t,k})$ the equivalent continuously compounded interest.
- Let $F_{t,k}$ denote the **forward foreign exchange rate**, i.e. the FX rate you can agree to today for a foreign currency transaction with delivery in k periods. If you sell the foreign currency forward, you will receive $F_{t,k}$ units of the domestic currency per unit of foreign currency at time $t + k$.

Covered Interest Rate Parity (CIP)

- By **no arbitrage**, the forward rate must be such that the return on a riskless investment in the domestic currency $(1 + I_{t,k})$ is identical to that of a **hedged** investment in the foreign currency, $(1 + I^*_{t,k})F_{t,k}/S_t$:

$$1 + I_{t,k} = \frac{F_{t,k}}{S_t}(1 + I^*_{t,k}) \qquad \rightarrow \qquad F_{t,k} = S_t \frac{1 + I_{t,k}}{1 + I^*_{t,k}} \ . \tag{4}$$

- This result is known as **covered interest parity (CIP)**. It says that borrowing at home and lending abroad or doing the reverse earns zero return if the FX risk is hedged.

- Covered interest rate parity can also be expressed **in logs**:

$$f_{t,k} = s_t + \left(i_{t,k} - i^*_{t,k}\right) \ , \tag{5}$$

where $f_{t,k} = \ln(F_{t,k})$ denotes the log of the forward exchange rate.

Covered Interest Rate Parity (CIP)

- Equation (5) is often written in terms of the **forward premium/discount**:

$$f_{t,k} - s_t = i_{t,k} - i^*_{t,k} \ . \tag{6}$$

- CIP is a **no-arbitrage** relation and does not depend on investor preferences. It used to hold well in data apart from short-lived deviations (Akram et al. [2008]). Persistent deviations have been found since the 2008 financial crisis.

- **Note:** Sometimes, I and I^* are used to denote the **per-period** return from investing in the respective currencies and i and i^* the continuously compounded returns per period. In this case, the covered interest parity relations for k periods become:

$$F_{t,k} = S_t \frac{(1 + I_{t,k})^k}{(1 + I^*_{t,k})^k} \ , \tag{7}$$

$$f_{t,k} = s_t + k(i_{t,k} - i^*_{t,k}) \ . \tag{8}$$

Overview

Uncovered Interest Rate Parity (UIP)

- Uncovered interest rate parity considers the return from an **unhedged** investment in foreign currency.
- Such an investment can be implemented in two ways:
  1. Borrow one unit of the domestic currency, change it in the foreign currency, invest abroad for k periods, and change the proceeds back to the domestic currency at time $t+k$. Your excess return is:
  $$R_{t,k} = \frac{S_{t+k}}{S_t}(1+I^*_{t,k}) - (1+I_{t,k}) \ . \tag{9}$$
  2. Buy one unit of the foreign currency forward for delivery at time $t+k$ and change it back to the domestic currency at time $t+k$. Your payoff is:
  $$\Pi^F_{t,k} = S_{t+k} - F_{t,k} \ . \tag{10}$$
- If CIP holds, both payoffs are proportional to each other:

$$\begin{aligned} \Pi^F_{t,k} &= S_{t+k} - S_t \frac{1+I_{t,k}}{1+I^*_{t,k}} \\ &= \frac{S_t}{1+I^*_{t,k}} \left(\frac{S_{t+k}}{S_t}(1+I^*_{t,k}) - (1+I_{t,k}) \right) = \frac{S_t}{1+I^*_{t,k}} R_{t,k} \ . \end{aligned} \tag{11}$$

Uncovered Interest Rate Parity (UIP)

- UIP states that the **expected return** from an investment in foreign currency should be the **same** as that of an investment in domestic currency – on average, the FX move should offset the interest rate differential.
- Equivalently, the **expected excess return** from an investment in foreign currency should be **zero**.
- The **UIP equation** is:

$$1 + I_{t,k} = \frac{\mathbb{E}_t[S_{t+k}]}{S_t}(1 + I^*_{t,k}) \ . \tag{12}$$

- For example, if $I^*_{t,k} > I_{t,k}$, UIP says that the foreign currency should, on average, depreciate at a rate matching the interest rate differential in order to make the domestic and foreign investments equally profitable.
- Thus, UIP claims that $F_{t,k} = \mathbb{E}_t[S_{t+k}]$ – the **forward rate is an unbiased predictor of the future spot rate**.
- Letting $s^{\mathbb{E}}_{t,t+k} = \ln(\mathbb{E}_t[S_{t+k}])$, UIP can be written **in logs** as

$$s^{\mathbb{E}}_{t,t+k} - s_t = i_{t,k} - i^*_{t,k} \ . \tag{13}$$

Uncovered Interest Rate Parity (UIP)

- By contrast with CIP, UIP is not an arbitrage relation. It is a condition based on **equilibrium reasoning** that may or may not hold.
  - CIP is the currency equivalent of the relation between spot and forward interest rates for the term structure.
  - UIP is the currency equivalent of the expectations hypothesis for the term structure.
- One case where UIP should hold is that where investors are risk-neutral.
- There are actually **two statements in UIP**:
  1. There is **no risk premium** from holding the foreign currency – the appreciation / depreciation of the foreign currency offsets the interest rate differential.
  2. Currency excess returns are **unpredictable**.

  We now consider both aspects.

Overview

Currency Risk Premia

- Recall that the excess log return from an unhedged money market investment in the foreign currency consists of two components:
  1. the forex return; and
  2. the interest rate differential between the two countries.

  Formally:

$$rx_{t,k} = \underbrace{(s_{t+k} - s_t)}_{\text{Forex return}} \quad + \quad \underbrace{(i^*_{t,k} - i_{t,k})}_{\text{Interest rate differential}}$$

- If UIP holds, the first component offsets the other – the average excess return from investing in different currencies should not be statistically different from zero.

Currency Risk Premia

This is not the case empirically. Over the period 1983-2009, G10 currencies with the highest average yields earned the highest average excess returns against the USD.

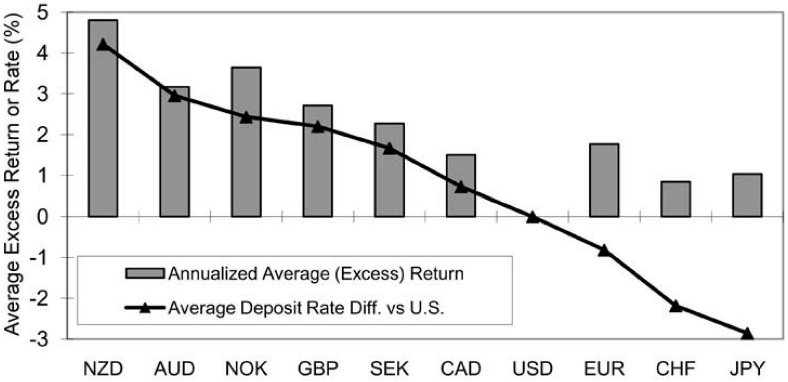


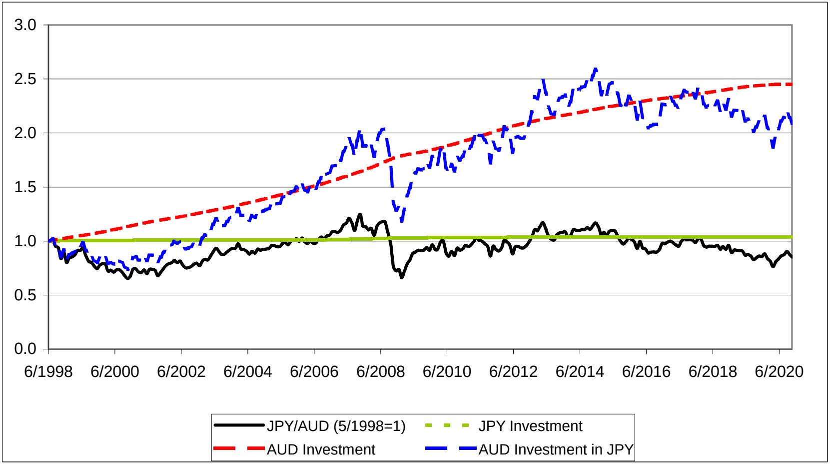
Figure 13.1. Pairwise average returns for dollar pairs vs. average carry, 1983–2009.
Sources: Bloomberg, Citigroup, own calculations.

Currency Risk Premia. Source: Ilmanen [2011]

Currency Risk Premia

- Note that although the differences are small, there was no depreciation of high-yielding currencies during the period. Rather, for most currencies, there was a small appreciation.
- Thus, in addition to the gain on the interest rate differential, investments in high-yielding currencies earned an extra return from the appreciation.
- The **currency risk premium is positive** – there is some compensation for the exchange rate risk incurred when making unhedged investments in high interest rate countries.
- The returns on investments in high-yielding currencies are **negatively skewed**. They deliver steady gains for long periods of time but sudden steep drawdowns wipe out years of gains. Drawdowns tend to occur in **bad times**.
- This suggests that the extra return from investments in high-yielding currencies is a **risk premium rather than mispricing**.

Currency Risk Premia: Drawdowns



Value of a money market investment in AUD and JPY.

Currency Risk Premia

Investing in the currencies based on their relative yields at a given point in time improves average returns (this is the so-called carry trade; we will consider it in detail when we look at the cross-section).

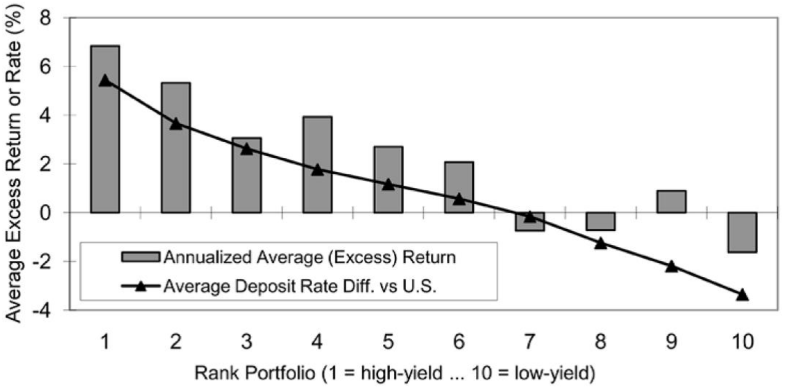


Figure 13.3. Average excess returns of G10 carry-ranked single-currency portfolios, 1983–2009.
Sources: Bloomberg, Citigroup, own calculations.

Carry Trade Returns. Source: Ilmanen [2011]

Overview

Predictability

- One way to test UIP (13) is to assess **whether the initial interest rate differential is offset by an equal change in exchange rates**, i.e. by estimating the following predictive regression:

$$s_{t+k} - s_t = \alpha + \beta(i_{t,k} - i^*_{t,k}) + \varepsilon_{t+k} \ . \tag{14}$$

- UIP implies
  1. $\alpha = 0$ (no currency risk premium); and
  2. $\beta = 1$ (exchange rate changes on average exactly offset the yield differential).

- Equivalently, one can invoke CIP, $f_{t,k} - s_t = i_{t,k} - i^*_{t,k}$, and use the forward discount/premium as explanatory variable:

$$s_{t+k} - s_t = \alpha + \beta(f_{t,k} - s_t) + \varepsilon_{t+k} \ . \tag{15}$$

- In this flavor of the test, one checks if the forward rate is an unbiased predictor of the future spot exchange rate.

Predictability

- An alternative test of UIP is to investigate **whether excess log returns** $rx_{t,k} = s_{t+k} - s_t - (i_{t,k} - i^*_{t,k})$ **are predictable** using the regression:

$$rx_{t,k} = \alpha + \beta(i_{t,k} - i^*_{t,k}) + \varepsilon_{t+k} \ . \qquad (16)$$

- When using this approach, UIP implies:
  1. $\alpha = 0$ (no risk premium); and
  2. $\beta = 0$ (no predictability).

- If one finds that $\beta \neq 0$, this means that expected currency excess returns are time-varying and predictable.

- Note that using CIP one has $rx_{t,k} = s_{t+k} - f_{t,k}$ so regression (16) can also be written in two additional equivalent forms:

$$s_{t+k} - f_{t,k} = \alpha + \beta(i_{t,k} - i^*_{t,k}) + \varepsilon_{t+k} \ , \qquad (17)$$

$$s_{t+k} - f_{t,k} = \alpha + \beta(f_{t,k} - s_t) + \varepsilon_{t+k} \ . \qquad (18)$$

Predictability

- Summarizing, there are **two ways to test UIP**:
  1. **Forward rates forecast future spot rates**, i.e. $\alpha = 0$ and $\beta = 1$ in the regression
  $$s_{t+k} - s_t = \alpha + \beta(f_{t,k} - s_t) + \varepsilon_{t+k} \ .$$
  2. **Excess returns are unpredictable**, i.e. $\alpha = 0$ and $\beta = 0$ in the regression
  $$s_{t+k} - f_{t,k} = \alpha + \beta(f_{t,k} - s_t) + \varepsilon_{t+k} \ .$$
- As was the case for tests of the expectations hypothesis of the term structure of interest rates, the two tests constitute **complementary regressions**:
  $$f_{t,k} - s_{t+k} = \alpha_1 + \beta_1(f_{t,k} - s_t) + \varepsilon_{1,t+k} \ ,$$
  $$s_{t+k} - s_t = \alpha_2 + \beta_2(f_{t,k} - s_t) + \varepsilon_{2,t+k} \ ,$$
  where by construction $\alpha_1 + \alpha_2 = 0$ and $\beta_1 + \beta_2 = 1$.
- The complementarity $\alpha_1 + \alpha_2 = 0$ and $\beta_1 + \beta_2 = 1$ also holds when using the interest rate differential as explanatory variable, i.e. if one estimates:
  $$f_{t,k} - s_{t+k} = \alpha_1 + \beta_1(i_{t,k} - i^*_{t,k}) + \varepsilon_{1,t+k} \ ,$$
  $$s_{t+k} - s_t = \alpha_2 + \beta_2(i_{t,k} - i^*_{t,k}) + \varepsilon_{2,t+k} \ .$$

Empirical Evidence

When estimating the complementary regressions

$$f_{t,k} - s_{t+k} = \alpha_1 + \beta_1(f_{t,k} - s_t) + \varepsilon_{1,t+k} \ ,$$
$$s_{t+k} - s_t = \alpha_2 + \beta_2(f_{t,k} - s_t) + \varepsilon_{2,t+k} \ ,$$

Fama [1984] finds that $\beta_1 = 0$ and $\beta_2 = 1$ are mostly **rejected**:

Table 2

OLS regressions: 8/31/73–12/10/82, $N = 122$.[a]

$F_t - S_{t+1} = \hat{\alpha}_1 + \hat{\beta}_1(F_t - S_t) + \hat{\varepsilon}_{1,t+1}$, $\quad S_{t+1} - S_t = \hat{\alpha}_2 + \hat{\beta}_2(F_t - S_t) + \hat{\varepsilon}_{2,t+1}$.

										Residual autocorrelations					
Country	$\hat{\alpha}_1$	$\hat{\beta}_1$	$\hat{\alpha}_2$	$\hat{\beta}_2$	$s(\hat{\alpha})$	$s(\hat{\beta})$	R_1^2	R_2^2	$s(\hat{\varepsilon})$	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6
Belgium	0.50	2.58	−0.50	−1.58	0.30	0.68	0.11	0.04	3.05	0.01	0.06	0.06	−0.03	0.02	0.02
Canada	0.25	1.87	−0.25	−0.87	0.11	0.61	0.07	0.01	1.12	0.12	−0.23	0.10	0.07	0.06	0.03
France	0.64	1.87	−0.64	−0.87	0.31	0.63	0.07	0.01	3.00	−0.07	0.04	0.13	−0.03	0.15	0.04
Italy	1.14	1.51	−1.14	−0.51	0.40	0.38	0.11	0.01	2.79	−0.00	0.16	−0.01	−0.09	0.10	0.01
Japan	−0.12	1.29	0.12	−0.29	0.29	0.43	0.07	0.00	3.06	0.15	−0.12	0.03	0.13	0.16	−0.08
Netherlands	−0.21	2.43	0.21	−1.43	0.31	0.86	0.06	0.01	2.99	−0.03	0.03	0.02	−0.17	−0.01	−0.02
Switzerland	−0.81	2.14	0.81	−1.14	0.56	0.92	0.04	0.00	3.75	−0.02	0.06	0.01	−0.12	0.10	0.02
United Kingdom	0.57	1.90	−0.57	−0.90	0.28	0.66	0.06	0.01	2.57	0.13	0.03	0.11	−0.06	0.10	0.05
West Germany	−0.36	2.32	0.36	−1.32	0.44	1.15	0.03	0.00	3.08	−0.01	0.07	0.00	−0.13	0.01	−0.03

[a] R_1^2 and R_2^2 are the coefficients of determination (regression R^2) for the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions. The complete complementarity of the $F_t - S_{t+1}$ and $S_{t+1} - S_t$ regressions for each country means that the standard errors $s(\hat{\alpha})$ and $s(\hat{\beta})$ of the estimated regression coefficients, the residual standard error $s(\hat{\varepsilon})$, and the residual autocorrelations, ρ_τ, are the same for the two regressions. Under the hypothesis that the true autocorrelations are zero, the standard error of the estimated residual autocorrelations is about 0.09.

Empirical Evidence

Estimating the regression $s_{t+k} - s_t = \alpha + \beta(i_{t,k} - i^*_{t,k}) + \varepsilon_{t+k}$ for 1979-2011, Chinn and Quayyum [2012] find that the UIP is **rejected in most countries** (the maturity of the interest rates used matches the forecasting horizon).

Base Currency: U.S. Dollar						
Currency	3-Month		6-Month		12-Month	
Canadian Dollar	-0.166	(0.713)	-0.084*	(0.700)	-0.055	(0.705)
British Pound	-1.847**	(0.988)	-1.554**	(0.985)	-1.006***	(0.905)
Japanese Yen	-2.478***	(0.733)	-2.785***	(0.628)	-2.440***	(0.512)
Swiss Franc	-2.213*	(1.058)	-2.864***	(1.362)	-2.779***	(1.138)
Euro	-2.251	(2.229)	-1.991	(2.178)	-2.179	(2.020)
Constrained Panel[1]	-1.241***	(0.558)	-1.638***	(0.382)	-1.801***	(0.458)
Base Currency: British Pound						
	3-Month		6-Month		12-Month	
Canadian Dollar	-3.536***	(1.005)	-2.503***	(0.964)	-1.257**	(0.876)
Japanese Yen	-2.101**	(1.347)	-2.006***	(1.043)	-1.651***	(0.843)
Swiss Franc	-2.828**	(1.476)	-1.556**	(0.978)	-2.287***	(0.709)
Euro	-0.299	(1.925)	-0.081	(1.767)	-0.662	(1.639)
Constrained Panel[1, 2]	-2.160***	(0.849)	-1.969***	(0.783)	-1.401***	(0.703)

Note: The table reports β estimates and their Newey-West standard errors in parentheses. *, **, *** denote coefficient estimates that are statistically different from 1 at the 10%, 5% and 1% levels, respectively.

Empirical Evidence

There are fewer rejections of UIP when estimating the regression $s_{t+k} - s_t = \alpha + \beta(i_{t,k} - i^*_{t,k}) + \varepsilon_{t+k}$ for a five-year forecasting horizon. Moreover, most β estimates are positive:

Panel A: Base Currency U.S. Dollar								
	$\hat{\alpha}$		$\hat{\beta}$		Reject H_0: $\beta = 1$	R^2	Sample Start	N
Canadian Dollar	0.004	(0.007)	0.691	(0.636)		0.027	1978Q1	136
British Pound	0.000	(0.009)	0.415	(0.371)		0.024	1978Q1	136
Japanese Yen	0.031	(0.012)	0.545	(0.374)		0.000	1979Q3	130
Swiss Franc	0.022	(0.013)	-0.165	(0.519)	**	0.002	1993Q1	76
Constrained Panel[1]			0.380	(0.186)	***		1978Q1	402

Panel B: Base Currency British Pound								
	$\hat{\alpha}$		$\hat{\beta}$		Reject H_0: $\beta = 1$	R^2	Sample Start	N
Canadian Dollar	-0.007	(0.006)	-0.232	(0.405)	***	0.0007	1978Q1	136
Japanese Yen	0.064	(0.034)	-0.624	(0.811)	**	0.012	1978Q1	136
Swiss Franc	0.014	(0.022)	0.188	(0.640)		0.002	1993Q1	76
Constrained Panel[1,2]			0.071	(0.178)	***		1978Q1	402

Predictability: Summary and Implications

- **UIP does not hold** in the data: there is a currency risk premium and foreign exchange returns are predictable.
- On average, countries with high interest rates also experience an appreciation of their currency.
- This means that there are profitable opportunities, i.e. one can capture a positive currency risk premium by borrowing in low interest rate countries and investing in high interest rate countries. However, such a strategy is subject to steep drawdowns.

Overview

Carry: Basic Idea

- The carry trade is a popular trading strategy that **exploits deviations from UIP**.
- Carry traders **borrow in low interest rate currencies and lend in high interest rate currencies**.
- Recall that the excess return from borrowing in the domestic currency and investing in the foreign currency is:

$$R_{t,k} = \frac{S_{t+k}}{S_t}(1 + I^*_{t,k}) - (1 + I_{t,k}) \ . \tag{19}$$

- The carry trade involves going long the foreign currency when $I^*_{t,k} - I_{t,k} > 0$ and short otherwise. Accordingly, carry (excess) returns are

$$R^C_{t,k} = \text{sign}[I^*_{t,k} - I_{t,k}] \left(\frac{S_{t+k}}{S_t}(1 + I^*_{t,k}) - (1 + I_{t,k}) \right) \ . \tag{20}$$

- As discussed in the context of UIP, an alternative to explicit borrowing and lending is to implement the carry trade using **forward or futures contracts**.

Carry: Portfolio Construction

- Burnside et al. [2011] investigate the profitability of the carry trade as well as of momentum for the period 1976-2010.
- The **carry portfolio** is an **equally weighted portfolio** of up to 20 individual currency carry trades against the USD. For each currency, the carry return (20) is computed each month. The portfolio return is the average of the returns across all currencies.
- The **momentum strategy** involves selling (buying) a currency forward if its return (19) during the previous month was negative (positive). Formally, for each currency and each month, the momentum (excess) return is given by

$$R_{t,1}^{M} = \text{sign}[R_{t-1,1}]R_{t,1} \ . \tag{21}$$

  Again, the authors consider an **equally weighted** portfolio of all currencies against the USD.

Overview

Carry: Profitability

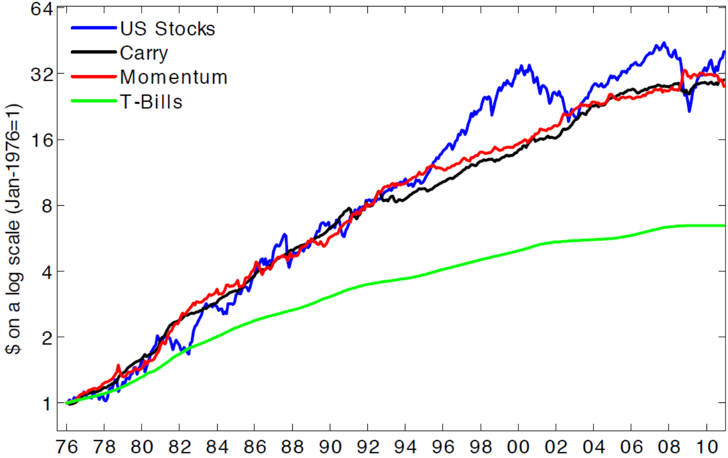
Burnside et al. [2011] find that the carry trade strategy earns large risk-adjusted returns that are uncorrelated with those of currency momentum. Skewness is negative but insignificant.

Table 1: **Annualized excess returns of investment strategies (Feb. 1976-Dec. 2010)**

	Mean (%)	SD (%)	Sharpe Ratio	Skewness	Excess Kurtosis	Correlation with Carry	Correlation with Momentum
Individual currency strategies (average)[a]							
Carry trade	4.6	11.3	0.42	-0.23	1.6		
Momentum trade	4.9	11.3	0.43	-0.02	1.5		
Portfolio strategies[b]							
Carry trade[c]	4.6	5.1	0.89	-0.53	4.1	1.00	0.10
	(0.9)	(0.4)	(0.21)	(0.40)	(1.5)		
Momentum[c]	4.5	7.3	0.62	0.08	2.9	0.10	1.00
	(1.2)	(0.5)	(0.16)	(0.32)	(0.9)		
50-50 strategy[d]	4.5	4.6	0.98	0.36	2.5	0.63	0.84
	(0.8)	(0.3)	(0.16)	(0.22)	(0.5)		
U.S. stocks[e]	6.5	15.7	0.41	-0.78	2.3	0.09	-0.09
	(2.8)	(1.0)	(0.19)	(0.28)	(1.1)		

Carry: Profitability

The cumulative returns of the carry and momentum portfolios are almost as high as the cumulative return to investing in stocks. Carry trade returns are less skewed than the returns of the U.S. stock market.



Source: Burnside et al. [2011]

Carry trade returns cannot be explained by exposure to conventional risk factors (e.g. stock market risk and Fama-French factors):

Table 2: Factor betas of the currency portfolios (1976-2010)

	Carry Trade				Momentum			
Factor Model	Beta(s)[a]			R^2	Beta(s)[a]			R^2
CAPM[b]	0.029 (0.017)			0.01	-0.042 (0.036)			0.01
Fama-French[c]	0.045* (0.018)	-0.034 (0.030)	0.042 (0.029)	0.02	-0.037 (0.040)	-0.030 (0.036)	-0.001 (0.047)	0.01
Quadratic CAPM[d]	0.033 (0.019)	0.286 (0.343)		0.01	-0.027 (0.028)	1.202 (1.368)		0.02
CAPM-Volatility[e]	-0.004 (0.026)	-0.010 (0.231)	2.093 (1.627)	0.02	-0.012 (0.066)	0.001 (0.232)	-1.885 (5.212)	0.01
C-CAPM[f]	0.006 (0.733)			0.00	-0.583 (0.840)			0.00
Extended C-CAPM[g]	-0.314 (0.824)	0.671 (0.572)	0.013 (0.031)	0.01	-0.176 (0.765)	-0.712 (0.718)	-0.070 (0.047)	0.04

Overview

Carry as a Factor

- Lustig et al. [2011] investigate the **returns of currency carry portfolios** during the period 1983–2009.
- The number of currencies varies over time; there were 9 currencies at the beginning of the sample, 26 at the end, and the maximum is 34 (before the launch of the Euro). They also consider a subset of 15 developed markets (Australia, Belgium, Canada, Denmark, euro area, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, UK).
- At the end of each month, **currencies are allocated to six portfolios** on the basis of their forward premium/discount $f_t - s_t$:
  - Portfolio 1 contains the currencies with the lowest interest rate.
  - Portfolio 6 those with the highest interest rate.
- The authors also consider **long-short portfolios** called HML_j that are long portfolio j and short portfolio 1.

Carry Portfolio Returns

The average change in the log spot exchange rate, Δs (which is the average rate of depreciation of the currencies in each portfolio), does not match the forward premium/discount $f - s$, resulting in nonzero excess returns.

Table 1
Currency portfolios—U.S. investor

Portfolio	1	2	3	4	5	6	1	2	3	4	5
	Panel I: All Countries						Panel II: Developed Countries				
	Spot change: Δs^j						Δs^j				
Mean	−0.64	−0.92	−0.95	−2.57	−0.60	2.82	−1.81	−1.87	−3.28	−1.57	−0.82
Std	8.15	7.37	7.63	7.50	8.49	9.72	10.17	9.95	9.80	9.54	10.26
	Forward Discount: $f^j - s^j$						$f^j - s^j$				
Mean	−2.97	−1.23	−0.09	1.00	2.67	9.01	−2.95	−0.94	0.11	1.18	3.92
Std	0.54	0.48	0.47	0.52	0.64	1.89	0.77	0.62	0.63	0.66	0.74
	Excess Return: rx^j (without b–a)						rx^j (without b–a)				
Mean	−2.33	−0.31	0.86	3.57	3.27	6.20	−1.14	0.93	3.39	2.74	4.74
Std	8.23	7.44	7.66	7.59	8.56	9.73	10.24	9.98	9.89	9.62	10.33
SR	−0.28	−0.04	0.11	0.47	0.38	0.64	−0.11	0.09	0.34	0.29	0.46
	Net Excess Return: rx^j_{net} (with b–a)						rx^j_{net} (with b–a)				
Mean	−1.17	−1.27	−0.39	2.26	1.74	3.38	−0.02	−0.11	2.02	1.49	3.07
Std	8.24	7.44	7.63	7.55	8.58	9.72	10.24	9.98	9.87	9.63	10.32
SR	−0.14	−0.17	−0.05	0.30	0.20	0.35	−0.00	−0.01	0.21	0.15	0.30
	High-minus-Low: $rx^j - rx^1$ (without b–a)						$rx^j - rx^1$ (without b–a)				
Mean		2.02	3.19	5.90	5.60	8.53		2.07	4.53	3.88	5.88
Std		5.37	5.30	6.16	6.70	9.02		7.18	7.11	8.02	9.64
SR		0.38	0.60	0.96	0.84	0.95		0.29	0.64	0.48	0.61
	High-minus-Low: $rx^j_{net} - rx^1_{net}$ (with b–a)						$rx^j_{net} - rx^1_{net}$ (with b–a)				
Mean		−0.10	0.78	3.42	2.91	4.54		−0.09	2.04	1.51	3.09
		[0.30]	[0.30]	[0.35]	[0.38]	[0.51]		[0.41]	[0.40]	[0.45]	[0.54]
Std		5.40	5.32	6.15	6.75	9.05		7.20	7.11	8.04	9.66
SR		−0.02	0.15	0.56	0.43	0.50		−0.01	0.29	0.19	0.32

Principal Components in Carry Returns

A principal component analysis reveals that **two principal components** explain over 80% of the variation in returns on the six portfolios:

- The first principal component is a **level factor**; all portfolios load approximately equally on it.
- The second principal component is a **slope factor**; portfolio loadings decrease monotonically across portfolios.

Table 3
Principal components

Panel I: All Countries

Portfolio	1	2	3	4	5	6
1	0.42	0.43	0.18	−0.15	0.74	0.20
2	0.38	0.24	0.15	−0.27	−0.61	0.58
3	0.38	0.29	0.42	0.12	−0.28	−0.71
4	0.38	0.04	−0.35	0.83	−0.03	0.18
5	0.43	−0.08	−0.72	−0.44	−0.03	−0.30
6	0.45	−0.81	0.35	−0.03	0.11	0.06
% Var.	71.95	11.82	5.55	4.00	3.51	3.16

Panel II: Developed Countries

Portfolio	1	2	3	4	5
1	0.44	0.66	−0.54	−0.25	0.12
2	0.45	0.25	0.75	0.01	0.41
3	0.46	0.02	0.19	0.04	−0.86
4	0.44	−0.27	−0.29	0.78	0.20
5	0.45	−0.66	−0.14	−0.57	0.17
% Var.	78.23	10.11	4.97	3.49	3.20

This table reports the principal component coefficients of the currency portfolios presented in Table 1. In each panel, the last row reports (in %) the share of the total variance explained by each common factor. Data are monthly, from Barclays and Reuters (Datastream). The sample period is 11/1983–12/2009.

Currency Factors

- Based on these results, the authors construct **two candidate currency risk factors**:
  1. **Dollar factor**: The average currency excess return, denoted RX. This corresponds (roughly) to the average portfolio return of a US investor who buys all available foreign currencies in the forward market.
  2. **Carry factor**: The difference between the return on the last portfolio and that on the first portfolio, denoted HML_{FX}. This corresponds (again roughly) to the return on a zero-cost strategy that goes long in the highest interest rate currencies and short in the lowest interest rate currencies.
- The correlation of the first principal component with RX is 0.99 and that of the second with HML_{FX} is 0.94.

Currency Factors: Risk Prices

- The **risk prices** of the two factors can be estimated using a cross-sectional regression of average returns on the factor exposures or the Fama-MacBeth approach. (The constant is assumed to be zero.)
- The risk price of the dollar factor is estimated to be about 1.34% per year, while that of the carry factor is about 5.50% per year.

Table 4
Asset pricing—U.S. investor

Panel I: Risk Prices

	All Countries							Developed Countries						
	$\lambda_{HML_{FX}}$	λ_{RX}	$b_{HML_{FX}}$	b_{RX}	R^2	RMSE	χ^2	$\lambda_{HML_{FX}}$	λ_{RX}	$b_{HML_{FX}}$	b_{RX}	R^2	RMSE	χ^2
GMM_1	5.50	1.34	0.56	0.20	70.11	0.96		3.29	1.90	0.29	0.20	64.78	0.64	
	[2.25]	[1.85]	[0.23]	[0.32]			14.39%	[2.59]	[2.20]	[0.23]	[0.23]			45.96%
GMM_2	5.51	0.40	0.57	0.04	41.25	1.34		3.91	3.07	0.35	0.32	−55.65	1.34	
	[2.14]	[1.77]	[0.22]	[0.31]			16.10%	[2.52]	[2.05]	[0.22]	[0.22]			52.22%
FMB	5.50	1.34	0.56	0.20	70.11	0.96		3.29	1.90	0.29	0.20	64.78	0.64	
	[1.79]	[1.35]	[0.19]	[0.24]			9.19%	[1.91]	[1.73]	[0.17]	[0.18]			43.64%
	(1.79)	(1.35)	(0.19)	(0.24)			10.20%	(1.91)	(1.73)	(0.17)	(0.18)			44.25%
Mean	**5.08**	**1.33**					**3.14**	**1.90**						

(Values in square brackets denote standard errors.)

Currency Factors: Cross-Sectional Pricing Performance

- Regressing the excess returns of the portfolios on the factors reveals that the alphas of portfolios 2 and 4 are significant at the 5% level, while those of the other portfolios are not.
- The joint test that all alphas are zero is insignificant.
- As expected, the portfolios' exposure to the dollar factor is similar; thus, the dollar factor's risk price does not explain the cross-sectional variation in portfolio returns and is hard to estimate. However, the factor accounts for the average level of portfolio returns.

Panel II: Factor Betas

	All Countries						Developed Countries					
Portfolio	α_0^j	$\beta_{HML_{FX}}^j$	β_{RX}^j	R^2	$\chi^2(\alpha)$	*p–value*	α_0^j	$\beta_{HML_{FX}}^j$	β_{RX}^j	R^2	$\chi^2(\alpha)$	*p–value*
1	−0.10	−0.39	1.05	91.64			0.36	−0.51	0.99	94.31		
	[0.50]	[0.02]	[0.03]				[0.53]	[0.03]	[0.02]			
2	−1.55	−0.11	0.94	77.74			−1.17	−0.09	1.01	80.69		
	[0.73]	[0.03]	[0.04]				[0.85]	[0.04]	[0.04]			
3	−0.54	−0.14	0.96	76.72			0.62	−0.00	1.04	86.50		
	[0.74]	[0.03]	[0.04]				[0.79]	[0.03]	[0.03]			
4	1.51	−0.01	0.95	75.36			−0.17	0.12	0.97	82.84		
	[0.77]	[0.03]	[0.05]				[0.85]	[0.03]	[0.04]			
5	0.78	0.04	1.06	76.41			0.36	0.49	0.99	94.32		
	[0.82]	[0.03]	[0.05]				[0.53]	[0.03]	[0.02]			
6	−0.10	0.61	1.05	93.84								
	[0.50]	[0.02]	[0.03]									
All					6.79	34.05%					2.63	75.64%

Overview

Carry and Equity Volatility Risk

- The carry factor has **poor returns in bad times**, in particular in periods of high equity market volatility (computed as the average across countries of the volatility of daily returns during the month).
- The exposure of the currency portfolios to innovations in volatility is monotonically decreasing – **high interest rate currencies have low returns when equity market volatility increases**. Thus, loading up on the carry factor amounts to increasing exposure to global risk.

Panel I: Factor Betas

	All Countries			Developed Countries		
Portfolio	$\beta^j_{Vol_{Equity}}$	β^j_{RX}	R^2	$\beta^j_{Vol_{Equity}}$	β^j_{RX}	R^2
1	0.37	1.04	74.78	0.58	0.99	72.55
	[0.12]	[0.05]		[0.25]	[0.06]	
2	0.22	0.94	76.21	0.16	1.01	80.01
	[0.10]	[0.04]		[0.14]	[0.04]	
3	0.19	0.95	74.34	0.20	1.04	86.67
	[0.10]	[0.04]		[0.13]	[0.03]	
4	0.13	0.95	75.44	–0.35	0.97	82.02
	[0.08]	[0.05]		[0.18]	[0.04]	
5	–0.10	1.06	76.30	–0.59	0.99	74.50
	[0.13]	[0.05]		[0.16]	[0.05]	
6	–0.81	1.07	63.84			
	[0.16]	[0.06]				

Carry and FX Volatility Risk

- Menkhoff et al. [2012a] investigate the impact of unexpected global **FX volatility risk** on the returns of carry trade strategies.

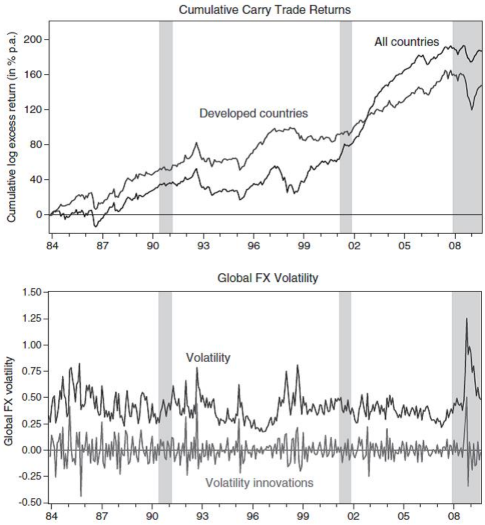
- They define global FX volatility as:

$$\sigma_t^{FX} = \frac{1}{T_t} \sum_{\tau \in T_t} \left[\sum_{k \in K_\tau} \left(\frac{|r_\tau^k|}{K_\tau} \right) \right] \tag{22}$$

where K_τ denotes the number of available currencies on day τ of month t, r_τ^k the spot foreign exchange return of currency k on that day (i.e. $r_\tau^k > 0$ corresponds to an appreciation of currency k against the USD), and T_t the number of trading days in month t.

Carry and FX Volatility Risk

They measure unexpected volatility shocks using innovations from an AR(1) process of global FX volatility (the AR(1) is estimated over the entire sample).



Carry and FX Volatility Risk

The **returns on high interest rate currencies** are **negatively related to FX volatility shocks**, explaining why they earn a positive premium.
Low interest rate currencies react positively to volatility shocks, i.e. they are hedge assets and therefore earn a low or negative unconditional premium.

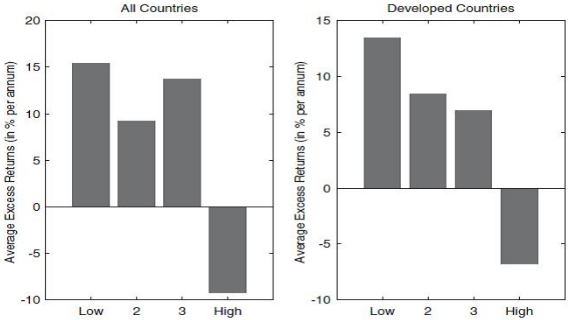


Figure 2. Excess returns and volatility. The figure shows mean excess returns for carry trade portfolios conditional on global FX volatility innovations being within the lowest to highest quartile of its sample distribution (four categories from "Low" to "High" shown on the x-axis of each panel). The bars show average excess returns for being long in portfolio 5 (largest forward discounts) and short in portfolio 1 (lowest forward discounts). The left panel shows results for all countries, while the right panel shows results for developed countries. The sample period is November 1983 to August 2009.

Overview

Carry Crashes

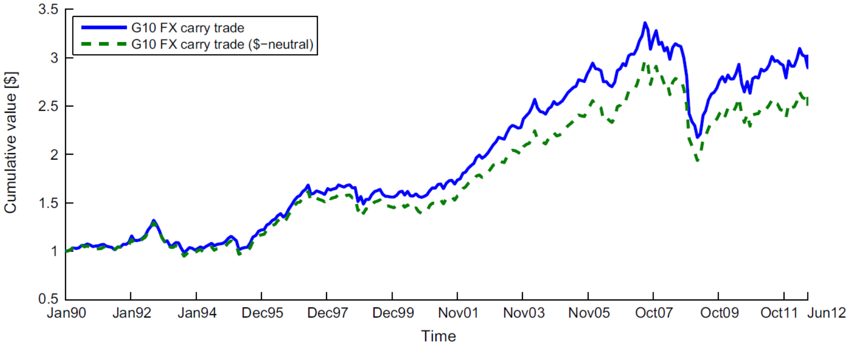
- Jurek [2014] investigates to what extent the carry risk premium is affected by a **peso problem** using G10 currencies for the period 1990-2012.
- The starting point are the returns on carry trade strategies that are either spread-weighted or equally weighted. The author also considers a variant that is constrained to be dollar-neutral at all times ($N in the table below). The returns on all these strategies are **negatively skewed**:

Panel A: G10 carry trade returns

	1990:1–2012:6				1999:1–2012:6			
	SPR	SPR-$N	EQL	EQL-$N	SPR	SPR-$N	EQL	EQL-$N
Mean	0.0521	0.0454	0.0336	0.0261	0.0558	0.0496	0.0351	0.0282
	[2.62]	[2.27]	[2.39]	[1.85]	[2.19]	[1.92]	[1.96]	[1.63]
Volatility	0.0942	0.0950	0.0667	0.0669	0.0938	0.0951	0.0659	0.0635
Skewness	−1.04	−1.03	−0.71	−0.63	−1.12	−1.07	−1.07	−0.96
Kurtosis	6.08	5.92	4.60	4.30	7.36	7.03	5.58	4.72
Minimum	−0.1383	−0.1394	−0.0836	−0.0743	−0.1383	−0.1394	−0.0836	−0.0743
Maximum	0.0860	0.0824	0.0562	0.0570	0.0860	0.0824	0.0438	0.0382
Carry	0.0532	0.0555	0.0405	0.0430	0.0457	0.0472	0.0331	0.0350
SR	0.55	0.48	0.50	0.39	0.59	0.52	0.53	0.44
JB	156.05	143.61	51.72	37.23	162.19	141.02	75.90	44.74
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Carry Crashes

- The dollar-neutral strategy's performance is slightly worse than that of the unconstrained strategy.
- The return differential arises because the unconstrained portfolios exhibited a negative average net exposure to the US dollar and the USD depreciated versus the G10 basket during the sample period.



Crash-Hedged Carry Returns

- To assess the importance of crash risk, the author compares the returns of these strategies with those of strategies that are hedged using out-of-the-money options with a Delta of 10%.
- Hedging is performed in three different ways:
  1. **Hierarchical hedging** uses the full set of 45 G10 cross-rate options, and aims to hedge the portfolio using the fewest number of options possible.
  2. **Combinatorial hedging** also uses the full set of the cross-rate options, but creates all possible pairings of long and short currencies.
  3. The third scheme is a variant of the combinatorial hedging scheme in which each long and short currency position is hedged using the corresponding X/USD options.
- The results (reported on the next page) show that **hedging removes most of the negative skewness in returns but reduces average returns only slightly**, by about 20 to 50 bps per year.

Crash-Hedged Carry Returns

Table 3
Returns to crash-neutral currency carry trade portfolios in G10 currencies.

This table reports summary statistics for returns to spread-weighted portfolios of G10 currency carry trades, which have been hedged using 10δ (out-of-the-money) FX options. The portfolio composition is rebalanced monthly, and is determined by sorting currencies on the basis of their prevailing one-month LIBOR rate, and going long (short) currencies with high (low) interest rates. Portfolio returns are computed over the period from January 1999 to June 2012 (N=162 months), and are reported separately for non-dollar-neutral portfolios (Panel A) an dollar-neutral portfolios (Panel B). The FX option hedge is established using the full set of 45 G10 cross-rate options (*I*/*J*), or only the nine USD FX options (*I*/*USD*). The *hierarchical* hedging scheme uses the smallest possible number of unique currency options by matching the long and short exposures into pairings on the basis of their allocations in the unhedged carry portfolio. The *combinatorial* scheme creates all possible pairings between the long and short currencies, when using the *I*/*J* option set; when constrained to *I*/*USD* options, the scheme hedges each long and short currency position using the corresponding *I*/*USD* FX option. The returns to crash-neutral portfolios, *CN*(10δ), are contrasted with the performance of the corresponding, unhedged portfolio. Means, volatilities, and Sharpe ratios (SR) are annualized; *t*-statistics reported in square brackets. *Minimum* is the smallest observed monthly return. *Difference* reports the difference in the mean return of the unhedged and hedged portfolios (*t*-statistics in brackets). *Share* (ϕ) captures the share of the jump risk premium in the total currency excess return, and is computed as the ratio of the difference between the unhedged and hedged portfolio returns, and the unhedged portfolio return. Finally, the table reports the average number of FX options in the portfolio at each point in time. *Unique pairs* reports the total number of unique currency pairs considered over the full span of the sample. *Fraction ITM* reports the fraction of FX options which expired in-the-money.

Panel A: Spread-weighted, non-dollar-neutral portfolio returns (SPR)

	Unhedged	CN(10δ)	CN(10δ)	CN(10δ)
Hedging scheme	None	Hierarchical	Combinatorial	Combinatorial
Option set	–	I/J	I/J	I/USD
Mean	0.0558	0.0527	0.0536	0.0507
	[2.19]	[2.08]	[2.12]	[2.03]
Volatility	0.0938	0.0932	0.0928	0.0917
Skewness	−1.12	−0.42	−0.42	−0.46
Minimum	−0.1383	−0.0967	−0.0993	−0.1065
Difference	–	0.0031	0.0022	0.0051
	–	[0.70]	[0.50]	[0.89]
Share (ϕ)	–	0.0553	0.0389	0.0912
Avg. # pairs	–	9	25	9
Unique pairs	–	37	44	9
Fraction ITM	–	0.0624	0.0617	0.0741

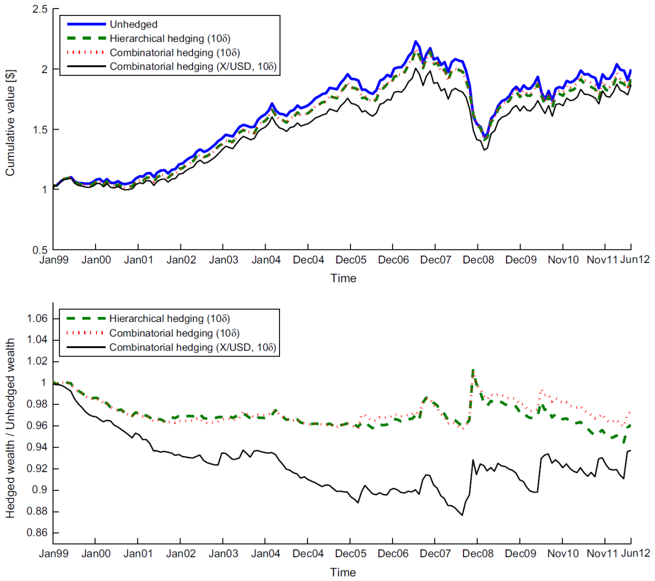
Crash-Hedged Carry Returns

Hedging also reduces returns only slightly for the dollar-neutral strategies:

Panel B: Spread-weighted, dollar-neutral portfolio returns (*SPR*-$N)

	Unhedged	CN(10δ)	CN(10δ)	CN(10δ)
Hedging scheme	None	Hierarchical	Combinatorial	Combinatorial
Option set	–	I/J	I/J	I/USD
Mean	0.0496	0.0445	0.0457	0.0426
	[1.92]	[1.72]	[1.78]	[1.68]
Volatility	0.0951	0.0951	0.0945	0.0929
Skewness	−1.07	−0.38	−0.40	−0.47
Minimum	−0.1394	−0.0959	−0.0998	−0.1082
Difference	–	0.0051	0.0039	0.0069
	–	[1.12]	[0.88]	[1.16]
Share (ϕ)	–	0.1022	0.0779	0.1401
Avg. # pairs	–	8	20	9
Unique pairs	–	28	35	9
Fraction ITM	–	0.0610	0.0599	0.0741

Crash-Hedged Carry Returns



Crash-Hedged Carry Returns

- Accounting for transaction costs increases estimates of the jump risk premium to 1.3–1.6% per year. These costs increase the cost of the option hedge and therefore the difference in returns between the unhedged and hedged portfolios.
- Thus, **tail risk accounts for less than one third of carry trade returns**. The crash premium is relatively modest in FX returns.

	Non-dollar-neutral (SPR)		Dollar-neutral (SPR-\$N)	
	CN(10δ)	CN(10δ)	CN(10δ)	CN(10δ)
Hedging scheme	Hierarchical	Combinatorial	Hierarchical	Combinatorial
Option set	I/J	I/J	I/J	I/J
Mean	0.0423	0.0432	0.0340	0.0353
	[1.66]	[1.71]	[1.31]	[1.27]
Volatility	0.0934	0.0929	0.0953	0.0947
Skewness	−0.45	−0.45	−0.41	−0.42
Minimum	−0.0984	−0.1009	−0.0976	−0.1014
Difference	0.0135	0.0126	0.0156	0.0143
	[3.02]	[2.86]	[3.39]	[3.22]
Share (ϕ)	0.2425	0.2251	0.3143	0.2885
Avg. # pairs	9	25	8	20
Unique pairs	37	44	28	35
Fraction ITM	0.0624	0.0617	0.0610	0.0599

Overview

Dollar Carry: Description

- Lustig et al. [2014] investigate an investment strategy which they call the "dollar-carry-trade".
- The strategy exploits the time-series variation in the **difference between US interest rates and the average interest rate in other countries**:
  1. Go long in a basket of foreign currencies and short in the dollar when the average foreign short-term interest rate is above the US interest rate (which typically happens during US recessions).
  2. Short all foreign currencies and take a long position in the dollar otherwise.
- Rebalancing occurs monthly.
- For the period 1983-2010, the strategy has a Sharpe ratio of 0.66 when using developed country currencies and 0.56 when using all currencies. Its correlation with the standard carry trade and equities is low.
- The dollar carry trade performs (slightly) better than the traditional carry trade that goes long the top currency bucket and short the bottom currency bucket sorted on interest rate differentials.

Dollar Carry: Returns

Table 1
Currency carry trades and equity market excess returns. The table reports the mean, standard deviation, and Sharpe ratios of three carry trade investment strategies in comparison to the U.S. equity market returns. The first strategy (USD, or dollar carry trade) goes long all available one-month currency forward contracts when the average forward discount of *developed countries* is positive, and short the same contracts otherwise. The second strategy (FX, or individual currency carry trade) is similar to the first one, but implemented at the level of individual currencies. For each country, the strategy goes long that currency if the corresponding one-month forward discount is positive, and short otherwise. We report the mean excess return across all countries. The third strategy (HML, or high-minus-low carry trade) is long in a basket of the currencies with the largest one-month forward discounts, and short in a basket of currencies with the lowest one-month forward discounts, with no direct exposure to the U.S. dollar. To construct this strategy, we sort all currencies into six bins (five when we exclude emerging market countries), and we go long in the last portfolio, short in the first, as in Lustig, Roussanov, and Verdelhan (2011). The fourth (equity benchmark) strategy is long the U.S. stock market and short the U.S. risk-free rate. In the left panel, we report the raw moments. In the right panel, we scale each currency strategy such that they exhibit the same volatility as the U.S. equity market. Data are monthly, from Reuters and Barclays (available on Datastream). Equity excess returns are for the CRSP value-weighted stock market index. Excess returns are annualized (means are multiplied by 12 and standard deviations are multiplied by $\sqrt{12}$). Sharpe ratios correspond to the ratio of annualized means to annualized standard deviations. Currency excess returns take into account bid–ask spreads on monthly forward and spot contracts, while equity excess returns do not take into account transaction costs. We report standard errors for all of the quantities (in brackets) obtained by stationary bootstrap. The sample period is 11/1983–6/2010.

	Raw returns				Scaled returns			
	USD	FX	HML	Equity	USD	FX	HML	Equity
Panel A: Developed countries								
Mean	5.60	0.48	3.00	6.26	10.18	0.91	4.77	6.26
	[1.66]	[1.65]	[1.92]	[2.98]	[3.29]	[3.11]	[3.14]	[2.98]
Std. Dev.	8.53	8.24	9.73	15.49	15.49	15.49	15.49	15.49
	[0.42]	[0.39]	[0.62]	[0.92]	[0.92]	[0.92]	[0.92]	[0.92]
Sharpe Ratio	0.66	0.06	0.31	0.40	0.66	0.06	0.31	0.40
	[0.20]	[0.20]	[0.21]	[0.20]	[0.20]	[0.20]	[0.21]	[0.20]
Corr(USD,.)		0.32	−0.03	0.01				
		[0.10]	[0.09]	[0.07]				
Panel B: All countries								
Mean	4.28	0.36	4.41	6.26	8.70	0.72	7.58	6.26
	[1.48]	[1.53]	[1.80]	[3.03]	[3.23]	[3.08]	[3.26]	[3.03]
Std. Dev.	7.61	7.77	9.02	15.49	15.49	15.49	15.49	15.49
	[0.39]	[0.38]	[0.48]	[0.92]	[0.92]	[0.92]	[0.92]	[0.92]
Sharpe Ratio	0.56	0.05	0.49	0.40	0.56	0.05	0.49	0.40
	[0.20]	[0.20]	[0.21]	[0.21]	[0.20]	[0.20]	[0.21]	[0.21]
Corr(USD,.)		0.29	0.01	−0.00				
		[0.11]	[0.08]	[0.07]				

Dollar Carry: Returns

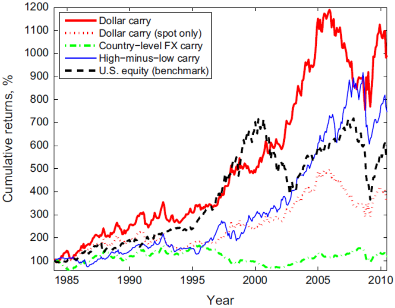


Fig. 2. Carry trade excess return indexes. This figure plots the total return index for four investment strategies, starting at $100 on November 30, 1983. The dollar carry trade goes long all one-month forward contracts in a basket of developed country currencies when the average one-month forward discount for the basket is positive, and short the same contracts otherwise. This strategy is labeled *Dollar carry*. The component of this strategy that is due to the spot exchange rate changes, i.e., excluding the interest rate differential, is *dollar carry* (*spot only*). The individual country-level carry trade is an equal-weighted average of long-short positions in individual currency one-month forward contracts that depend on the sign of the bilateral forward discounts; this strategy is labeled *Country-level FX carry*. The third strategy corresponds to dollar-neutral high-minus-low currency carry trades in one-month forward contracts (*High-minus-low carry*). The fourth strategy, *U.S. equity* (*benchmark*), is simply long the excess return on the CRSP value-weighted U.S. stock market portfolio. All strategies are levered to match the volatility of the stock market.

Dollar Carry: Interpretation

- The profitability of the strategy arises from the fact that aggregate returns on currency markets are predictable.
- **Expected currency returns against the USD are countercyclical**: they go up in US recessions and down in US expansions. Put differently, when the US economy is sluggish, the dollar tends to depreciate.
- Thus, while the traditional carry trade bears global risk, the dollar carry trade also bears a country-specific (US) risk. This risk gets averaged out in the traditional carry trade because of the presence of both long and short positions.
- Predictive regressions show that the average forward discount versus the USD and the change in the US industrial production index explain up to 25% of the subsequent variation in average annual excess returns realized by shorting the USD and going long in baskets of currencies.

Dollar Carry: Predictability

Table 2

Forecasting currency excess returns and exchange rates with the average forward discount. This table reports results of forecasting regressions for average excess returns and average exchange rate changes for baskets of currencies at horizons of one, two, three, six, and 12 months. For each basket we report the R^2, and the slope coefficient ψ_f in the time-series regression of the log currency excess return on the average log forward discount of developed countries, and similarly the slope coefficient ζ_f and the R^2 for the regressions of average exchange rate changes. The *t*-statistics for the slope coefficients in brackets are computed using the following methods. *HH* denotes Hansen and Hodrick (1980) standard errors computed with the number of lags equal to the length of overlap plus one lag. The *VAR*-based statistics are adjusted for the small-sample bias using the bootstrap distributions of slope coefficients under the null hypothesis of no predictability, estimated by drawing from the residuals of a VAR with the number of lags equal to the length of overlap plus one lag. Data are monthly, from Barclays and Reuters (available via Datastream). The returns do not take into account bid–ask spreads. The sample period is 11/1983–6/2010.

	Developed countries				Emerging countries				All countries			
	Excess returns		Exchange rates		Excess returns		Exchange rates		Excess returns		Exchange rates	
Horizon	ψ_f	R^2	ζ_f	R^2	ψ_f	R^2	ζ_f	R^2	ψ_f	R^2	ζ_f	R^2
1	2.45	2.91	1.45	1.03	2.06	2.21	2.28	2.63	2.19	2.93	1.56	1.51
HH	[2.55]		[1.51]		[2.09]		[2.22]		[2.54]		[1.80]	
VAR	[2.61]		[1.53]		[2.20]		[2.47]		[2.57]		[1.93]	
2	2.49	5.00	1.49	1.86	2.09	3.96	2.34	4.70	2.25	5.08	1.64	2.75
HH	[2.52]		[1.51]		[2.14]		[2.24]		[2.50]		[1.81]	
VAR	[2.37]		[1.51]		[2.02]		[2.12]		[2.39]		[1.66]	
3	2.46	6.52	1.46	2.40	2.04	4.94	2.29	5.84	2.21	6.49	1.60	3.53
HH	[2.46]		[1.46]		[1.97]		[2.05]		[2.40]		[1.73]	
VAR	[2.19]		[1.47]		[1.94]		[2.16]		[2.39]		[1.63]	
6	2.45	10.23	1.45	3.84	2.02	6.96	2.29	8.25	2.19	9.95	1.61	5.63
HH	[2.50]		[1.48]		[1.80]		[1.87]		[2.38]		[1.73]	
VAR	[2.49]		[1.49]		[2.03]		[2.12]		[2.48]		[1.93]	
12	2.12	13.14	1.12	4.05	2.27	12.94	2.54	14.86	1.90	12.37	1.32	6.45
HH	[2.18]		[1.15]		[1.91]		[1.93]		[2.10]		[1.42]	
VAR	[2.14]		[1.20]		[2.79]		[3.19]		[2.21]		[1.51]	

Table 10

Forecasting excess returns and exchange rates with industrial production and the average forward discount. This table reports results of forecasting regressions for average excess returns and average exchange rate changes for baskets of currencies at horizons of one, two, three, six, and 12 months. For each basket we report the R^2, and the slope coefficients in the time-series regression of the log currency excess return on the 12-month change in the U.S. Industrial Production Index (ψ_{IP}) and on the average log forward discount (ψ_f), and similarly the slope coefficients ζ_{IP}, ζ_f, and the R^2 for the regressions of average exchange rate changes. The *t*-statistics for the slope coefficients in brackets are computed using the following methods. *HH* denotes Hansen and Hodrick (1980) standard errors computed with the number of lags equal to the length of overlap plus one lag. The *VAR*-based statistics are adjusted for the small-sample bias using the stationary bootstrap distributions of slope coefficients under the null hypothesis of no predictability, estimated by drawing random blocks of residuals of a VAR with the number of lags equal to the length of overlap plus one lag. Data are monthly, from Barclays and Reuters (available via Datastream). We also report the Wald tests (*W*) of the hypothesis that both slope coefficients are jointly equal to zero; the percentage *p*-values in brackets are for the χ^2-distribution under the parametric cases (*HH*) and for the bootstrap distribution of the *F*-statistic under *VAR*. Data are monthly, from Barclays and Reuters (available via Datastream). The returns do not take into account bid–ask spreads. The sample period is 11/1983–6/2010.

	Developed countries								Emerging countries								All countries							
	Excess returns				Exchange rates				Excess returns				Exchange rates				Excess returns				Exchange rates			
Horizon	ψ_{IP}	ψ_f	W	R^2	ζ_{IP}	ζ_f	W	R^2	ψ_{IP}	ψ_f	W	R^2	ζ_{IP}	ζ_f	W	R^2	ψ_{IP}	ψ_f	W	R^2	ζ_{IP}	ζ_f	W	R^2
1	−0.54	2.14	7.00	3.40	−0.54	1.14	3.16	1.53	−1.15	−0.20	3.78	2.74	−1.15	−1.20	6.73	4.93	−0.65	1.68	5.00	2.72	−0.65	0.68	2.49	1.41
HH	[−0.96]	[2.06]	[1.24]		[−0.96]	[1.10]	[29.79]		[−1.95]	[−0.27]	[28.75]		[−1.95]	[−1.57]	[7.64]		[−1.23]	[1.50]	[10.49]		[−1.23]	[0.61]	[49.35]	
VAR	[−1.02]	[2.32]	[0.00]		[−0.97]	[1.26]	[0.00]		[−2.39]	[−0.47]	[0.00]		[−2.32]	[−2.26]	[0.00]		[−1.31]	[1.66]	[0.00]		[−1.41]	[0.70]	[0.10]	
2	−0.65	2.09	10.35	6.25	−0.65	1.09	6.71	3.14	−1.17	−0.64	7.10	6.54	−1.17	−1.64	6.64	11.66	−0.74	1.64	7.53	5.24	−0.74	0.64	4.97	3.06
HH	[−1.34]	[2.02]	[0.63]		[−1.34]	[1.05]	[17.97]		[−2.38]	[−0.80]	[9.83]		[−2.38]	[−2.05]	[2.40]		[−1.65]	[1.52]	[3.43]		[−1.65]	[0.60]	[25.98]	
VAR	[−1.24]	[1.90]	[0.00]		[−1.21]	[1.02]	[0.00]		[−2.35]	[−1.14]	[0.00]		[−2.32]	[−2.78]	[0.00]		[−1.41]	[1.52]	[0.00]		[−1.60]	[0.55]	[0.10]	
3	−0.72	1.99	23.67	8.68	−0.72	0.99	19.77	4.65	−1.28	−0.54	8.01	9.81	−1.28	−1.54	7.59	15.74	−0.82	1.52	10.17	7.57	−0.82	0.52	9.45	4.77
HH	[−1.66]	[1.97]	[0.43]		[−1.66]	[0.98]	[12.21]		[−2.71]	[−0.68]	[3.00]		[−2.71]	[−1.94]	[1.33]		[−2.08]	[1.53]	[1.72]		[−2.08]	[0.53]	[13.49]	
VAR	[−1.28]	[1.69]	[0.00]		[−1.49]	[0.96]	[0.00]		[−2.64]	[−0.92]	[0.00]		[−2.67]	[−2.36]	[0.00]		[−1.76]	[1.23]	[0.00]		[−1.76]	[0.41]	[0.00]	
6	−0.87	1.84	38.02	15.58	−0.87	0.84	32.04	9.57	−1.48	−0.25	6.37	18.21	−1.48	−1.25	6.88	24.14	−0.96	1.59	11.94	15.92	−0.96	0.59	10.58	11.21
HH	[−2.60]	[2.03]	[0.00]		[−2.60]	[0.93]	[0.53]		[−3.06]	[−0.35]	[0.27]		[−3.06]	[−1.74]	[0.50]		[−3.15]	[2.06]	[0.01]		[−3.15]	[0.76]	[0.22]	
VAR	[−1.71]	[1.78]	[0.00]		[−1.85]	[0.84]	[0.00]		[−3.46]	[−0.46]	[0.00]		[−3.24]	[−1.87]	[0.00]		[−2.16]	[1.37]	[0.00]		[−2.36]	[0.51]	[0.00]	
12	−0.91	1.37	16.75	23.20	−0.91	0.37	13.05	15.16	−1.53	−0.07	7.37	28.40	−1.53	−1.07	7.35	34.51	−1.00	1.14	12.55	24.36	−1.00	0.14	10.25	18.49
HH	[−3.39]	[1.50]	[0.00]		[−3.39]	[0.41]	[0.00]		[−3.06]	[−0.08]	[0.24]		[−3.06]	[−1.24]	[0.60]		[−3.64]	[1.71]	[0.00]		[−3.64]	[0.21]	[0.01]	
VAR	[−2.15]	[1.35]	[0.00]		[−2.23]	[0.40]	[0.10]		[−5.27]	[−0.17]	[0.00]		[−5.00]	[−1.77]	[0.00]		[−2.89]	[1.18]	[0.00]		[−2.93]	[0.13]	[0.00]	

Overview

Theory: Pricing Kernel

- The carry trade uses short-term interest rates to predict excess foreign exchange returns. Ang and Chen [2013] investigate the ability of **additional term structure variables** to predict these returns.
- They show theoretically how other yield curve variables may affect expected FX returns using a no-arbitrage framework. Let M denote the pricing kernel in the domestic country. The price of any asset, P, satisfies

$$P_t = \mathbb{E}_t[M_{t+1}P_{t+1}] \; . \tag{23}$$

This is in particular the case for the price of a n-period zero coupon bond:

$$P_t^{(n)} = \mathbb{E}_t[M_{t+1}P_{t+1}^{(n-1)}] \; . \tag{24}$$

- They assume that the pricing kernel takes the following form:

$$M_{t+1} = \exp\left(-r_t - \frac{1}{2}\lambda_t^2 - \lambda_t \varepsilon_{t+1}\right) \; , \tag{25}$$

where r_t is the one-period riskless rate and λ_t a time-varying market price of risk which prices shocks to the short rate, ε_{t+1} (assumed to be a scalar and uncorrelated with other shocks).

Theory: Pricing Kernel

- The price of risk λ_t is potentially driven by multiple factors. Time-varying prices of risk give rise to time-varying risk premia on long-term bonds.

- We have seen that priced risk factors include yield curve variables like the level and the slope of the yield curve. Macroeconomic variables like inflation and output can also play a role. Ang and Chen [2013] focus on yield curve factors.

- The pricing kernel in foreign country i is assumed to take a similar form:

$$M^i_{t+1} = \exp\left(-r^i_t - \frac{1}{2}(\lambda^i_t)^2 - \lambda^i_t \varepsilon^i_{t+1}\right) , \tag{26}$$

  and the price of a n-period zero coupon bond denominated in currency i must satisfy:

$$P^{i,(n)}_t = \mathbb{E}_t[M^i_{t+1} P^{i,(n-1)}_{t+1}] . \tag{27}$$

Theory: Pricing Kernel and Exchange Rate

- Letting R_{t+1} denote the gross return on a domestic asset, one must have

$$\mathbb{E}_t[M_{t+1}R_{t+1}] = 1\ . \tag{28}$$

- For an investor in country i starting with one unit of foreign currency, converting to the domestic currency at rate S_t^i, earning the domestic currency return R_{t+1} and converting back to foreign currency in period $t+1$ at rate S_{t+1}^i must satisfy

$$\mathbb{E}_t\left[M_{t+1}^i \frac{S_t^i R_{t+1}}{S_{t+1}^i}\right] = 1\ . \tag{29}$$

- Hence, under complete markets one must have

$$M_{t+1} = M_{t+1}^i \frac{S_t^i}{S_{t+1}^i} \tag{30}$$

  and (one plus) the **exchange rate change is the ratio of the pricing kernels** in the foreign and domestic country:

$$\frac{S_{t+1}^i}{S_t^i} = \frac{M_{t+1}^i}{M_{t+1}}\ . \tag{31}$$

Theory: FX Risk Premium

- Taking logs, this expression can be rewritten as

$$\begin{aligned}\Delta s^i_{t+1} = s^i_{t+1} - s^i_t &= m^i_{t+1} - m_{t+1} \\ &= r_t - r^i_t + \frac{1}{2}(\lambda^2_t - (\lambda^i_t)^2) + \lambda_t \varepsilon_{t+1} - \lambda^i_t \varepsilon^i_{t+1} \; . \end{aligned} \tag{32}$$

- Hence, the foreign exchange risk premium (expected excess return) of the *i*th currency is half the difference in the conditional variances of the domestic and foreign pricing kernels:

$$\mathbb{E}_t[rx^i_{t,1}] = \mathbb{E}_t[\Delta s^i_{t+1} + r^i_t - r_t] = \frac{1}{2}(\lambda^2_t - (\lambda^i_t)^2) \; . \tag{33}$$

- UIP assumes that the right hand side of this expression is zero. However, the equation shows that **any factor affecting the domestic or foreign prices of risk can potentially predict currency excess returns**.

- Expected foreign exchange returns are high when the domestic pricing kernel is more volatile than the foreign one. Since the domestic pricing kernel is volatile in bad times, the carry trade has **high expected returns in bad times**.

Theory: Term Structure Variables

- The authors then use term structure models to show how a number of term structure variables might affect the variance of the pricing kernel.
- The variables that might affect that variance are:
  - Short rates
  - Changes in rates
  - Long-term bond yields
  - Term spread
  - Interest rate volatility
- They then show empirically that portfolios constructed by ranking currencies based on these variables generate excess returns.

Overview

Sample and Portfolio Construction

- The empirical analysis is based on 23 countries (G10 plus 13 others) for the period 1975-2009.
- For each term structure variable, currency portfolios are formed in two ways:
  1. **Equally weighted**. Go long currencies in the top tercile and short currencies in the bottom tercile.
  2. **Signal-weighted**. To ensure zero net positions and constant long and short portfolio weights, each month the signals are standardized to have zero mean and a constant standard deviation of two. This ensures that all positive signal values sum to one and all negative signal values sum to -1.
- The portfolios are rebalanced monthly.

Variable Description

Overview of the term structure variables considered in the empirical analysis:

Table 1: Variable Definitions

Variable	Description	Notation
Short rates	One-month interbank rates	r_t
Δ Short rate	Changes in short rates	$\Delta r_t = r_t - r_{t-1}$
Long rates	10-year bond rates	y_t
Δ Long rate	Changes in long rates	$\Delta y_t = y_t - y_{t-1}$
Level	Interest rate levels	$(y_t + r_t)/2$
Change	Changes in interest rate levels	$\Delta(y_t + r_t)/2 =$ $(y_t + r_t)/2 - (y_{t-1} + r_{t-1})/2$
Term	Difference between 10-year bond rates and one-month interbank rates	$y_t - r_t$
Δ Term	Changes in term spreads	$\Delta(y_t - r_t) =$ $(y_t - r_t) - (y_{t-1} - r_{t-1})$
Volatility	Annualized standard deviation of daily short rate changes over the past 12 months	

Equally Weighted Portfolio Returns

Equally weighted long-short portfolios constructed based on the different variables exhibit sizable Sharpe ratios. The portfolios based on term spreads have a negative Sharpe ratio so they should be implemented in reverse – buy currencies with low (or negative) term spreads and sell currencies with a steep yield curve.

	Mean (per month)	Stdev (per month)	Sharpe Ratio (Annualized)	Skewness
Panel A: All Developed Countries				
Short rate ("carry")	0.181	0.934	0.673	-1.106
Δ Short rate	0.088	0.688	0.442	-0.272
Long rate	0.116	0.870	0.462	-1.280
Δ Long rate	0.111	0.702	0.548	0.610
Level	0.169	0.913	0.642	-1.243
Change	0.094	0.694	0.470	-0.256
Term	-0.196	0.841	-0.809	0.847
Δ Term	-0.032	0.655	-0.169	0.447
Volatility	0.052	0.771	0.233	-0.226
Panel B: G10 Currencies Only				
Short rate ("carry")	0.217	1.327	0.567	-1.012
Δ Short rate	0.100	0.993	0.350	-0.069
Long rate	0.143	1.269	0.390	-0.796
Δ Long rate	0.159	1.060	0.519	0.328
Level	0.172	1.339	0.445	-0.897
Change	0.132	1.015	0.449	0.006
Term	-0.219	1.137	-0.667	0.492
Δ Term	0.007	1.030	0.024	-0.098
Volatility	0.063	1.039	0.209	-0.370

Signal-Weighted Portfolio Returns

Signal-weighted portfolios generate the following returns:

	Mean (per month)	Stdev (per month)	Sharpe Ratio (Annualized)	Skewness
Panel A: All Developed Countries				
Short rate	0.245	0.992	0.856	-0.964
Δ Short rate	0.116	0.833	0.482	0.171
Long rate	0.156	0.973	0.554	-1.458
Δ Long rate	0.067	0.804	0.287	-0.379
Level	0.214	0.989	0.749	-1.096
Change	0.117	0.815	0.496	0.366
Term	-0.241	0.920	-0.907	0.341
Δ Term	-0.075	0.785	-0.331	-0.138
Volatility	0.117	0.878	0.463	-0.297
Panel B: G10 Currencies Only				
Short rate	0.235	1.342	0.606	-0.865
Δ Short rate	0.133	1.073	0.431	0.164
Long rate	0.155	1.376	0.391	-1.022
Δ Long rate	0.134	1.154	0.403	-1.181
Level	0.207	1.363	0.527	-0.919
Change	0.163	1.055	0.536	0.257
Term	-0.233	1.171	-0.691	0.483
Δ Term	-0.046	1.103	-0.146	-0.491
Volatility	0.076	1.142	0.231	-0.413

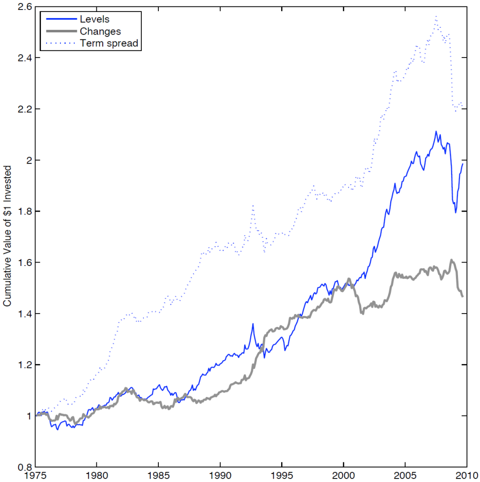
Portfolio Correlations

Several correlations between the returns on (equally weighted) portfolios formed using different term structure variables are relatively low; thus, combining them provides diversification benefits.

	Short rate	Δ Short rate	Long rate	Δ Long rate	Level	Change	Term	Δ Term
Short rate	1.000							
Δ Short rate	0.040	1.000						
Long rate	0.900	0.034	1.000					
Δ Long rate	-0.021	0.214	0.020	1.000				
Level	0.973	0.063	0.933	-0.011	1.000			
Change	0.033	0.781	0.043	0.503	0.061	1.000		
Term	-0.728	-0.164	-0.562	0.090	-0.698	-0.106	1.000	
Δ Term	-0.047	-0.697	-0.029	0.227	-0.061	-0.389	0.114	1.000
Volatility	0.340	-0.144	0.390	-0.032	0.351	-0.120	-0.090	0.110

Cumulative Returns

Based on these findings, the authors focus on three portfolios – Level, Change, and Term. The equity lines of these portfolios are shown below. The Level and Term portfolios had huge drawdowns in 2008 which wiped out about 5 years of gains.



Level, Change, and Term Predict Currency Returns

This means that changes in interest rate levels and term spreads contain **additional predictive power** independent of carry.

Results of pooled regressions of cumulative excess returns in percent per month. The regressions include month fixed effects.

	Excess FX Return Horizon (Months)					
	1	2	3	6	9	12
Panel A: Level, Change, and Term						
Level	0.098**	0.100**	0.096**	0.087**	0.086**	0.087**
	(0.029)	(0.023)	(0.021)	(0.017)	(0.016)	(0.016)
Change	0.073**	0.060**	0.044*	0.020+	0.040**	0.038**
	(0.028)	(0.021)	(0.018)	(0.011)	(0.014)	(0.015)
Term	-0.126**	-0.105**	-0.099**	-0.089**	-0.083**	-0.086**
	(0.030)	(0.029)	(0.030)	(0.027)	(0.024)	(0.027)
Panel B: Level, Change, Term, and Volatility						
Level	0.093**	0.099**	0.096**	0.088**	0.093**	0.099**
	(0.035)	(0.029)	(0.027)	(0.022)	(0.021)	(0.021)
Change	0.080**	0.066**	0.048**	0.023*	0.042**	0.040**
	(0.027)	(0.021)	(0.018)	(0.011)	(0.014)	(0.014)
Term	-0.121**	-0.098**	-0.093**	-0.085**	-0.077**	-0.080**
	(0.031)	(0.029)	(0.030)	(0.026)	(0.024)	(0.026)
Volatility	0.025	0.016	0.010	0.003	-0.010	-0.019
	(0.042)	(0.040)	(0.038)	(0.032)	(0.032)	(0.032)

Factor Exposures

The factor exposures of the strategies differ. The excess returns of the Change and Term strategies remain significant after controlling for carry returns. By contrast with carry, the Change portfolio returns are not affected by volatility. Level, Change and Term portfolio returns are unrelated to consumption growth rates.

	Level	Change	Term	Volatility	FX Moment	FX Value
Panel A: Carry Trade						
Constant	-0.003	0.090*	-0.078*	0.001	0.193**	-0.064
	(0.010)	(0.036)	(0.031)	(0.036)	(0.059)	(0.059)
Carry Trade	0.951**	0.025	-0.655**	0.281**	0.034	-0.225+
	(0.013)	(0.061)	(0.050)	(0.069)	(0.130)	(0.122)
Panel B: ΔVIX						
ΔVIX	-0.070**	-0.008	0.034+	-0.022+	0.017	0.008
	(0.020)	(0.008)	(0.020)	(0.012)	(0.026)	(0.024)
Panel C: Real U.S. Non-Durable Consumption Growth						
Consumption Growth	0.023	0.006	-0.036	-0.022*	-0.037*	0.032
(Non-Durables)	(0.034)	(0.015)	(0.039)	(0.011)	(0.017)	(0.022)
Panel D: Real U.S. Durable Goods Consumption Growth						
Consumption Growth	0.001	-0.004	-0.002	-0.010**	-0.009**	0.008+
(Durables)	(0.008)	(0.004)	(0.009)	(0.003)	(0.003)	(0.005)

Yield Curve: Summary

Summarizing, the main findings of the Ang and Chen [2013] study are:

- Predictability of foreign exchange returns by information in the term structure is consistent with a no-arbitrage framework. Any variable which affects the prices of domestic bonds can potentially predict exchange rates.
- Yield curves contain significant information beyond carry that is useful for predicting currency returns.
- Specifically, changes in interest rate levels and term spreads contain additional predictive power for currency returns independent of carry. Currencies with large changes in interest rate levels tend to appreciate and currencies with a steep yield curve tend to depreciate.
- Portfolios constructed on the basis of changes in interest rate levels and term spreads exhibit large Sharpe ratios. The term spread yields the largest Sharpe ratio but has negative skewness.
- Common risk factors including carry cannot explain the returns of the Change and Term portfolios.

Overview

Momentum Strategies

- We have seen that there is momentum in equity returns. It turns out that **momentum is also present in currency returns**. Past 1 to 12 month returns positively predict future 1 to 12 month returns.
- Momentum strategies involve buying winners and selling losers. This can be done in the time series and in the cross-section:
  1. **Time series**: Buy all currencies that appreciated during the past k months and sell all currencies that depreciated during the past k months (see Moskowitz et al. [2012] for an example of a time series implementation).
  2. **Cross-section**: Sort currencies into quantiles based on past returns. Buy those in the upper bucket and sell those in the bottom bucket.
- Cross-sectional strategies tend to be more robust.
- Currency momentum strategies are usually implemented using long-short portfolios that are dollar-neutral – one is one dollar long in the past winners and one dollar short in the past losers. Within the long and short legs one can use equal weights or weights based on the strength of the signal (e.g. return size or rank).

Momentum Returns before Transaction Costs

- Menkhoff et al. [2012b] investigate currency momentum strategies for up to 48 currencies during the period 1976-2010. Momentum portfolios earn sizable returns which tend to be largest for a holding period of one month.
- The profitability of currency momentum strategies is also visible in spot rate changes themselves (right panel) and is thus not mostly driven by the interest rate differential (by contrast with carry).

This table shows annualized average returns for different momentum strategies ($\overline{r^{f,h}}$) in Panel A. The rows show formation periods (f) whereas the columns indicate holding periods (h) in months. Numbers in brackets are t-statistics based on Newey and West (1987) heteroscedasticity and autocorrelation consistent (HAC) standard errors. The left part of the table shows currency excess returns (spot rate changes adjusted for interest rate differentials) whereas the right part shows pure spot rate returns. Panel B shows annualized Sharpe Ratios. t-Statistics based on a moving block-bootstrap are in squared brackets. The right panel shows average annualized spot rate changes (in percent) divided by the annualized standard deviation of mean exchange rate changes. The sample period is January 1976–January 2010 and we employ monthly returns.

Panel A: Excess returns and spot rate changes

	Excess returns						Spot rate changes				
	Holding period h						Holding period h				
f	1	3	6	9	12	f	1	3	6	9	12
1	9.46	7.00	6.17	5.15	5.75	1	7.91	4.42	3.38	4.75	3.13
	[5.31]	[4.11]	[3.13]	[2.73]	[3.6]		[4.55]	[3.07]	[1.93]	[2.94]	[2.02]
3	9.40	6.32	4.96	4.67	4.43	3	8.54	5.73	5.28	4.63	5.10
	[5.30]	[3.80]	[3.03]	[2.92]	[2.74]		[5.10]	[3.59]	[3.66]	[2.88]	[3.51]
6	8.54	6.31	3.66	3.25	3.14	6	6.50	5.75	3.47	3.64	3.17
	[4.78]	[3.63]	[2.06]	[1.79]	[1.69]		[3.88]	[4.00]	[2.15]	[2.32]	[1.80]
9	7.18	6.80	5.36	3.86	3.24	9	8.33	7.06	6.50	4.91	4.09
	[3.80]	[3.65]	[2.86]	[2.05]	[1.67]		[4.82]	[4.23]	[3.91]	[2.87]	[2.35]
12	6.16	5.48	3.02	2.05	1.89	12	7.59	6.04	3.94	3.19	3.03
	[3.40]	[3.24]	[1.75]	[1.17]	[1.04]		[4.63]	[4.02]	[2.59]	[1.97]	[1.92]

Momentum Returns before Transaction Costs

The Sharpe ratios are large:

Panel B: Sharpe Ratios and normalized spot rate changes

	Excess returns						Spot rate changes				
	Holding period *h*						Holding period *h*				
f	1	3	6	9	12	*f*	1	3	6	9	12
1	0.95	0.76	0.59	0.56	0.61	1	0.84	0.53	0.37	0.57	0.37
	[5.48]	[4.10]	[3.15]	[2.47]	[2.95]		[5.52]	[4.23]	[3.25]	[2.81]	[3.21]
3	0.88	0.60	0.50	0.53	0.51	3	0.86	0.57	0.58	0.50	0.63
	[5.37]	[3.70]	[3.04]	[2.74]	[2.42]		[5.17]	[3.73]	[3.45]	[2.99]	[2.61]
6	0.79	0.60	0.37	0.34	0.33	6	0.64	0.60	0.38	0.41	0.35
	[4.55]	[3.53]	[1.94]	[1.76]	[1.48]		[4.76]	[3.70]	[2.06]	[2.05]	[1.43]
9	0.67	0.63	0.50	0.36	0.30	9	0.85	0.71	0.66	0.51	0.41
	[3.76]	[3.61]	[2.95]	[1.95]	[1.57]		[3.99]	[3.66]	[3.07]	[2.12]	[1.84]
12	0.61	0.56	0.32	0.21	0.19	12	0.77	0.64	0.44	0.35	0.33
	[3.18]	[3.05]	[1.64]	[1.17]	[1.05]		[3.48]	[3.32]	[1.89]	[1.27]	[1.14]

Momentum Returns after Transaction Costs

However, returns after transaction costs are much lower:

This table shows annualized average returns for different momentum strategies ($\overline{r^{f,h}}$) after adjusting for bid–ask spreads. Panel A shows results for net excess returns (left part) and net spot rate changes (right part) when deducting the full quoted spread. Numbers in brackets are t-statistics based on Newey and West (1987) standard errors. Panel B shows results only for net excess returns and for the case that effective spreads equal 75% (left part) or 50% (right part) of the quoted spread. The sample period is January 1976–January 2010 and we employ monthly returns.

Panel A: Quoted spreads

Net excess returns (Holding period h)

f	1	3	6	9	12
1	3.92	2.02	1.26	0.38	0.39
	[2.20]	[1.16]	[0.61]	[0.18]	[0.20]
3	4.41	2.12	0.88	0.97	−0.07
	[2.39]	[1.20]	[0.53]	[0.58]	[-0.04]
6	3.86	2.12	−0.27	−0.92	−1.28
	[2.09]	[1.19]	[−0.15]	[−0.49]	[−0.67]
9	2.48	2.43	0.99	−0.40	−1.06
	[1.26]	[1.27]	[0.51]	[−0.21]	[−0.54]
12	1.40	0.80	−1.46	−1.98	−2.44
	[0.74]	[0.45]	[−0.84]	[−1.11]	[−1.31]

Net spot rate changes (Holding period h)

f	1	3	6	9	12
1	4.84	3.36	2.69	4.43	2.53
	[2.81]	[2.37]	[1.57]	[2.76]	[1.65]
3	6.80	4.58	4.72	4.33	4.86
	[3.99]	[2.81]	[3.18]	[2.58]	[3.32]
6	5.06	4.83	3.06	3.27	3.29
	[3.03]	[3.37]	[1.94]	[2.08]	[1.88]
9	7.53	6.73	6.19	4.81	3.84
	[4.34]	[4.00]	[3.69]	[2.88]	[2.20]
12	6.65	5.53	3.75	2.92	2.77
	[4.01]	[3.66]	[2.47]	[1.79]	[1.73]

Panel B: Effective spreads and net excess returns

Effective spread of 75% (Holding period h)

f	1	3	6	9	12
1	5.28	3.24	2.51	1.53	1.69
	[2.98]	[1.89]	[1.25]	[0.76]	[0.88]
3	5.61	3.16	1.86	1.85	0.97
	[3.07]	[1.82]	[1.12]	[1.12]	[0.59]
6	5.03	3.17	0.70	0.15	−0.18
	[2.76]	[1.80]	[0.39]	[0.08]	[−0.10]
9	3.66	3.56	2.16	0.68	0.08
	[1.89]	[1.89]	[1.13]	[0.35]	[0.04]
12	2.60	1.97	−0.35	−0.94	−1.36
	[1.39]	[1.12]	[−0.20]	[−0.53]	[−0.74]

Effective spread of 50% (Holding period h)

f	1	3	6	9	12
1	6.64	4.47	3.77	2.69	3.00
	[3.76]	[2.62]	[1.89]	[1.36]	[1.61]
3	6.81	4.20	2.83	2.74	2.00
	[3.76]	[2.45]	[1.72]	[1.68]	[1.23]
6	6.20	4.23	1.68	1.21	0.92
	[3.43]	[2.41]	[0.94]	[0.66]	[0.49]
9	4.85	4.69	3.33	1.75	1.24
	[2.53]	[2.52]	[1.76]	[0.93]	[0.64]
12	3.80	3.13	0.78	0.09	−0.28
	[2.07]	[1.81]	[0.45]	[0.05]	[−0.15]

Momentum and Carry Returns

Long-short momentum portfolio returns have low correlation with carry trade returns:

This table shows correlation coefficients between portfolio returns. Panel A shows correlation coefficients between momentum returns based on strategies with formation horizons of f equal to one, six, and 12 months and holding periods of $h=1$ month (denoted $MOM_{1,1}$, $MOM_{6,1}$, $MOM_{12,1}$, respectively) and forward discount-sorted portfolio returns (denoted C since they form the basis of the carry trade). Returns are based on six portfolios and a long-short portfolio for both momentum and the carry trade. We only report correlations for corresponding pairs of portfolios. For example, in row $\rho(M_{1,1},C)$, we report the correlation of the "Low" momentum portfolio with the "Low" carry trade portfolio in column "Low," the correlation of the third momentum portfolio with the third carry trade portfolio, and so on for all six portfolios and the long-short portfolios. Row $\rho(M_6,C)$ shows the correlations between portfolio pairs of the momentum strategy with a six-month formation period with the carry trade and row $\rho(M_{12},C)$ shows the correlations between portfolio pairs of the 12-month formation period momentum strategy and the carry trade. Panel B shows correlations for momentum portfolios with different formation horizons. The sample period is January 1976–January 2010 and we employ monthly returns.

Panel A: Momentum and carry trade portfolios

	Low	2	3	4	5	High	H – L
$\rho(MOM_{1,1},C)$	0.68	0.84	0.83	0.85	0.81	0.73	0.04
$\rho(MOM_{6,1},C)$	0.63	0.84	0.82	0.83	0.81	0.74	0.01
$\rho(MOM_{12,1},C)$	0.67	0.85	0.81	0.87	0.82	0.74	0.07

Momentum: Long-Term Reversal

Cumulative returns peak for a holding period of about 8–12 months and decline thereafter. This is similar to what has been documented for equities.

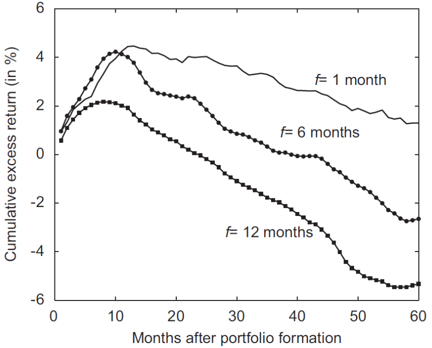


Fig. 4. Long-horizon momentum excess returns. This figure shows cumulative average excess returns to three different long-short currency momentum portfolios after portfolio formation. Momentum portfolios differ in their formation period (f=1,6,12 months) and post-formation returns are shown for 1,2,…,60 months following the formation period (i.e., we build new portfolios each months but track these portfolios for the first 60 months after their formation so that we are effectively using overlapping horizons). Excess returns are monthly and the sample period runs from January 1976 to January 2010.

Momentum Returns and the Business Cycle

There is no obvious correlation of momentum returns with the state of the business cycle:

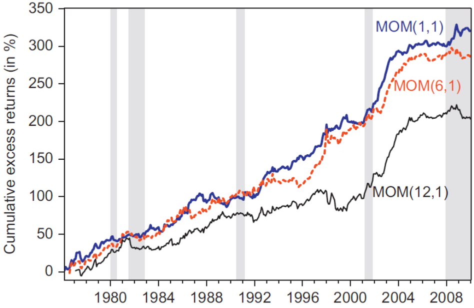


Fig. 2. Cumulative excess returns of momentum strategies. This figure shows cumulative log excess returns (not adjusted for transaction costs) accruing to three different momentum returns. The momentum strategies are for a formation period of 1, 6, and 12 months, respectively, and the holding period is one month. The bold line shows returns to the momentum strategy with a one-month formation period (MOM(1,1) in the figure), the dashed line shows returns to a strategy with a six-month formation period (MOM(6,1)), whereas the thin, black line shows returns to a momentum strategy with a 12-month formation period (MOM(12,1)). Shaded areas correspond to NBER recessions.

Momentum returns have little relation to macroeconomic risks:

This table shows time-series regression estimates of currency momentum returns (long–short portfolios $MOM_{1,1}$,$MOM_{6,1}$, and $MOM_{12,1}$) on various macrofactors and other risk factors. Consumption is real consumption growth, Employment denotes U.S. total nonfarm employment growth, ISM denotes the ISM manufacturing index, IP denotes growth in real industrial production, CPI denotes the inflation rate, M2 is the growth in real money balances, Disp inc is growth in real disposable personal income, TED denotes the TED spread, Term denotes the term spread (20 years minus 3 months), HML_{FX} is the return to the carry trade long–short portfolio (Lustig, Roussanov, Verdelhan, 2011), and VOL_{FX} is a proxy for global FX volatility (Menkhoff, Sarno, Schmeling, and Schrimpf, 2012). MKTRF, HML, and SMB are the Fama-French factors and UMD denotes the return to a long–short U.S. momentum portfolio. Panel A shows results for univariate regressions (intercepts α, slope coefficients β, and the adjusted R^2) whereas Panel B shows results from a multivariate regression of momentum returns on the three Fama-French factors and UMD. Bold numbers indicate significance at the 5%-level or below.

Panel A: Univariate regressions

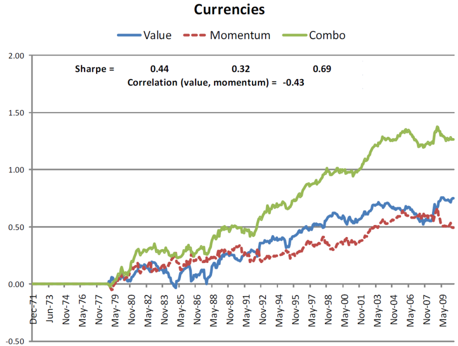
	$MOM_{1,1}$			$MOM_{6,1}$			$MOM_{12,1}$		
	α	β	R^2	α	β	R^2	α	β	R^2
Consumption	**9.65**	−0.05	0.00	**8.95**	−0.12	0.00	**6.03**	0.07	0.00
Employment	**10.57**	−0.72	0.00	**7.74**	0.62	0.00	**5.86**	0.23	0.00
ISM	**9.46**	0.04	0.00	**8.60**	0.03	0.00	**6.14**	0.04	0.00
IP	**9.72**	0.11	0.00	**8.72**	0.04	0.00	**6.26**	0.03	0.00
CPI	**11.73**	−0.55	0.00	**9.11**	−0.12	0.00	**6.60**	−0.10	0.00
M2	**9.97**	0.34	0.00	**8.68**	0.02	0.00	**6.18**	−0.01	0.00
Disp inc	**9.33**	0.07	0.00	**8.42**	0.10	0.00	**5.95**	0.10	0.00
TED	**13.64**	**−0.38**	0.01	**11.95**	−0.30	0.01	**9.73**	−0.32	0.01
Term	4.48	**0.22**	0.01	**7.54**	0.05	0.00	5.05	0.05	0.00
HML_{FX}	**9.50**	0.04	0.00	**8.65**	0.02	0.00	**6.21**	0.08	0.00
VOL_{FX}	**11.70**	−0.44	0.00	**18.75**	−2.04	0.01	**27.59**	**−4.29**	0.04

Momentum: Summary and Interpretation

- Currency momentum is a profitable investment strategy that has low correlation with carry trade returns.
- Momentum returns exhibit a strong reversal in performance at long horizons if the portfolios are not rebalanced.
- The return patterns – initial continuation and subsequent reversal at longer horizons – are consistent with behavioral explanations such as slow processing of information/investor underreaction to news.
- Momentum returns cannot be explained by exposure to macroeconomic risks.

Momentum and Value

- Asness et al. [2013] investigate momentum and value strategies in different asset classes. Value is hard to define for currencies; the authors use the opposite of momentum over a 5-year lookback period. The losers of the last 5 years become the long portfolio and the winners of the last 5 years the short portfolio.
- As was the case in other asset classes, value and momentum are negatively correlated for currencies so that it is advantageous to combine them.



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