Section 10: Currencies

Ralph S.J. Koijen   Stijn Van Nieuwerburgh*

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*Koijen: University of Chicago, Booth School of Business, NBER, and CEPR. Van Nieuwerburgh: Columbia Business School, CEPR, and NBER. If you find typos, or have any comments or suggestions, then please let us know via ralph.koijen@chicagobooth.edu or svnieuwe@gsb.columbia.edu.

1. Basic structure of the notes

- High-level summary of theoretical frameworks to interpret empirical facts.
- Per asset class, we will discuss:
  1. Key empirical facts in terms of prices (unconditional and conditional risk premia) and asset ownership.
  2. Interpret the facts using the theoretical frameworks.
  3. Facts and theories linking financial markets and the real economy.
  4. Active areas of research and some potentially interesting directions for future research.
- The notes cover the following asset classes:
  1. Equities (weeks 1-5).
     - Discount rates and the term structure of risk (week 1)
     - The Cross-section and the factor zoo (week 2)
     - Intermediary-based Asset Pricing (week 3)
     - Production-based asset pricing (week 4)
     - Demand-based asset pricing (week 5)
  2. Mutual funds and hedge funds (week 6).
  3. Volatility (week 7).
  4. Government bonds (week 8).
  5. Corporate bonds (week 9).
  6. Currencies (week 10).
  7. Commodities (week 11).
  8. Real estate (week 12).

2. Currencies

2.1. Some Basics

2.1.1. The Currency Risk Premium

- Assume that financial markets are complete.
- In each country, at each date, a representative investor has access to
  - A domestic bond that pays off one unit of domestic consumption next period in all states of the world
  - A foreign bond with return that pays off one unit of foreign consumption next period in all states of the world
- The Euler equation for a foreign investor buying a foreign bond with return $R^{\star}_{t+1}$ is:

$$E_t\left[M^{\star}_{t+1}R^{\star}_{t+1}\right] = 1.$$

- The Euler equation for a domestic investor buying the same foreign bond is:

$$E_t\left[M_{t+1}R^{\star}_{t+1}\frac{S_t}{S_{t+1}}\right] = 1.$$

- S_t is the spot real exchange rate expressed in foreign goods ("pounds") per unit of domestic goods ("dollars").
- Because the stochastic discount factor is unique *in complete markets*, the change in the real exchange rate equals the ratio of the two stochastic discount factors at home and abroad:

$$\frac{S_{t+1}}{S_t} = \frac{M_{t+1}}{M^{\star}_{t+1}},$$

- Given S_0, the exchange rate at date 0, this equation describes the entire path of S.

- In logs: $\Delta s_{t+1} = m_{t+1} - m^{\star}_{t+1}$

- The **exchange rate risk premium** or **currency risk premium** is the expected excess return of a domestic investor who borrows funds at home, changes her currency to a foreign equivalent, lends on the foreign market for a defined period and finally reconverts her earnings to the original currency.

- In logs, the (realized) **foreign currency excess return** r^e_{t+1} is equal to:

$$r^e_{t+1} \simeq r^{\star}_t - r_t - \Delta s_{t+1},$$

  where r_t and $r^{\star}_t$ are respectively the domestic and foreign risk-free real interest rates.

- The domestic investor has to repay r_t but gains $r^{\star}_t$, and gains if the foreign currency appreciates ($\Delta s < 0$) in real terms, or equivalently the dollar depreciates, while her assets are abroad.

- Backus, Foresi, and Telmer (2002) show that the exchange rate risk premium is equal to the half difference in conditional variances of the two pricing kernels. Assuming log-normal stochastic discount factors leads to domestic and foreign risk-free rates equal to:

$$\begin{aligned} r_t &= -\log E_t[M_{t+1}] = -\ E_t[m_{t+1}] - \frac{1}{2} Var_t[m_{t+1}], \\ r^{\star}_t &= -\log E_t[M^{\star}_{t+1}] = -\ E_t[m^{\star}_{t+1}] - \frac{1}{2} Var_t[m^{\star}_{t+1}]. \end{aligned}$$

- The expected change in the exchange rate is then:

$$\begin{aligned} E_t[\Delta s_{t+1}] &= E_t[m_{t+1}] - E_t[m^\star_{t+1}] \\ &= r^\star_t - r_t - \frac{1}{2}Var_t(m_{t+1}) + \frac{1}{2}Var_t(m^\star_{t+1}). \end{aligned}$$

- Thus, the currency risk premium is equal to:

$$E_t[r^e_{t+1}] = \frac{1}{2}Var_t(m_{t+1}) - \frac{1}{2}Var_t(m^\star_{t+1}).$$

- When the domestic pricing kernel has relatively high conditional variance, an investor who is long in foreign bonds will receive a positive risk premium.

2.1.2. Uncovered Interest Rate Parity

- **UIP**: The domestic interest rate must be lower than the foreign interest rate by an amount equal to the expected appreciation of the domestic currency:

$$E_t[\Delta s_{t+1}] = r^\star_t - r_t.$$

- Put differently, the foreign currency risk premium is **zero**:

$$E_t[r^e_{t+1}] = 0$$

- Test of UIP: Regression of exchange rate changes Δs_{t+1} on lagged interest rate differential $r^\star_t - r_t$ should have a slope coefficient of one.

- UIP requires risk-neutrality; it is the “expectations hypothesis” of currency markets.

2.1.3. Forward rates and Covered Interest Rate Parity

- Recall that S_t is the spot exchange rate expressed in units of foreign currency per U.S. dollar.

- F_t is the 1-year forward exchange rate expressed in foreign currency per U.S. dollar. It is the exchange rate locked in at time t at which one unit of the domestic currency ($) will be exchanged for foreign currency (£) at time $t + 1$.

- By *no arbitrage*, the strategy of buying pounds, investing for one period in foreign bonds, converting back to dollars and hedging the exchange rate risk must make zero profits. This is **CIP**. In logs:

$$r_t^{\star} - r_t + s_t - f_t = 0$$

  or

$$f_t = s_t + r_t^{\star} - r_t$$

- The **forward premium** or forward spread is the forward rate minus the spot exchange rate: $f_t - s_t$. It equals $r_t^{\star} - r_t$ under CIP.

- CIP relies on two assumptions:

  - The domestic and the foreign currency deposit rates are default-free.

  - The forward contract has no counter-party risk.

- The foreign currency excess return can be written as:

$$r_{t+1}^e = r_t^{\star} - r_t - \Delta s_{t+1} = (f_t - s_t) - \Delta s_{t+1}$$

- The currency risk premium (under CIP) is:

$$E_t[r^e_{t+1}] = (f_t - s_t) - E_t[\Delta s_{t+1}]$$

- If UIP holds, $E_t[r^e_{t+1}] = 0$, and the forward spread measures the expected change in the exchange rate (expected appreciation of the dollar):

$$E_t[\Delta s_{t+1}] = f_t - s_t$$

- The second test of UIP is to regress the realized change of the exchange rate on the forward spread. UIP predicts the slope is one.

- If (and only if) UIP holds, the forward rate is an unbiased estimator of the expected spot rate:

$$UIP \Leftrightarrow f_t = E_t[s_{t+1}].$$

- Note that covered and uncovered interest rate parity can also be tested at longer horizons. Let $r_t(h)$ be the yield on a h-period government bond and $f_{t,t+h}$ be the $h-$period forward exchange rate. Then CIP:

$$f_{t,t+h} = s_t + r^\star_t(h) - r_t(h)$$

- UIP implies:

$$E_t[s_{t+h} - s_t] = r^\star_t(h) - r_t(h) = f_{t,t+h} - s_t$$

2.2. *Facts*

2.2.1. The Failure of Uncovered Interest Parity

- Hansen and Hodrick (1980), Bilsen and Hsieh (1987) and Fama (1984) test UIP by estimating a regression of exchange rate changes on the difference between the forward (f_t) and spot exchange rate (s_t),

$$\Delta s_{t+1} = \alpha + \beta_2(f_t - s_t) + u_{t+1}.$$

- If risk premia are constant, $f_t = E_t(s_{t+1})$ and $\beta_2 = 1$ and $R^2 = 1$.

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.

- β_2 is much smaller than 1 (significantly so), and in fact *negative* for all 9 countries in the table. UIP strongly rejected!

- UIP puzzle in words:
  - Currencies where $f_t - s_t$ is high ($r_t^{\star} - r_t$ is high) are expected to appreciate, but in fact *depreciate*.
  - Currencies with higher than average interest rates tend to gain in value relative to the domestic currency (dollar), rather than lose value. Dollar depreciates rather than appreciating.
  - Investors in foreign one-period bonds earn the interest rate spread (known at time of their investment) **plus a bonus** from foreign currency appreciation (dollar depreciation) during the holding period, on average.
  - $\Rightarrow$ positive predictable excess returns for investments in high interest rate currencies and negative predictable excess returns for investments in low interest rate currencies
- Due to time-varying risk premia or expectational errors (irrationality)?

2.2.2. Deviations from CIP

- Even though it is a *no-arbitrage* relationship, there is evidence that CIP was violated during and after the financial crisis. Garleanu and Pedersen (2011) and Du, Tepper, and Verdelhan (2018).
- Garleanu and Pedersen (2011) show that CIP violations comove with the TED spread, the spread between 3-month uncollateralized LIBOR and the 3-month T-bill rate. The TED spread is a measure of funding illiquidity. Suggests limits to arbitrage or slow-moving arbitrage capital.

- However, Du, Tepper, and Verdelhan (2018) show that CIP violations occur at short horizons, making it a puzzle for classic limits-to-arbitrage models that rely on long-term market risk (Schleifer and Vishny, 1997).

- Moreover, they show that the violations persist long after the financial crisis is over, and for the most liquid G10 currencies.

- **Cross-currency basis** $x_t = r_t - r_t^\star + f_t - s_t$, is zero under CIP:

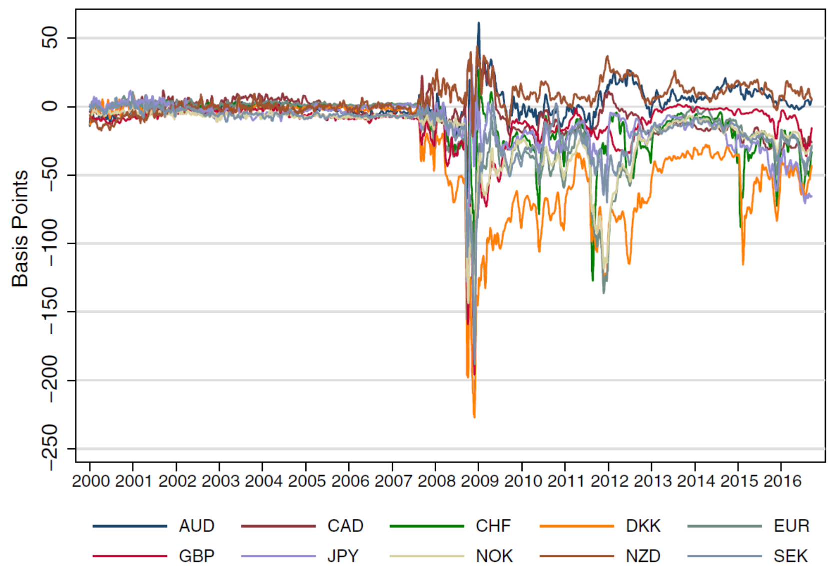


Figure 2. Short-term Libor-based deviations from covered interest rate parity. This figure plots the 10-day moving averages of the three-month Libor cross-currency basis, measured in bps for G10 currencies. Covered interest rate parity implies that the basis should be zero. The Libor basis is equal to $y_{t,t+n}^{\$,Libor} - (y_{t,t+n}^{Libor} - \rho_{t,t+n})$, where $n =$ three months, $y_{t,t+n}^{\$,Libor}$ and $y_{t,t+n}^{Libor}$ denote the U.S. and foreign three-month Libor rates, and $\rho_{t,t+n} \equiv \frac{1}{n}(f_{t,t+n} - s_t)$ denotes the forward premium obtained from the forward $f_{t,t+n}$ and spot s_t exchange rates. (Color figure can be viewed at wileyonlinelibrary.com)

- Cross-currency basis is difference between USD rate from the cash market and the synthetic USD rate obtained by swapping foreign currency into USD. Close to zero before crisis.

- Not due to differential credit risk in say yen LIBOR vs. dollar LIBOR; also holds using GC repo rates instead of LIBOR.

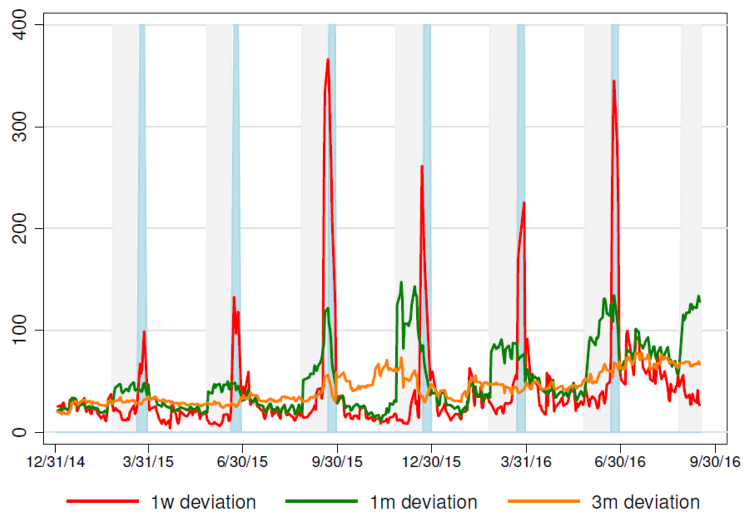
- Investors can earn 0.11-0.18% per year, risk-free, in 2010-2016. Strategy: borrow (short) in USD GC repo, invest (long) in negative basis currency GC repo (Japanese yen, Danish krona, euro). Or, borrow in positive basis currency GC repo (CAD, AUD), invest in USD GC repo. There is no exchange rate risk and no credit risk in these transactions. Arbitrage = infinite SR.

- They argue the key culprit for the CIP violation is the interaction of:

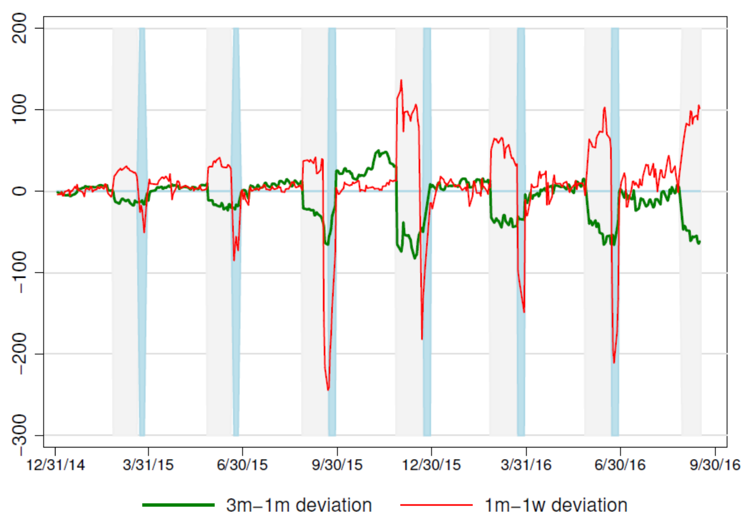
  1. Balance sheet constraints that financial intermediaries face, due to post-crisis regulatory reform (e.g., Supplementary Leverage Ratio rule, Volcker rule). CIP arbitrage trades make leverage ratio requirements more binding.
  2. International imbalances in investment demand and funding supply across currencies (e.g., persistently high net demand for NZD and AUD and high net supply of JPY). Accounted for by imbalances in savings and investments across countries.

- Costs prevents intermediaries from arbitraging away the profits.

  – Smoking gun: quarter-end anomaly. Investors pay more attention to regulatory constraints at quarter-end.
  – One-month CIP deviations increase exactly one month before quarter end, when the one-month forward has to appear on quarter-end balance sheet ("treated"). Three-month forwards needs to appear on quarter-end report regardless of when it is executed ("control").
  – Diff-in-diff: banking regulation causally affects asset prices.



(a) Level of Yen CIP Deviations



(b) Term Structure of Yen CIP Deviations

Figure 7: **Illustration of Quarter-End Dynamics for the Term Structure of CIP Deviations**: In both figures, the blue shaded area denotes the dates for which the settlement and maturity of a one-week contract spans two quarters. The grey shaded area denotes the dates for which the settlement and maturity dates of a one-month contract spans two quarters, and excludes the dates in the blue shaded area. The top figure plots one-week, one-month and three-month CIP Libor CIP deviations for the yen in red, green and orange, respectively. The bottom figure plots the difference between 3-month and 1-month Libor CIP deviation for the yen in green and between 1-month and 1-week Libor CIP deviation for the yen in red.

2.2.3. Cross-sectional Predictability

Carry

- Since Lustig and Verdelhan (2007), it is common to form **portfolios** of countries/currencies, based on the interest rate differential/forward spread.

- Carry is defined as the return if market conditions do not change. In this case, it means that the exchange rate does not change. The carry return is then given by

$$C_t = \frac{S_t}{F_t} \simeq r_t^\star - r_t.$$

- Hence, when the carry is high (that is the foreign interest rate is high compared to the US interest rate), the dollar is expected to appreciate (S expected to increase).

- In the data, we find that the currency does not appreciate (=failure of UIP). The carry trade makes money (high SR).

- Many papers study the currency carry strategy, see for instance Burnside, Eichenbaum, Kleshchelski , and Rebelo (2021), Lustig, Roussanov, and Verdelhan (2011), and Koijen, Moskowitz, Pedersen, and Vrugt (2018) for a recent update, alongside carry strategies in other asset classes:

PANEL A: CARRY TRADES BY SECURITY WITHIN AN ASSET CLASS

Asset class	Strategy	Mean	Stdev	Skewness	Kurtosis	Sharpe ratio
Global equities	Carry	9.14	10.42	0.22	4.74	0.88
	EW	5.00	15.72	-0.63	3.91	0.32
	D/P	4.71	11.83	-0.10	5.32	0.40
Fixed income 10Y global (level)	Carry	3.85	7.45	-0.43	6.66	0.52
	EW	5.04	6.85	-0.11	3.70	0.74
	Yield	3.55	7.73	-0.81	10.13	0.46
Fixed income 10Y−2Y global (slope)	Carry	0.68	0.66	0.33	4.92	1.03
	EW	0.01	0.43	-0.28	4.08	0.01
US Treasuries (maturity)	Carry	0.46	0.67	0.47	10.46	0.68
	EW	0.69	1.22	0.58	12.38	0.57
Commodities	Carry	11.22	18.78	-0.40	4.55	0.60
	EW	1.05	13.45	-0.71	6.32	0.08
	Basis	11.22	18.78	-0.40	4.55	0.60
Currencies	Carry	5.29	7.80	-0.68	4.46	0.68
	EW	2.88	8.10	-0.16	3.44	0.36
	Carry	5.29	7.80	-0.68	4.46	0.68

- Foreign currency excess return is 5.3% per year (for developed markets). The Sharpe ratio is 0.68. **Carry factor**.
- A simple equally-weighted portfolio of the same currencies earns only a 2.9% return and a Sharpe ratio of 0.36. **Dollar factor**.
- Carry strategies generally earn high Sharpe ratios. Moreover, these strategies are independent. Gains from diversification! Global carry factor across all asset classes has SR of 1.2.

- An important feature of the currency carry trade that received significant attention is the negative skewness, or currency crashes. Investing in carry trade is like "picking up nickels in front of a steam roller."
- See in particular Brunnermeier, Nagel, and Pedersen (2008).
- Skewness (under P and Q) and interest rate differentials:

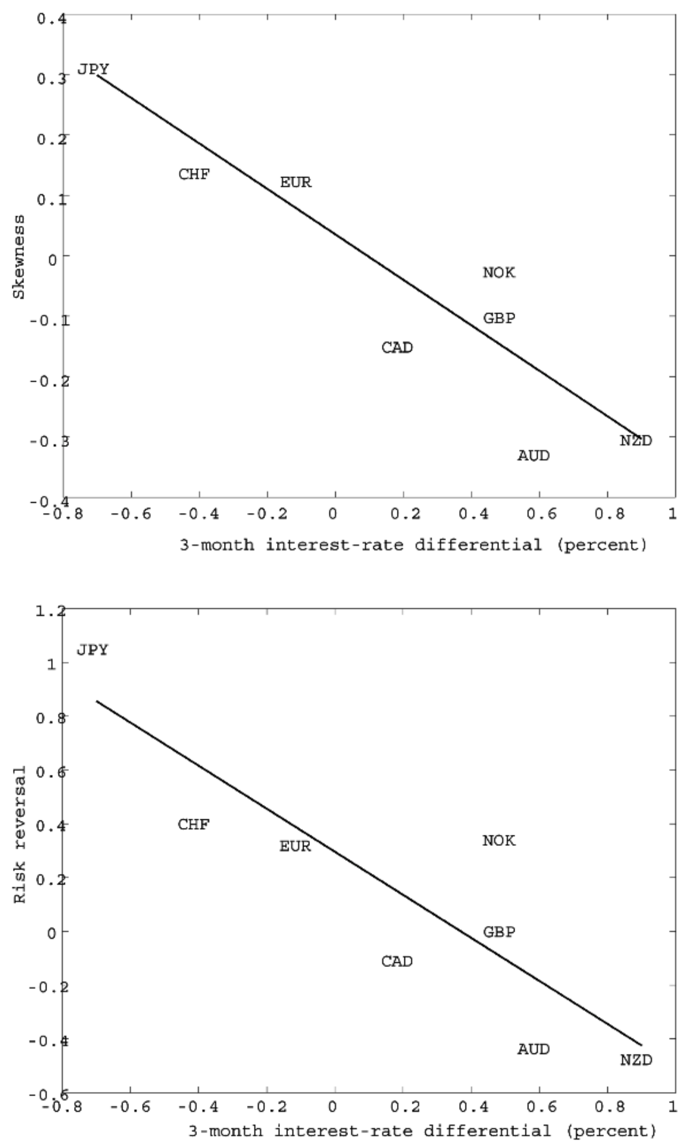


Fig. 2. Cross-section of empirical skewness (*top panel*) and of risk reversal (*bottom panel*), reflecting implied (risk-neutral) skewness, for different quarterly interest rate differentials $i^* - i$.

Momentum and Value

- Momentum is defined analogously to equities, based on currency excess returns between 12 and 2 months ago.
- Value is defined as deviation from UIP over past 5-years. (Recall our discussion of value as akin to long-term reversals.) Current spot exchange rate compared to exchange rate 5-years ago, taking into account interest earned using 3-month LIBOR. Essentially a measure of changes in purchasing power parity.
- Asness, Moskowitz, Pedersen (2013) study momentum and value for currencies, alongside many other asset classes.

Panel A: Individual Stock Portfolios

		Value Portfolios					Momentum Portfolios					50/50 Combination	
		P1	P2	P3	P3–P1	Factor	P1	P2	P3	P3–P1	Factor	P3–P1	Factor
Global stocks 01/1972 to 07/2011	Mean	8.1%	11.0%	14.6%	6.2%	5.8%	8.5%	11.1%	14.1%	5.6%	7.1%	6.3%	6.8%
	(t-stat)	(3.17)	(4.54)	(5.84)	(3.60)	(3.18)	(3.10)	(4.82)	(5.46)	(2.94)	(3.73)	(6.52)	(8.04)
	Stdev	16.6%	15.2%	15.7%	10.9%	11.4%	17.1%	14.5%	16.2%	12.0%	12.0%	6.1%	5.3%
	Sharpe	0.50	0.72	0.93	0.57	0.51	0.49	0.77	0.87	0.47	0.59	1.04	1.28
	Alpha	−2.3%	0.7%	4.2%	6.6%	6.1%	−3.3%	0.5%	3.1%	6.4%	8.1%	6.8%	7.5%
	(t-stat)	(−1.70)	(0.69)	(3.49)	(3.79)	(3.37)	(−3.00)	(1.00)	(2.78)	(3.37)	(4.31)	(7.09)	(8.98)
									Correlation (Val, Mom) =			−0.52	−0.60

Panel B: Other Asset Class Portfolios

		P1	P2	P3	P3–P1	Factor	P1	P2	P3	P3–P1	Factor	P3–P1	Factor
Country indices 01/1978 to 07/2011	Mean	3.1%	6.6%	9.1%	6.0%	5.7%	2.3%	5.8%	11.0%	8.7%	7.4%	7.3%	10.6%
	(t-stat)	(1.10)	(2.40)	(3.20)	(3.45)	(3.40)	(0.81)	(2.13)	(3.72)	(4.14)	(3.57)	(6.62)	(5.72)
	Stdev	16.2%	15.7%	16.2%	9.8%	9.5%	16.2%	15.4%	16.8%	11.9%	11.8%	6.3%	10.6%
	Sharpe	0.19	0.42	0.56	0.61	0.60	0.14	0.37	0.65	0.73	0.63	1.16	1.00
	Alpha	−3.2%	0.5%	2.7%	5.9%	5.3%	−3.9%	−0.3%	4.4%	8.2%	7.1%	7.1%	10.0%
	(t-stat)	(−3.24)	(0.48)	(2.76)	(3.45)	(3.24)	(−3.41)	(−0.40)	(4.00)	(4.00)	(3.47)	(6.49)	(5.47)
									Correlation (Val, Mom) =			−0.34	−0.37
Currencies 01/1979 to 07/2011	Mean	−0.5%	0.3%	2.8%	3.3%	3.9%	−0.7%	0.3%	2.8%	3.5%	3.0%	3.4%	5.6%
	(t-stat)	(−0.30)	(0.23)	(1.98)	(1.89)	(2.47)	(−0.40)	(0.20)	(1.91)	(1.90)	(1.77)	(3.51)	(3.89)
	Stdev	9.2%	8.3%	7.9%	9.7%	9.0%	9.4%	8.0%	8.2%	10.3%	9.6%	5.4%	8.0%
	Sharpe	−0.05	0.04	0.35	0.34	0.44	−0.07	0.04	0.34	0.34	0.32	0.63	0.69
	Alpha	−1.4%	−0.6%	2.0%	3.4%	4.1%	−1.6%	−0.6%	2.0%	3.6%	3.1%	3.5%	5.7%
	(t-stat)	(−1.53)	(−0.94)	(2.25)	(2.04)	(2.63)	(−1.58)	(−1.01)	(2.18)	(1.99)	(1.84)	(3.83)	(4.11)
									Correlation (Val, Mom) =			−0.42	−0.43

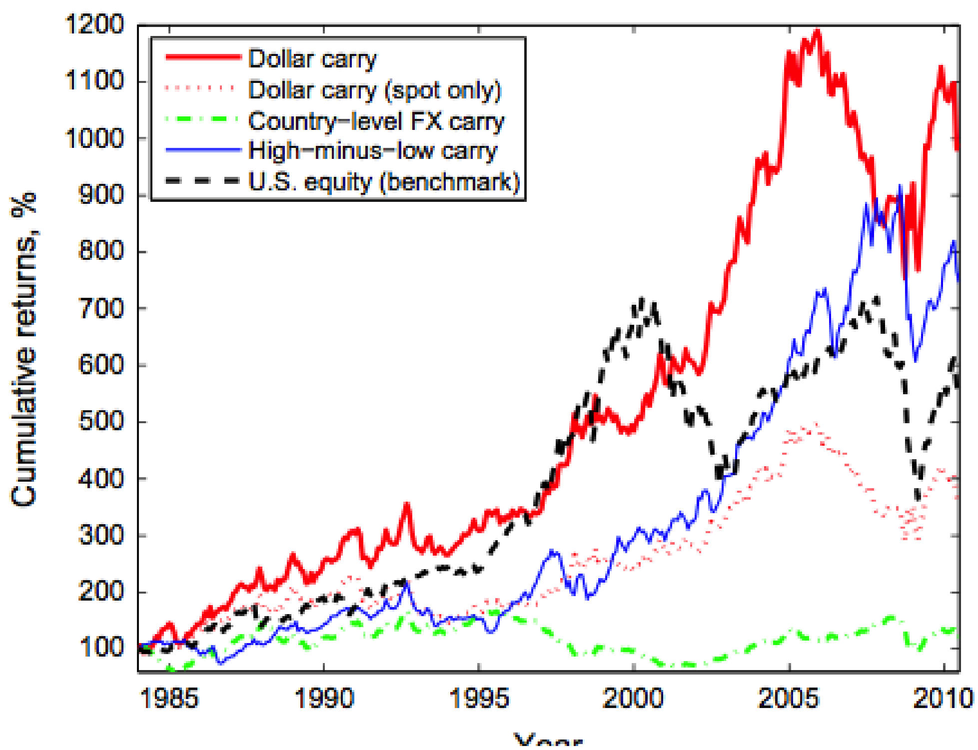
- Currency value and momentum strategies have annual returns of 3.3% and 3.5%. The 50-50 combo has a Sharpe ratio of 0.63.

- Strategy that goes long in currencies with strong *economic* momentum (high real growth or low inflation in past 60 months) and short currencies with weak economic momentum generates significant alpha, after controlling for carry, value, and return momentum strategies (Dahlquist and Hasseltoft, 2020).

2.2.4. Time-Series Predictability

- In addition to cross-sectional predictability, Lustig, Roussanov, and Verdelhan (2014) study the **dollar carry trade**, which is a time-series predictability strategy different from the cross-sectional high-minus-low portfolio carry strategy.

- In this case, we compute the average interest rate in developed markets and compare it to the US risk-free rate. If the foreign average short rate is higher, then we buy all currencies and borrow in the US, and vice versa.



- They develop a no-arbitrage model to reconcile these findings.
- When the volatility of the U.S. SDF is high, U.S. short-term interest rates tend to be low relative to the rest of the world, because of large precautionary savings and increased demand for dollar liquidity. We then go long foreign currencies.

$$E_t[r^e_{t+1}] = \frac{1}{2}Var_t[m_{t+1}] - \frac{1}{2}Var_t[m^\star_{t+1}]$$

- U.S. investors in the dollar carry strategy are long in foreign currencies and short in the dollar when the U.S. SDF is more volatile than foreign SDF. This strategy is risky, because the dollar appreciates in the case of a bad shock to the U.S. pricing kernel, when its volatility is higher than abroad.
  Recall: $\uparrow \Delta s_{t+1} = \uparrow m_{t+1} - m^*_{t+1}$.
- See Hassan and Mano (2019) for more on the link between the failure of uncovered interest parity, the cross-sectional carry trade, and the dollar carry trade.

2.3. *Interpreting the Facts*

2.3.1. Factor Models

- Lustig, Roussanov, and Verdelhan (2011) propose a 2-factor model with the **dollar factor** (equally-weighted average of all currencies, level factor) and a **carry factor** (slope factor) to explain the cross-section of currency returns.
- They start from 6 portfolios sorted on the forward discount $f_t - s_t = r_t^\star - r_t$ (under CIP):

Table 1: Currency Portfolios - US 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	−0.97	−1.33	−1.55	−2.73	−0.99	1.88	−1.86	−2.54	−4.05	−2.11	−1.11
Std	8.04	7.29	7.41	7.42	7.74	9.16	10.12	9.71	9.24	8.92	9.20
	Forward Discount: $f^j - s^j$						$f^j - s^j$				
Mean	−3.90	−1.30	−0.15	0.94	2.55	7.78	−3.09	−1.02	0.07	1.13	3.94
Std	1.57	0.49	0.48	0.53	0.59	2.09	0.78	0.63	0.65	0.67	0.76
	Excess Return: rx^j (without b-a)						rx^j (without b-a)				
Mean	−2.92	0.02	1.40	3.66	3.54	5.90	−1.24	1.52	4.11	3.24	5.06
Std	8.22	7.36	7.46	7.53	7.85	9.26	10.20	9.75	9.35	9.01	9.30
SR	−0.36	0.00	0.19	0.49	0.45	0.64	−0.12	0.16	0.44	0.36	0.54
	Net Excess Return: rx^j_{net} (with b-a)						rx^j_{net} (with b-a)				
Mean	−1.70	−0.95	0.12	2.31	2.04	3.14	−0.11	0.46	2.71	1.98	3.35
Std	8.21	7.35	7.43	7.48	7.85	9.25	10.20	9.75	9.32	9.02	9.30
SR	−0.21	−0.13	0.02	0.31	0.26	0.34	−0.01	0.05	0.29	0.22	0.36
	High-minus-Low: $rx^j - rx^1$ (without b-a)						$rx^j - rx^1$ (without b-a)				
Mean		2.95	4.33	6.59	6.46	8.83		2.75	5.35	4.47	6.29
Std		5.36	5.54	6.65	6.34	8.95		6.42	6.44	7.38	8.70
SR		0.55	0.78	0.99	1.02	0.99		0.43	0.83	0.61	0.72
	High-minus-Low: $rx^j_{net} - rx^1_{net}$ (with b-a)						$rx^j_{net} - rx^1_{net}$ (with b-a)				
Mean		0.75	1.82	4.00	3.73	4.83		0.57	2.82	2.09	3.46
Std		5.36	5.56	6.63	6.35	8.98		6.45	6.44	7.41	8.73
SR		0.14	0.33	0.60	0.59	0.54		0.09	0.44	0.28	0.40

Notes: This table reports, for each portfolio j, the average change in log spot exchange rates Δs^j, the average log forward discount $f^j - s^j$, the average log excess return rx^j without bid-ask spreads, the average log excess return rx^j_{net} with bid-ask spreads, and the average return on the long short strategy $rx^j_{net} - rx^1_{net}$ and $rx^j - rx^1$ (with and without bid-ask spreads). Log currency excess returns are computed as $rx^j_{t+1} = -\Delta s^j_{t+1} + f^j_t - s^j_t$. All moments are annualized and reported in percentage points. For excess returns, the table also reports Sharpe ratios, computed as ratios of annualized means to annualized standard deviations. The portfolios are constructed by sorting currencies into six groups at time t based on the one-month forward discount (i.e nominal interest rate differential) at the end of period $t-1$. Portfolio 1 contains currencies with the lowest interest rates. Portfolio 6 contains currencies with the highest interest rates. Panel I uses all countries, panel II focuses on developed countries. Data are monthly, from Barclays and Reuters (Datastream). The sample period is 11/1983 - 03/2008.

Table 2: Principal Components

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

Notes: This table reports the principal component coefficients of the currency portfolios. 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 - 03/2008.

- The first principal component loads equally on all portfolios. It's a level factor. It is a **dollar factor**.

- The second principal component is a slope factor. Construct HML_{FX} factor that goes long the countries with high interest rates (portfolio 6) and short the countries with low interest rates (portfolio 1). This is the **carry factor**.

- These two factors account for 82.3% of the variation in currency returns in all countries and 88.4% in developed markets.

- The 2-factor model does a good job explaining the excess returns on the 6 currency portfolios. Here are the market prices of risk from the second stage of the Fama-MacBeth/GMM:

Table 3: Asset Pricing - US 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	5.46	1.35	0.59	0.26	69.28	0.95		3.56	2.24	0.43	0.32	71.06	0.61	
	[2.34]	[1.68]	[0.25]	[0.32]			13.83	[2.19]	[2.02]	[0.24]	[0.24]			41.06
GMM_2	4.88	0.58	0.52	0.12	47.89	1.24		3.78	3.03	0.46	0.42	20.41	1.00	
	[2.23]	[1.63]	[0.24]	[0.31]			15.42	[2.14]	[1.95]	[0.23]	[0.23]			44.36
FMB	5.46	1.35	0.58	0.26	69.28	0.95		3.56	2.24	0.42	0.32	71.06	0.61	
	[1.82]	[1.34]	[0.19]	[0.25]			13.02	[1.80]	[1.71]	[0.20]	[0.20]			41.34
	(1.83)	(1.34)	(0.20)	(0.25)			14.32	(1.80)	(1.71)	(0.20)	(0.20)			42.35
$Mean$	**5.37**	**1.36**						**3.44**	**2.24**					

Panel II: Factor Betas												
	All Countries						Developed Countries					
$Portfolio$	α_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	−0.56	−0.39	1.06	91.36			0.00	−0.50	1.00	94.95		
	[0.52]	[0.02]	[0.03]				[0.48]	[0.02]	[0.02]			
2	−1.21	−0.13	0.97	78.54			−0.90	−0.11	1.02	82.38		
	[0.76]	[0.03]	[0.05]				[0.81]	[0.04]	[0.04]			
3	−0.13	−0.12	0.95	73.73			1.01	−0.02	1.02	85.22		
	[0.82]	[0.03]	[0.04]				[0.83]	[0.03]	[0.03]			
4	1.62	−0.02	0.93	68.86			−0.12	0.13	0.97	81.43		
	[0.86]	[0.04]	[0.06]				[0.85]	[0.04]	[0.04]			
5	0.84	0.05	1.03	76.37			0.00	0.50	1.00	93.87		
	[0.80]	[0.04]	[0.05]				[0.48]	[0.02]	[0.02]			
6	−0.56	0.61	1.06	93.03								
	[0.52]	[0.02]	[0.03]									
All					10.11	0.12					2.61	0.76

Notes: The panel on the left reports results for all countries. The panel on the right reports results for the developed countries. Panel I reports results from GMM and Fama-McBeth asset pricing procedures. Market prices of risk λ, the adjusted R^2, the square-root of mean-squared errors $RMSE$ and the p-values of χ^2 tests on pricing errors are reported in percentage points. b denotes the vector of factor loadings. Excess returns used as test assets and risk factors take into account bid-ask spreads. All excess returns are multiplied by 12 (annualized). Shanken (1992)-corrected standard errors are reported in parentheses. We do not include a constant in the second step of the FMB procedure. Panel II reports OLS estimates of the factor betas. R^2s and p-values are reported in percentage points. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The χ^2 test statistic $\alpha' V_\alpha^{-1} \alpha$ tests the null that all intercepts are jointly zero. This statistic is constructed from the Newey-West variance-covariance matrix (1 lag) for the system of equations (see Cochrane (2001), p. 234). Data are monthly, from Barclays and Reuters in Datastream. The sample period is 11/1983 - 03/2008. The alphas are annualized and in percentage points.

- Of course, the cross-section is relatively small for currencies.

- Economic interpretation of these facts in Verdelhan (2018): SDF must exhibit at least two global shocks that are priced.
  - High interest rate (high HML_{FX} beta countries) countries offer high returns because they are exposed more to global shocks priced globally, for example global volatility on equity markets. When there is a bad global shock, these currencies depreciate. This makes the carry trade risky.
  - An investment strategy that is long high-dollar beta countries and short low-dollar beta countries when U.S. interest rates are lower than the world average (and vice versa otherwise) also earns excess returns. High dollar-beta countries have low country-specific volatility. Their currencies depreciate in times of bad global shocks, a second source of aggregate risk.

- Tessari (2020) argues that the carry trade can be understood from different exposures of currencies to the common idiosyncratic volatility in currencies.
  Recall our discussion of the CIV factor in equity markets (Herskovic, Kelly, Lustig, and Van Nieuwerburgh, 2016)
  - Form idiosyncratic currency returns using a factor model (e.g., principal components, or dollar and carry factors)
  - CIV factor is first PC of these idiosyncratic (=country-specific) currency volatilities
  - Sort currencies on CIV-beta. High interest rate currencies have negative CIV betas. Market price of CIV shocks is negative. This produces a positive excess return for high rate countries.
  - In incomplete markets model, investors cannot diversify country-specific currency risk away. When international risk sharing deteriorates (CIV is high), these high-interest rate currencies appreciate, and result in low carry trade returns.
  - Effect is separate from effect of shocks to global market volatility in currencies (Menkhoff, Sarno, Schmeling, Schrimpf, 2012)

2.3.2. Consumption-based Models

Three puzzles in the CCAPM

- 2 countries, a representative agent in each country with CRRA utility, each consumes its endowment stream
- SDF: $M^i_{t+1} = \beta \left(\frac{C^i_{t+1}}{C^i_t}\right)^{-\gamma}$ or $m_{t+1} = \log \beta - \gamma \Delta c_{t+1}$.
- Consumption growth has same constant mean and variance across countries.
- CCAPM implies UIP puzzle
  - $\frac{1}{2} Var_t(m_{t+1}) = \frac{\gamma^2 \sigma_c^2}{2} = \frac{1}{2} Var_t(m^\star_{t+1})$
  - $E_t(r^e_{t+1}) = 0$; no currency risk premium
  - $E_t[\Delta s_{t+1}] = r^\star_t - r_t$: UIP holds
  - Generalized version of UIP if consumption variance differs: $E_t(r^e_{t+1}) = \frac{\gamma^2}{2}(\sigma_c^2 - (\sigma_c^\star)^2)$; constant currency risk premium (and small unless γ is large)
- Under complete markets, real exchange rates S_t satisfy:

$$S_{t+1}/S_t = \frac{(C_{t+1}/C_t)^{-\gamma}}{\left(C^\star_{t+1}/C^\star_t\right)^{-\gamma}}$$

- In logs:

$$\Delta s_{t+1} = \gamma \left(\Delta c^\star_{t+1} - \Delta c_{t+1}\right)$$

- Hence, CCAPM implies perfect positive correlation between Δs_{t+1} and $\Delta c^{\star}_{t+1} - \Delta c_{t+1}$.
  - Under perfect risk-sharing, countries with relative low prices should receive a transfer to take advantage of cheap consumption. Dollar appreciation: consumption growth in UK should be higher.
- But in the data, this correlation is close to zero or even negative
- This is the real exchange rate anomaly or Backus-Smith puzzle (Backus and Smith, 1993).
- Variance of real exchange rate changes:

$$Var\left(\Delta s_{t+1}\right) = Var\left(m^{\star}_{t+1}\right) + Var\left(m_{t+1}\right) - 2Cov\left(m^{\star}_{t+1}, m_{t+1}\right)$$

- Solving for the correlation of SDFs:

$$Corr\left(m^{\star}_{t+1}, m_{t+1}\right) = \frac{1}{2}\frac{Var\left(m^{\star}_{t+1}\right) + Var\left(m_{t+1}\right) - Var\left(\Delta s_{t+1}\right)}{Std\left(m_{t+1}\right) Std\left(m^{\star}_{t+1}\right)}$$

- In the data:
  - $Std\left(m^{UK}_{t+1}\right) \approx .37$ and $Std\left(m^{US}_{t+1}\right) \approx .39$ to explain equity returns (setting max SR = equity SR)
  - $Std\left(\Delta s_{t+1}\right) = .11$
  - These imply $Corr\left(m^{\star}_{t+1}, m_{t+1}\right) = .96$

- In the CCAPM with CRRA preferences:

$$Var\left(\Delta s_{t+1}\right)=\gamma^{2}\left[Var\left(\Delta c_{t+1}^{\star}\right)+Var\left(\Delta c_{t+1}\right)-2Cov\left(\Delta c_{t+1},\Delta c_{t+1}^{\star}\right)\right]$$

- Under symmetry and no correlation between consumption growth this simplifies to

$$Std\left(\Delta s_{t+1}\right)=\sqrt{2}\gamma\sigma_{c}$$

- For $\gamma = 5$ and $\sigma_c = .015$, $Std\left(\Delta s_{t+1}\right) = .11$, which matches the observed volatility of real exchange rate changes.

- But, CCAPM implies $Corr(m, m^{\star}) = Corr(\Delta c, \Delta c^{\star}) \approx 0.2$, missing completely on the high correlation across countries in asset prices. This is the correlation puzzle of Brandt, Cochrane, and Santa Clara (2006).

Extending and rescuing the CCAPM

- Lustig and Verdelhan (2007) augment the CCAPM with Epstein-Zin preferences and split consumption into a durable and non-durable component.

- In context of equity pricing, Yogo (2006) shows that durable consumption is much more cyclical than non-durable consumption. This feature is important also for currency risk premia.

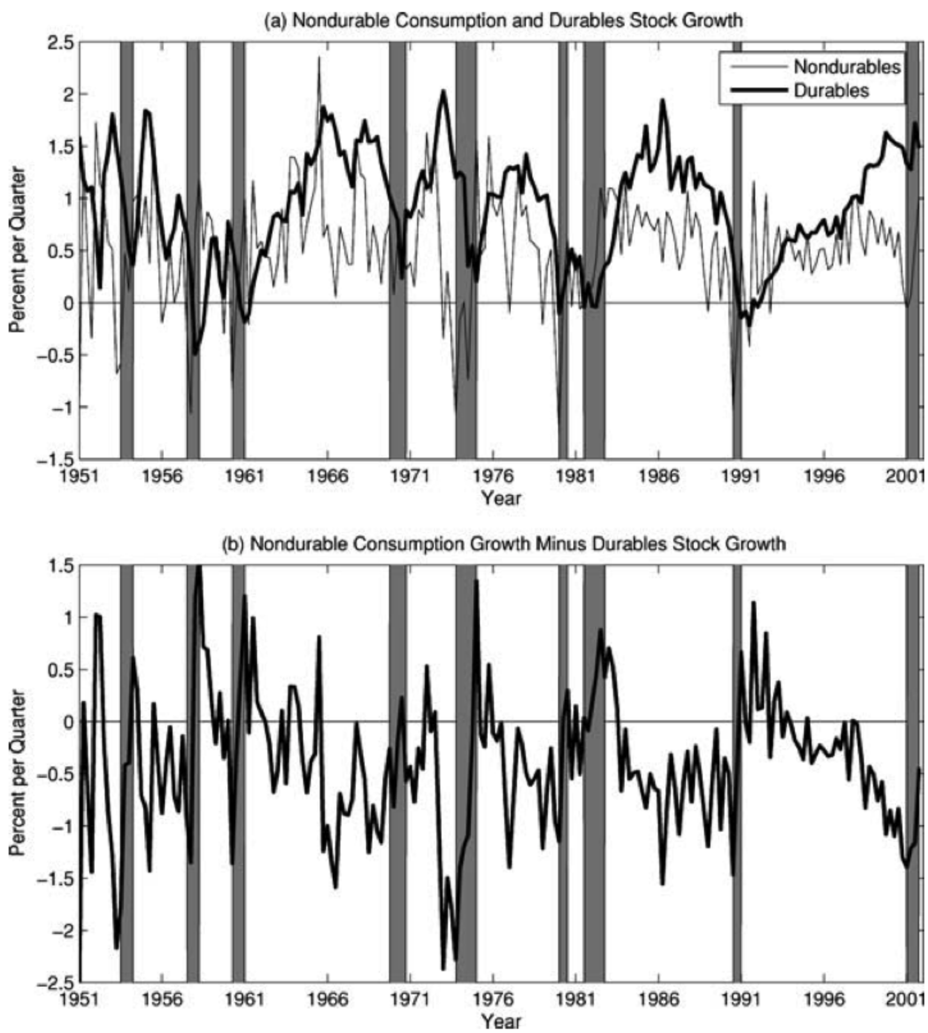


Figure 2. Nondurable and Durable Consumption Growth. The figure is a time-series plot of (a) the real growth rates of nondurable consumption and the stock of durables and (b) the difference in the growth rates. The sample period is 1951:1–2001:4; the shaded regions are NBER recessions.

- Implies linear three-factor model, estimated by Fama-MacBeth:

$$E[R^{j,e}] = b_1 cov(\Delta c_t, R_t^{j,e}) + b_2 cov(\Delta d_t, R_t^{j,e}) + b_3 cov(r_t^w, R_t^{j,e})$$

- Main table for the cross-section of currency portfolios:

TABLE 5—ESTIMATION OF LINEAR FACTOR MODELS WITH EIGHT CURRENCY PORTFOLIOS SORTED ON INTEREST RATES

	CCAPM	DCAPM	EZ-CCAPM	EZ-DCAPM
Factor prices				
Nondurables	1.938	1.973	2.021	2.194
	[0.917]	[0.915]	[0.845]	[0.830]
Durables		4.598		4.696
		[0.987]		[0.968]
Market			8.838	3.331
			[7.916]	[7.586]
Parameters				
γ	92.032	104.876	94.650	113.375
	[6.158]	[6.236]	[5.440]	[5.558]
σ			−0.008	0.210
			[0.003]	[0.056]
α		1.104		1.146
		[0.048]		[0.001]
Stats				
MAE	2.041	0.650	1.989	0.325
R^2	0.178	0.738	0.199	0.869
$p - value$	[0.025]	[0.735]	[0.024]	[0.628]

Notes: This table reports the Fama-MacBeth estimates of the risk prices (in percentage points) using eight annually rebalanced currency portfolios as test assets. The sample is 1953–2002 (annual data). The factors are demeaned. The standard errors are reported between brackets. The last three rows report the mean absolute pricing error (in percentage points), the R^2 and the p-value for a χ^2 test.

- Conclude that aggregate U.S. (durable) consumption growth risk explains a large fraction of average currency excess returns. High interest rate currencies, while appreciating on average, depreciate when U.S. durable expenditure growth is low. This makes them risky and investors require a risk premium for holding them.

External Habit Model

- Verdelhan (2010) shows that external habit model in both countries can generate observed deviations from UIP, alongside equity risk premium and risk-free rate. Resolves UIP puzzle.
- Difference in surplus consumption-ratios across countries preicts future currency excess returns.
- Requires pro-cyclical real interest rates, which implies downward sloping real yield curve.
- Does not resolve Backus-Smith or correlation puzzles.

Long-run Risk Model

- Colacito and Croce (2011) write down long-run risk model with Epstein-Zin preference in both countries.
- Long-run consumption growth component nearly perfectly correlated between countries.
- This ensures high correlation between SDF without high correlation between consumption growth, because transitory consumption growth components are not highly correlated and account for a large share of overall consumption growth fluctuations.
- Resolves correlation puzzle. Backus-Smith puzzle mostly unresolved however.
- Model has no time-varying consumption growth volatility, therefore constant risk premia, and UIP puzzle holds.

- Bansal and Shaliastovich (2013) add time-varying consumption growth volatility to resolve UIP puzzle. Differences in consumption growth volatility across countries predict currency excess returns. Their model matches simultaneously the violation of expectations hypothesis and UIP puzzles in bond and currency markets.

- Colacito and Croce (2013) add international trade to the international LRR framework. The model endogenously generates consumption growth volatility, and resolves UIP, correlation, and Backus-Smith puzzles!

- Colacito, Croce, Gavazzoni, and Ready (2018) show that one needs heterogenous exposure to long-run growth news shocks in a LRR framework to explain the mean of the HML_{FX} factor.

Variable rare disasters

- Farhi and Gabaix (2016) write down two-country model with time-varying probability of rare disasters, and generate violations from UIP.

2.3.3. Financial Frictions in Currency Markets

- There is a longer literature focusing on microstructure issues in the currency literature. See for instance Evans and Lyons (2002).

- Gabaix and Maggiori (2015) propose an interesting model with financial frictions, where portfolio flows matter for the level and volatility of exchange rates.

- We already mentioned the Garleanu and Pedersen (2011), He, Kelly, and Manela (2017), and Du, Tepper, and Verdelhan (2018) all of which relate the cross-section of currencies to variables capturing intermediary capital scarcity/stress.

- Du, Hebert, and Wang (2023) use CIP deviations (cross-currency basis) as a way to measure the Lagrange multiplier on intermediary constraints (alternative to using leverage), thus implementing an intermediary-based asset pricing model.

2.3.4. Scapegoat Theory of Exchange Rates

- Bacchetta and Van Wincoop (2004) present a scapegoat theory of exchange rates.
- The main motivation is the weak link between exchange rates and macro-economic fundamentals (Backus-Smith puzzle).
- In addition, to the extent that macro-economic fundamentals matter, different fundamentals matter at different points in time.
- To reconcile these findings, they propose an explanation using a noisy rational expectations model, where investors have heterogeneous information on some structural parameter of the economy.
- There may be rational confusion about the true source of exchange rate fluctuations, so that if an unobservable variable affects the exchange rate, investors may attribute this movement to some current macroeconomic fundamental.

2.4. *Other Areas*

- There is a huge literature in international finance on all kinds of topics that have a link to asset pricing, and that are worth exploring:
- Some examples:

1. The link between capital flows and risk premia, see Gourinchas and Rey (2007).
2. International portfolio holdings, see Garleanu, Panageas, and Yu (2015).
3. The link between commodities and currencies, see Ready, Roussanov, and Ward (2017).
4. The special role of the dollar as a global reserve and invoicing currency, see Maggiori, Neiman, Schreger (2020), Jiang, Krishnamurthy and Lustig (2021), Gopinath and Stein (2021)
5. Explaining contemporaneous movements in exchange rates: Verdelhan (2018) shows that we can explain about 60% of the variation in exchange rate changes using the contemporaneous Dollar and Carry factor returns.
6. Firms' hedging of currency risk (e.g., recent paper by Adams and Verdelhan (2022))