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Comment

Hanno Lustig, *University of California, Los Angeles and NBER*
Adrien Verdelhan, *Boston University*

I. Carry Trade

A "naive" investment strategy that chases high yields around the world works remarkably well in currency markets. This strategy is typically referred to as the carry trade in foreign exchange, and it has consistently been very profitable over the last 3 decades. Figure 1 compares the performance of a levered carry trade strategy (denoted HML_{FX}) net of transaction costs to that of an unlevered buy-and-hold strategy in the U.S. stock market. The figure plots the cumulative return on both strategies, starting in November of 1983.[1] This carry trade strategy simply involves taking short positions in a portfolio of low interest rate currencies and long positions in a portfolio of high interest rate currencies. We levered the carry trade strategy up to match the volatility of stock returns in our sample of 14.84%. Investing one dollar in the stock market would have yielded \$2.71 while investing one dollar in the carry trade produced \$3.36 by July of 2008. That is a cumulative return difference of 65% over 25 years.

The seminal work on the failure of uncovered interest rate parity by Hansen and Hodrick (1980) and Fama (1984) was published before or around the start of our sample in 1983. More than 25 years have gone by. The profitability of the carry trade is presumably well understood by now. Moreover, the daily volume in currency markets has increased nearly tenfold in a market that is dominated by large, sophisticated investors. Many hedge funds and, more recently, some ETFs (exchange traded funds) are actively engaged in the carry trade. However, as is clear from the slope of the carry trade line in figure 1, the carry trade premium has increased substantially in the second part of the sample. The average log excess return after transaction costs has increased from

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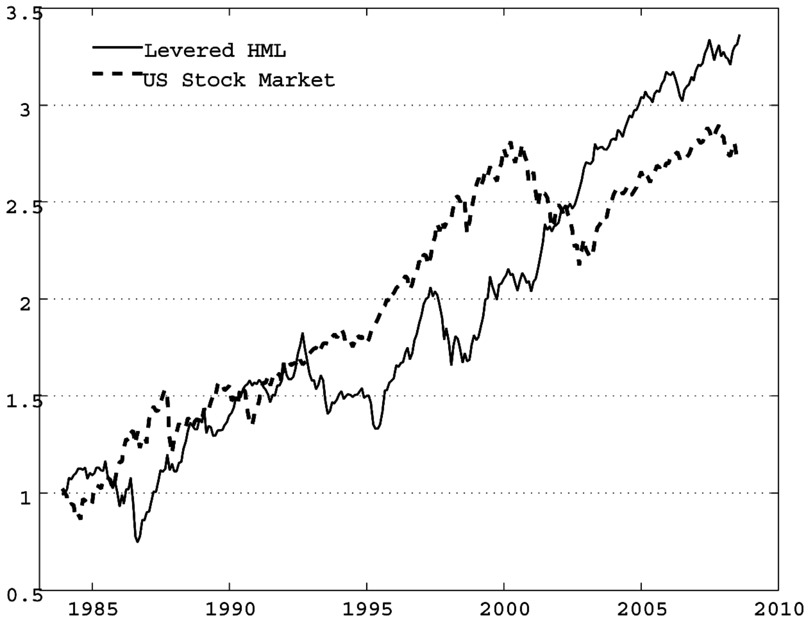

Fig. 1

227 basis points in the first part of the sample to 698 basis points per annum in the second part of the sample. Clearly, this is not a temporary anomaly that is about to be arbitraged away, and understanding carry trade returns is a critical step toward a better understanding of exchange rates. So what accounts for the carry trade premium?

The size of these carry trade returns in highly liquid and interconnected foreign exchange markets presents a challenge to modern asset-pricing theory. In their innovative piece for this volume, Brunnermeier, Nagel, and Pedersen contribute to our understanding of the carry trade by documenting a new stylized fact, the skewness of returns on the carry trade. Brunnermeier et al. argue that carry trade investors incur crash risk, because exchange rate movements between high interest rate and low interest rate currencies are negatively skewed, and they conclude that this negative skewness is due to sudden unwinding of carry trades, which tend to occur during liquidity shortfalls.[2]

We show that the skewness documented by Brunnermeier et al. in individual currency crosses shows up in currency portfolios as well. Currency portfolios allow investors to eliminate some of the idiosyncratic risk in individual currencies while still capturing the carry trade premium. These currency portfolio returns are positively skewed, even though it is not entirely clear that higher interest rate currencies expose investors to more skewness, and this is a necessary condition if crash risk is the main determinant of currency risk premia. Nonetheless, there is a growing body of evidence that low and high interest rate currencies have very different risk characteristics, and this new evidence on crash risk will become an important part of that.

We start in Section II by reviewing the evidence on the failure of uncovered interest rate parity. Section III documents the skewness of currency portfolio returns, and, finally, Section IV demonstrates that high interest rates expose currency investors not only to more crash risk but to more aggregate risk, broadly defined. The currency portfolio data are available from our Web site.

II. The Failure of Uncovered Interest Rate Parity

The time-series evidence for individual currency pairs suggests that investors earn high excess returns by investing in currencies with interest rates that are higher than usual. We review this evidence in this section. The next section shows that investors earn large excess returns simply by investing in currencies with currently high interest rates.

We start by setting up some notation. Lowercase symbols denote logs. We use s to denote the log of the spot exchange rate in units of foreign currency per U.S. dollar and f for the log of the forward exchange rate, also in units of foreign currency per U.S. dollar. An increase in s means an appreciation of the home currency. The log excess return rx on buying a foreign currency in the forward market and then selling it in the spot market after 1 month is simply

$$rx_{t+1} = f_t - s_{t+1}.$$

This excess return can also be stated as the log forward discount minus the change in the spot rate: $rx_{t+1} = f_t - s_t - \Delta s_{t+1}$. In normal conditions, forward rates satisfy the covered interest rate parity condition; the forward discount is equal to the interest rate differential: $f_t - s_t \approx i_t^* - i_t$, where i^* and i denote the foreign and domestic nominal risk-free rates over the maturity of the contract. Hence, the log currency excess return approximately equals the interest rate differential less the rate of depreciation:

$$rx_{t+1} \approx i_t^* - i_t - \Delta s_{t+1}.$$

The carry trade consists of taking long positions in foreign currency with high interest rates i^*:

$$rx_{t+1} = \underbrace{(f_t - s_t)}_{\text{forward premium}} - \underbrace{\Delta s_{t+1}}_{\text{depreciation}} = i_t^* - i_t - \underbrace{\Delta s_{t+1}}_{\text{depreciation}},$$

and short positions in foreign currency with low interest rates i^*:

$$-rx_{t+1} = -(f_t - s_t) + \underbrace{\Delta s_{t+1}}_{\text{depreciation}} = i_t - i_t^* + \underbrace{\Delta s_{t+1}}_{\text{depreciation}}.$$

We use m to denote the log of the investor's IMRS (intertemporal marginal rate of substitution) or stochastic discount factor. The carry trade investor's Euler equation implies that the average returns on the carry trade satisfy

$$E_t[rx_{t+1}] + \frac{1}{2}\operatorname{Var}_t[rx_{t+1}] = -\operatorname{Cov}[m_{t+1}, rx_{t+1}].$$

We can simply ignore the Jensen inequality term for now, because it is second order. When investors are risk neutral or when the returns do not covary with the investors' intertemporal marginal rate of substitution, then we do not expect the carry trade to produce positive or negative excess returns. There is no reason to expect investors to be risk neutral or to assume that this covariance is zero. However, this is a useful benchmark, commonly referred to as uncovered interest rate parity or UIP. In reality, the carry trade is very profitable, even after accounting for transaction costs.

A. Time-Series Evidence

The failure of uncovered interest rate parity in time-series data for individual currencies is well documented (Hansen and Hodrick 1980; Fama 1984).[3] Regressions of the rate of depreciation on the interest rate difference or the forward discount almost invariably reveal negative slope coefficients $b^i < 0$:

$$\Delta s_{t+1}^i = a^i + b^i(f_t^i - s_t^i) + \varepsilon_{t+1}^i.$$

This means that higher than usual interest rates lead to further appreciation. Hence, investors earn more by holding bonds from currencies with interest rates that are higher than usual:

$$E_t[rx^i_{t+1}] = (1 - b^i)(f^i_t - s^i_t) - a^i.$$

As many have pointed out, it might be challenging for an investor to implement this trading strategy. What does "usual" mean? This requires a precise estimate of the constant in the regression a^i. In addition, there might be a peso problem for individual currencies (see Cochrane [2001, chap. 20] for a comprehensive discussion).

B. Cross-Sectional Evidence

We adopt a much simpler approach that sidesteps these issues. We build portfolios of positions in 1-month forward contracts sorted on forward discounts (Lustig and Verdelhan 2007; Lustig, Roussanov, and Verdelhan 2008), and we show that UIP fails in the cross section too:

1. For high (h) interest rate currencies, the average interest rate difference exceeds the rate of depreciation:

$$E_h[rx^i_{t+1}] = E_h[f^i_t - s^i_t] - E_h[\Delta s^i_{t+1}] > 0.$$

2. For low (l) interest rate currencies, the average interest rate difference is not offset by the average rate of depreciation:

$$E_l[rx^i_{t+1}] = E_l[f^i_t - s^i_t] - E_l[\Delta s^i_{t+1}] < 0.$$

Investors earn more by holding bonds from currencies with interest rates that are currently high. Whether the interest rate is higher than usual does not matter. In addition, the peso problem that is paramount for individual currencies is less important.

Building currency portfolios. At the end of each period t, we allocate all currencies in the sample to six portfolios on the basis of their forward discounts $f - s$ observed at the end of period t.[4] Portfolios are rebalanced at the end of every month. They are ranked from low to high interest rates; portfolio 1 contains the currencies with the lowest interest rate or smallest forward discounts, and portfolio 6 contains the currencies with the highest interest rates or largest forward discounts. We compute the log currency excess return rx^j_{t+1} for portfolio j by taking the average of the log currency excess returns in each portfolio j. For the purpose of computing returns net of bid-ask spreads we assume that investors short all the foreign currencies in the first portfolio and go long in all the other foreign currencies.

The total number of currencies in our portfolios varies over time. We have a total of nine countries at the beginning of the sample in 1983 and 26 at the end in 2008. We include only currencies for which we have forward and spot rates in the current and subsequent period. The maximum number of currencies attained during the sample is 34; the launch of the euro accounts for the subsequent decrease in the number of currencies. The average number of portfolio switches per month is 6.01 for portfolios sorted on 1-month forward rates. We define the average frequency as the time average of the following ratio: the number of portfolio switches divided by the total number of currencies at each date. The average frequency is 29.32%, implying that currencies switch portfolios roughly every 3 months.

Since we have bid-ask quotes for spot and forward contracts, we can compute the investor's actual realized excess return net of transaction costs. The net log currency excess return for an investor who goes long in foreign currency is

$$rx^l_{t+1} = f^b_t - s^a_{t+1}.$$

The investor buys the foreign currency or equivalently sells the dollar forward at the bid price (f^b) in period t and sells the foreign currency or equivalently buys dollars at the ask price (s^a_{t+1}) in the spot market in period $t+1$. Similarly, for an investor who is long in the dollar (and thus short the foreign currency), the net log currency excess return is given by

$$rx^s_{t+1} = -f^a_t + s^b_{t+1}.$$

UIP fails in the cross section. Tables 1 and 2 provide an overview of the properties of the six currency portfolios from the perspective of a U.S. investor in currency markets between November 1983 and July 2008. Detailed results are available in Lustig et al. (2008).

For each portfolio j, we report average changes in the spot rate Δs^j, the forward discounts $f^j - s^j$, the log currency excess returns $rx^j = -\Delta s^j + f^j - s^j$, and the log currency excess returns net of bid-ask spreads rx^j_{net}. Finally, we also report log currency excess returns on carry trades or high-minus-low investment strategies that go long in portfolio $j = 2, 3 \ldots , 6$ and short in the first portfolio: $rx^j_{\text{net}} - rx^1_{\text{net}}$. All exchange rates and returns are reported in U.S. dollars, and the moments of returns are annualized: we multiply the mean of the monthly data by 12 and the standard deviation by $\sqrt{12}$. The Sharpe ratio is the ratio of the annualized mean to the annualized standard deviation. In table 1, panel 1 reports for the comprehensive sample of currencies, while panel 2 looks only at developed country currencies. The data appendix contains a comprehensive list of currencies.

According to the standard UIP condition, the average rate of depreciation $E_T(\Delta s^j)$ of currencies in portfolio j should equal the average forward discount on these currencies $E_T(f^j - s^j)$, reported in table 1, panel C. Instead, currencies in the first portfolio trade at an average forward discount of –388 basis points, but they appreciate on average only by 86 basis points over this sample. This adds up to a log currency excess return of –302 basis points on average, which is reported in panel D. Currencies in the last portfolio trade at an average discount of 776 basis points, but they depreciate only by 168 basis points on average. This adds up to a log currency excess return of 608 basis points on average.

Panel E of table 1 reports average log currency excess returns net of transaction costs. Since we rebalance portfolios monthly, and transaction costs are incurred each month, these estimates of net returns to currency speculation are conservative. Moreover, Lyons (2001, 115) reports that bid-ask spreads from Reuters are roughly twice the size of interdealer spreads. As a result, our estimates of the transaction costs are probably too high. After taking into account bid-ask spreads, the average return on the first portfolio drops to –170 basis points. Note that the first column reports *minus* the actual log excess return for the first portfolio, because the investor is short in these currencies. The corresponding Sharpe ratio on this first portfolio is –0.22. The return on the sixth portfolio drops to 334 basis points. The corresponding Sharpe ratio on the last portfolio is 0.36.

Panel F reports returns on zero-cost strategies that go long in the high interest rate portfolios and short in the low interest rate portfolio. The spread between the net returns on the first and the last portfolio is 513 basis points. This high-minus-low strategy delivers a Sharpe ratio of 0.57, after taking into account bid-ask spreads. Equity returns provide a natural benchmark. Over the same sample, the (annualized) Fama-French monthly log excess return on the U.S. stock market is 5.78%, and the equity Sharpe ratio is 0.38. Note that this equity return does not reflect any transaction cost.

Exotic currencies? The carry trade premium does not disappear when we exclude developing country currencies from our sample. These results are reported in panel 2 on the right-hand side of table 1. After accounting

Table 1
Currency Portfolios: U.S. Investor

	Panel 1: All Countries						Panel 2: Developed Countries				
	1	2	3	4	5	6	1	2	3	4	5
A. Spot change: Δs^j:							Δ				
Mean	−.86	−1.21	−1.55	−2.60	−.91	1.68	−1.56	−2.49	−3.93	−2.06	−1.02
SD	8.00	7.25	7.37	7.38	7.69	9.11	10.11	9.65	9.18	8.86	9.16
Skewness	−.24	−.19	.01	.26	.42	.42	−.27	−.07	−.06	.47	.14
Kurtosis	4.10	4.32	3.74	6.39	5.18	4.27	3.59	3.57	3.04	4.94	3.59
B. Spot change: $\Delta s^j – \Delta s^1$:											
Skewness		.27	.38	1.06	.30	.93		.52	.49	.36	.76
C. Forward discount: $f^j - s^j$:											
Mean	−3.88	−1.29	−.14	.95	2.56	7.76	−3.07	−.99	.09	1.16	3.96
SD	1.56	.49	.48	.53	.58	2.07	.78	.63	.65	.67	.76
D. Excess return: rx^j (without b-a):											
Mean	−3.02	−.08	1.41	3.55	3.47	6.08	−1.51	1.49	4.02	3.22	4.99
SD	8.17	7.31	7.41	7.49	7.80	9.21	10.18	9.68	9.29	8.95	9.26
Sharpe ratio	−.37	−.01	.19	.47	.45	.66	−.15	.15	.43	.36	.54
Skewness	.10	.08	−.07	−.17	−.33	−.29	.20	.01	.05	−.38	−.06
E. Net excess return: rx^j_{net} (with b-a):											
Mean	−1.80	−1.06	.13	2.20	1.98	3.34	−.38	.44	2.61	1.96	3.29
SD	8.16	7.31	7.39	7.43	7.80	9.20	10.19	9.68	9.27	8.96	9.26
Sharpe ratio	−.22	−.14	.02	.30	.25	.36	−.04	.05	.28	.22	.36
Skewness	.12	.07	−.11	−.20	−.37	−.35	.21	.01	.03	−.41	−.09

continued

Table 1
Continued

	Panel 1: All Countries						Panel 2: Developed Countries				
	1	2	3	4	5	6	1	2	3	4	5
F. High minus low: $rx^j - rx^1$ (without b-a):											
Mean		2.93	4.43	6.57	6.49	9.10		3.00	5.52	4.72	6.49
SD		5.33	5.52	6.61	6.31	8.93		6.47	6.43	7.39	8.75
Sharpe ratio		.55	.80	.99	1.03	1.02		.46	.86	.64	.74
Skewness		−.01	−.12	−.91	−.16	−.75		−.51	−.48	−.34	−.78
G. High minus low: $rx^j_{\text{net}} - rx^1_{\text{net}}$ (with b-a):											
Mean		.74	1.93	3.99	3.78	5.13		.82	2.99	2.34	3.67
SD		5.33	5.54	6.59	6.31	8.96		6.50	6.44	7.42	8.77
Sharpe ratio		.14	.35	.61	.60	.57		.13	.47	.32	.42
Skewness		−.05	−.17	−.92	−.18	−.77		−.52	−.48	−.33	−.77

Source: Lustig et al. (2008). Data are monthly, from Barclays and Reuters (Datastream).

Note: The table uses monthly data. b-a = bid-ask spread. The table reports 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 $rx^j_{\text{net}} - rx^1_{\text{net}}$ and $rx^j - rx^1$ (with and without bid-ask spreads), for each portfolio j. 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 1-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 1 uses all countries, and panel 2 focuses on developed countries. The sample period is November 1983–July 2008.

Table 2
Currency Portfolios: U.S. Investor–Time Subsamples

	Panel 1: 1983–95						Panel 2: 1995–2008					
	1	2	3	4	5	6	1	2	3	4	5	6
A. Spot change: Δs^j:												
Mean	−2.59	−2.64	−1.29	−4.25	−1.61	1.67	.42	−.28	−1.87	−1.49	−.49	2.06
SD	8.81	8.11	8.38	8.85	9.56	10.00	7.31	6.51	6.49	5.91	5.76	8.37
B. Forward discount: $f^j - s^j$:												
Mean	−2.95	−1.28	.18	1.53	3.12	7.72	−4.70	−1.33	−.43	.43	2.04	7.79
SD	.68	.65	.63	.67	.65	2.45	2.02	.29	.29	.30	.49	1.72
C. Excess return: rx^j (without b-a):												
Mean	−.36	1.36	1.47	5.77	4.73	6.05	−5.11	−1.05	1.43	1.91	2.53	5.73
SD	8.91	8.22	8.42	8.99	9.70	10.17	7.53	6.52	6.54	5.97	5.83	8.41
Sharpe ratio	−.04	.17	.17	.64	.49	.60	−.68	−.16	.22	.32	.43	.68
D. Net excess return: rx^j_{net} (with b-a):												
Mean	1.00	.29	−.20	3.99	3.06	3.27	−4.00	−1.94	.49	.91	1.18	2.99
SD	8.92	8.21	8.35	8.91	9.68	10.15	7.49	6.52	6.56	5.97	5.86	8.41
Sharpe ratio	.11	.04	−.02	.45	.32	.32	−.53	−.30	.08	.15	.20	.35
E. High minus low: $rx^j - rx^1$ (without b-a):												
Mean		2.95	4.33	6.59	6.46	8.83		4.06	6.55	7.03	7.65	10.84
SD		5.52	5.82	6.55	6.74	8.98		5.21	5.23	6.75	5.97	8.89
Sharpe ratio		.31	.32	.94	.76	.71		.78	1.25	1.04	1.28	1.22

continued

Table 2
Continued

	Panel 1: 1983–95						Panel 2: 1995–2008					
	1	2	3	4	5	6	1	2	3	4	5	6
E. High minus low: $rx^j - rx^1$ (without b-a):												
Mean		2.95	4.33	6.59	6.46	8.83		4.06	6.55	7.03	7.65	10.84
SD		5.52	5.82	6.55	6.74	8.98		5.21	5.23	6.75	5.97	8.89
Sharpe ratio		.31	.32	.94	.76	.71		.78	1.25	1.04	1.28	1.22
F. High minus low: $rx^j_{\mathrm{net}} - rx^1_{\mathrm{net}}$ (with b-a):												
Mean		–.71	–1.20	2.99	2.06	2.27		2.06	4.49	4.91	5.18	6.98
SD		5.56	5.86	6.55	6.79	9.03		5.17	5.20	6.69	5.91	8.88
Sharpe ratio		–.13	–.20	.46	.30	.25		.40	.86	.73	.88	.79

Source: Lustig et al. (2008). Data are monthly, from Barclays and Reuters (Datastream).

Note: b-a = bid-ask spread. 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 $rx^j_{\mathrm{net}} - rx^1_{\mathrm{net}}$ 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 1-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. Both panels use data from developed and emerging countries. The sample periods are November 1983–January 1995 and January 1995–March 2008.

for transaction costs, the Sharpe ratio on the high-minus-low strategy is still .43, in spite of the fact that there are fewer currencies in each portfolio and hence the benefits of diversification are much smaller. Clearly, the carry trade risk premium is not specific to emerging markets. This is in line with the findings of Bansal and Dahlquist (2000), who examine the time-series evidence for a large sample of currencies. They find that the UIP slope coefficients actually increase for currencies in developing countries with higher inflation.

Temporary anomaly? If this is an anomaly that will be arbitraged away, then one would expect the carry premium to diminish over time, as the volume in currency markets has exploded in the last decades. Between 1992 and 2008, the Bank for International Settlements estimates that the average daily volume in currency markets increased from 800 billion to 3.75 trillion (2007 annual report). This number dwarfs the volume of trade in any other asset market. Of course, most of this volume occurs in the major crosses. However, we found that the carry premium does not disappear when we limit ourselves to the currencies of developed countries. Instead, the size of the carry premium seems to have gone up over time. The size of the carry premium after transaction costs increased from 227 basis points between 1983 and 1995 to 698 basis points between 1995 and 2008. Over the same period, the Sharpe ratio increased from .46 to .79. If anything, the carry trade premium has increased in the second part of the sample. The next section explores whether the skewness of these exchange rate shocks and currency portfolio returns can explain the cross-sectional variation.

III. Currency Crashes and the Skewness of Carry Trade Returns

Brunnermeier et al. find substantial evidence of skewness in individual currency crosses. We examine the skewness of exchange rate changes and returns on a portfolio-by-portfolio basis. An investor can easily construct these portfolios to eliminate some of the idiosyncratic risk in individual currencies. In table 1, we report the skewness of exchange rate changes and carry trade returns. The conditional skewness of log returns $\text{skewness}[rx_{t+1}] = \text{skewness}_t[\Delta s_{t+1}]$ depends only on the skewness of the changes in the exchange rate, because the interest rates are known at the time of the investment. The unconditional skewness of returns also depends on the properties of the forward discount. We find that the carry trade definitely exposes investors to crash risk, but it is less clear that higher interest rate corresponds to more crash risk.

Does skewness explain the cross section of currency returns? We start in table 1, panel 1, by looking at the skewness of exchange rate changes (third row) in the comprehensive sample, and we find a beautiful pattern. Higher interest rates mean more skewness against the dollar. The skewness varies monotonically from −.24 for the first portfolio to .42 for the last portfolio. As pointed out by Brunnermeier et al., in high interest rate currencies large depreciations are much more likely. This pattern is especially remarkable because the second moments of exchange rate changes do not seem to vary at all across portfolios: the volatility of exchange rate changes is between 7.5% and 9% per annum for all currencies. Moreover, there is no clear pattern in the kurtosis of exchange rate changes. In panel 2, we report the same numbers for the limited sample of developed currencies. In this case, currencies in the fourth portfolio have more skewness (.47) than those in the fifth portfolio (.14). However, these numbers are less reliable, because there are fewer currencies in each portfolio, and hence the idiosyncratic risk is not averaged out as well.

However, what really matters is the conditional skewness of returns on a long position in high interest rate currencies and a short position in low interest rate currencies: $\text{skewness}_t[rx^j_{t+1} - rx^1_{t+1}] = \text{skewness}_t[\Delta s^j_{t+1} - \Delta s^1_{t+1}]$. These statistics are reported in panel B. The conditional skewness of these carry trade positions is always positive. This implies that large simultaneous depreciations of high interest rate currencies and appreciations of low interest rate currencies are more likely. However, in this case, the variation across portfolios is not monotonic. The skewness for the fourth portfolio is 1, roughly the same as that of the last portfolio, but the skewness for the fifth portfolio is only .3. Higher interest rates do not seem to imply more skewness against the lowest interest rate currencies. Figure 2 plots the skewness of exchange rate changes in dollars against the mean excess return for each portfolio in the left panel. The right panel plots the skewness of exchange rate changes for the long-short strategy against the mean excess returns on the long-short strategy. While the skewness of exchange rate shocks against the dollar ($\text{skewness}_t[\Delta s^j_{t+1}]$) is a promising candidate to explain the cross-sectional variation in excess returns, the skewness of exchange rate shocks for the long-short strategy ($\text{skewness}_t[\Delta s^j_{t+1} - \Delta s^1_{t+1}]$) is not. For carry trade investors, the latter is what matters most.

The unconditional skewness of returns ($\text{skewness}_t[rx^j_{t+1}]$) also depends on the properties of interest rates. These statistics are reported in panels D–F of table 1. Panel D shows the properties of returns without bid-ask spreads. Panel E shows the same statistics after accounting for

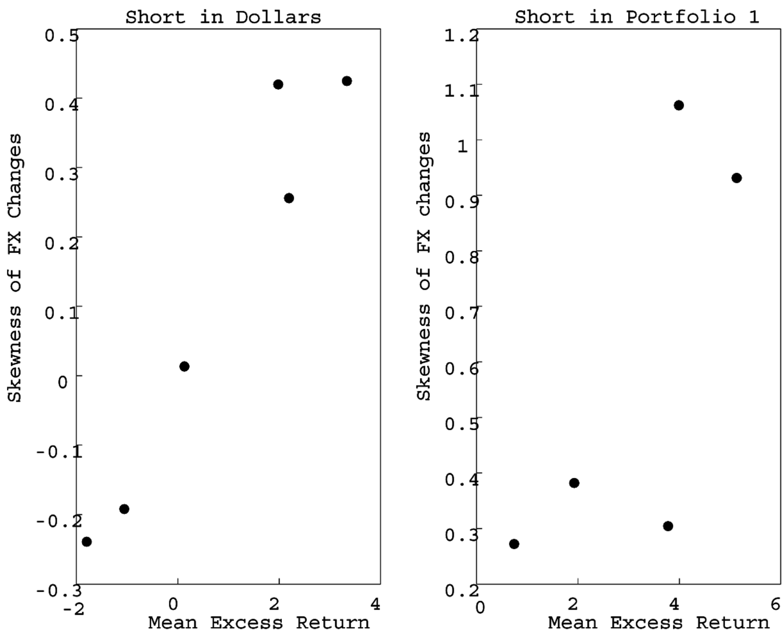

Fig. 2

the bid-ask spreads. Not surprisingly, we find a similar pattern. The skewness of net returns varies quasi-monotonically from .12 for the first portfolio to −.35 for the last portfolio. However, what really matters is the skewness of returns on the long-short strategy, and these do not vary monotonically with interest rates. After accounting for bid-ask spreads, the skewness of the returns on long in 6 and short in 1 is −.77. However, the skewness of the returns on a strategy that goes long in 5 and short in 1 is only −.18, even though the average returns are still 378 basis points per annum for this strategy.

How much crash risk is there in the carry trade? To assess the quantity of crash risk in these returns, it helps to use stock returns as benchmark. The skewness of monthly excess returns on the stock market (in logs) is −1.24 over the same sample, compared to −.77 for the carry trade strategy. We found the same pattern in daily returns (not reported). While there is crash risk in the carry trade, it is considerably less than the crash risk that the buy-and-hold investor is exposed to in U.S. stock markets. We conclude our discussion by showing that low and high interest rate currencies differ along other dimensions as well.

IV. Interest Rates and Risk

If short-term interest rates measure the amount of risk in the economy, and there is plenty of evidence that they do, then high interest rate currencies are riskier than low interest rate currencies, and they will earn a higher risk premium.

Implications of no arbitrage: Backus-Foresi-Telmer. In the absence of arbitrage opportunities, there exists a domestic m and a foreign m^* such that the change in the log of the exchange rate equals the difference in the log of the pricing kernels:[5]

$$s_{t+1} - s_t = m_{t+1} - m^*_{t+1}.$$

If markets are complete, m and m^* are unique. As a result, the forward premium can be decomposed into a risk premium and an expected depreciation component:

$$f_t - s_t = (f_t - E_t s_{t+1}) + E_t \Delta s_{t+1},$$

$$\log E_t[M_{t+1}] - \log E_t[M^*_{t+1}] = E_t[rx_{t+1}] + E_t[m_{t+1}] - E_t[m^*_{t+1}],$$

where we have used covered interest rate parity to go from the first to the second equation. Hence, this gives rise to the no-arbitrage risk premium decomposition for currency (Backus, Foresi, and Telmer 2001):

$$E_t[rx_{t+1}] = (\log E_t[M_{t+1}] - E_t[m_{t+1}]) - (\log E_t[M^*_{t+1}] - E_t[m^*_{t+1}]).$$

If we assume lognormality of the domestic pricing kernel M and the foreign pricing kernel M^*, then the moments of order > 2 drop out and the conditional risk premium on shorting the foreign currency is given by the half the spread in conditional variances:[6]

$$E_t[rx_{t+1}] = .5(\mathrm{Var}_t[m_{t+1}] - \mathrm{Var}_t[m^*_{t+1}]).$$

The implications of this equation are very clear. To replicate the cross-sectional pattern in table 1, we need larger conditional variance $\mathrm{Var}_t[m_{t+1}]$ in low interest rate currencies, and smaller conditional variance in $\mathrm{Var}_t[m_{t+1}]$ in high interest rate currencies. In other words, we can replicate the carry trade risk premium if short-term interest rates measure the quantity and price of risk in the economy. This turns out to be exactly what one would expect on the basis of a cursory inspection of monetary policy and the evidence from bond markets.

The U.S. experience. We take a closer look at the U.S. experience over the last 2 decades. It seems reasonable to use the implied volatility in the U.S. stock market as a measure of the conditional variance of the pricing kernel $\mathrm{Var}_t[m_{t+1}]$. Figure 3 plots the 12-month change in the 3-month T-Bill yield against the VIX index implied volatility. We use the 12-month change in the yield instead of the level in order to eliminate the effect of changes in the level of inflation at lower frequencies, because we are not interested in these. Clearly, large increases in the implied volatility in U.S. stock markets invariably coincide with large declines in the yields on Treasury bills. Most of the variation in short-term interest rates seems related to changes in market risk ($\mathrm{Var}_t[m_{t+1}]$). On September 18, 2008 (not shown in fig. 3), the VIX exceeded 42 and the T-Bill yield fell below 9 basis points.

This relation between monetary policy and risk in financial markets is at the heart of the contribution by Atkeson and Kehoe (2009) to this volume. They present evidence from bond markets that supports this link between risk and interest rates. Most changes in short-term interest rates seem to signal changes in bond risk premia and hence risk, rather than changes in expected inflation.

Why do high risk currencies or currencies with a high $\mathrm{Var}_t[m_{t+1}]$ offer insurance against aggregate risk?[7] Consider the simplest case of a common shock. Different countries have different exposures to these shocks. In particular, as the volatility of the common shock increases,

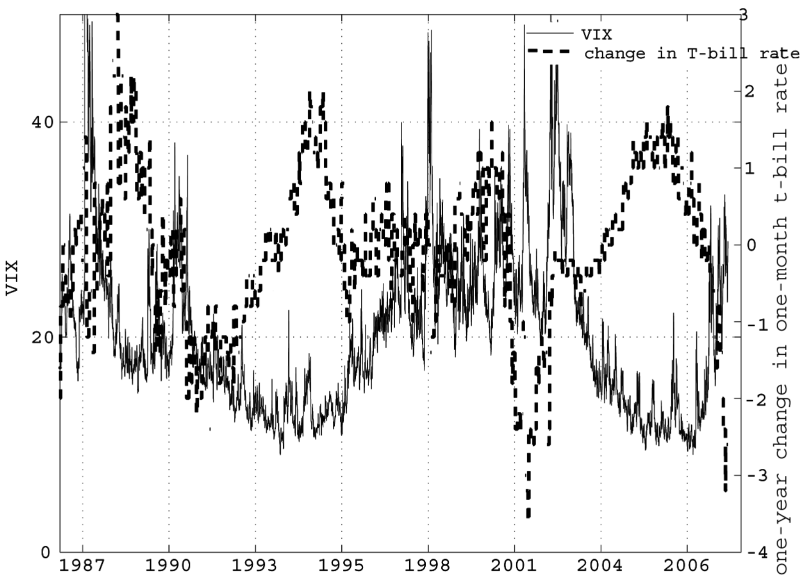

Fig. 3

interest rates decline more in the countries with more exposure and less in those with smaller exposure. Now, in case of negative common shock realization, the currency of the country with the largest exposure to the common shock appreciates:

$$s_{t+1} - s_t = \log m_{t+1} - \log m^*_{t+1},$$

because it experiences a large increase in m^*, and similarly, in countries with smaller exposure to the common shock, the currency depreciates in case of a negative shock realization. Hence, low interest rate currencies provide insurance against bad shocks in times of high volatility.

Case study: The mortgage crisis. This is exactly what happened during the recent mortgage crisis. We use this episode as a case study. Figure 4 plots the monthly rate of appreciation of the yen against the world stock market return (in daily data) between July of 2007 and March of 2008. The yen appreciates when the world stock market declines. By contrast, the NZD depreciates when the world stock market declines. Figure 5 plots the monthly rate of appreciation of the NZD against the world stock market return over the same period. Low interest rate currencies provide a hedge against market risk while high interest rate currencies expose investors to more market risk.

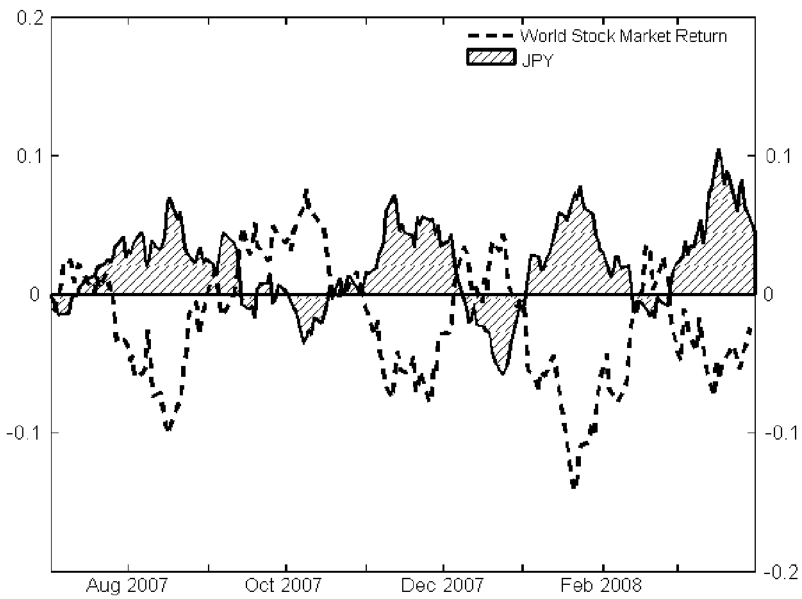

Fig. 4

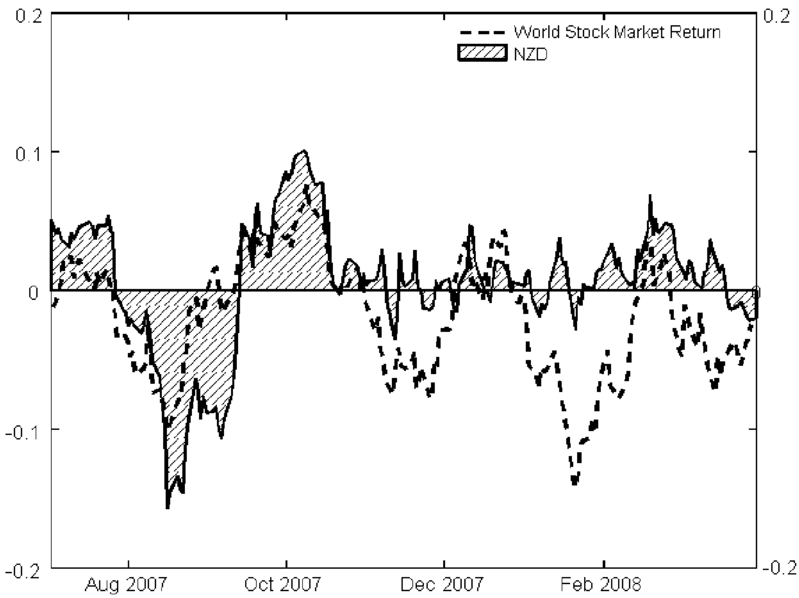

Fig. 5

As a result, HML_{FX}, a long position in the sixth portfolio and a short position in the first portfolio, exposes U.S. and foreign investors to lots of systematic or aggregate risk. Figure 6 plots the HML_{FX} return against the U.S. stock market return between February of 2007 and March of 2008. The correlation between these monthly returns is .76 in daily data. Moreover, this is not an isolated event. Lustig et al. (2008) document the same pattern in a number of episodes characterized by increased volatility in global financial markets. For example, before, during, and after the LTCM crisis, the correlation between the carry trade returns and U.S. stock market returns increased to .73, as shown in figure 7.

So high interest rate currencies expose investors to more risk, not just because these are more exposed to crash risk but, more generally, because these are more exposed to aggregate risk, while low interest rate currencies provide insurance against aggregate risk. This is exactly what is implied by the no-arbitrage conditions in currency markets if interest rates measure exposure to common risk.[8] Lustig et al. (2008) show that all of these stylized facts about the carry trade are consistent with a standard no-arbitrage model.[9]

Now, during these episodes, carry trade investors may be forced to unlever. This may contribute to unwinding of the carry trades, putting downward pressure on high interest rate currencies and upward pressure on

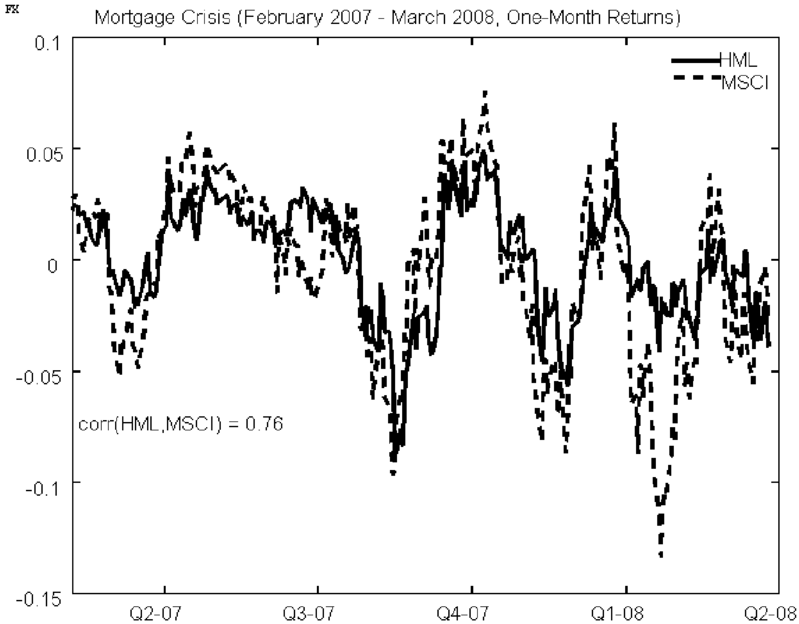
FX
Mortgage Crisis (February 2007 - March 2008, One-Month Returns)
HML
MSCI
corr(HML,MSCI) = 0.76
0.1
0.05
0
-0.05
-0.1
-0.15
Q2-07
Q3-07
Q4-07
Q1-08
Q2-08

Fig. 6

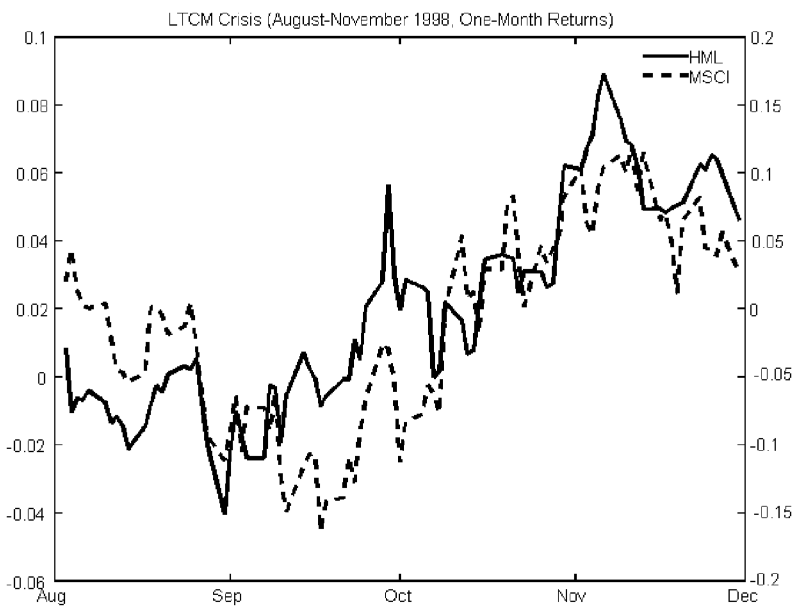
LTCM Crisis (August-November 1998, One-Month Returns)
HML
MSCI
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
Aug
Sep
Oct
Nov
Dec

Fig. 7

low interest rate currencies. Brunnermeier et al. provide some compelling evidence for this. However, this is perfectly consistent with the macroeconomic risk perspective that we adopt in our research. From a macro perspective, the liquidity shortfalls in currency markets seem less like a cause, more like a symptom, similar to doctors who tend to appear when there is an epidemic outbreak somewhere. It is not clear that we want to blame the doctors for the outbreaks. This distinction has bite. If we are right, then there is no need for a new paradigm to understand exchange rates. In addition, in that case, there is no reason to believe that high interest rate currencies start to trade like distressed assets in times of high volatility at prices far below their intrinsic value. However, if we are wrong about this and these liquidity shortfalls themselves cause high interest rate currencies to depreciate during crises, then the welfare implications of large and persistent mispricing in currency markets could be enormous given the volume of trade and capital flows that is governed by exchange rates.

V. Conclusion

Interest rates are to currency what book-to-market ratios are for stocks. They measure a currency's risk characteristics for foreign investors, simply because of the response of short-term interest rates to the quantity of risk in financial markets. If interest rates measure how much risk there is in the economy, as suggested by the evidence from bond and currency markets, then low interest rate currencies offer insurance against aggregate risk and high interest rate currencies increase exposure to aggregate risk. Brunnermeier et al. contribute to our understanding of these differences in risk characteristics between high and low interest rate currencies by showing that long positions in high interest rate currencies and short positions in low interest rate currencies expose investors to substantial crash risk.

Data Appendix

We start from daily spot and forward exchange rates in U.S. dollars. We build end-of-month series from November 1983 to March 2008. These data are collected by Barclays and Reuters and available on Datastream. Lyons (2001, 115) reports that bid-ask spreads from Reuters are roughly twice the size of interdealer spreads. As a result, our estimates of the transaction costs are conservative. Lyons (2001) also notes that these indicative quotes track interdealer quotes closely, only lagging the interdealer market slightly at very high intraday frequency. This is clearly not an issue here at monthly horizons. Our main data set contains 37 currencies: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Euro Area, Finland, France, Germany, Greece, Hong Kong, Hungary, India, Indonesia, Ireland, Italy, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, and United Kingdom. Some of these currencies have pegged their exchange rate partly or completely to the U.S. dollar over the course of the sample. We keep them in our sample because forward contracts were easily accessible to investors. We leave out Turkey and United Arab Emirates, even if we have data for these countries, because their forward rates appear disconnected from their spot rates. As a robustness check, we also study a smaller data set that contains only 15 developed countries: Australia, Belgium, Canada, Denmark, Euro Area, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, and United Kingdom. We present all of our results on these two samples.

Endnotes

1. The carry trade returns are taken from Lustig, Roussanov, and Verdelhan (2008). The next section explains in detail how these carry trade returns are constructed. The return on the U.S. stock market is the cum dividend return on the CRSP value-weighted index.

2. There is a large class of papers that look for risk-based explanations of the carry trade returns. This segment includes recent papers by Backus, Foresi, and Telmer (2001), Harvey, Solnik, and Zhou (2002), Alvarez, Atkeson, and Kehoe (2005), Brennan and Xia (2006), Campbell, de Medeiros, and Viceira (2006), Graveline (2006), Bansal and Shaliastovich (2007), Farhi and Gabaix (2007), Hau and Rey (2007), Lustig and Verdelhan (2007), Colacito (2008), Brunnermeier et al. (in this volume), and Verdelhan (forthcoming). Earlier work includes Hansen and Hodrick (1980), Fama (1984), Korajczyk (1985), Bekaert and Hodrick (1992), and Bekaert (1995, 1996). The second class looks for non-risk-based explanations. This segment includes papers by Froot and Thaler (1990), Lyons (2001), Gourinchas and Tornell (2004), Bacchetta and van Wincoop (2006), Burnside et al. (2006), Sarno, Leon, and Valente (2006), Burnside, Eichenbaum, and Rebelo (2007a, 2007b), Frankel and Poonawala (2007), Plantin and Shin (2007), and Burnside et al. (2008).

3. Hodrick (1987) and Lewis (1995) provide extensive surveys and updated regression results. UIP appears to be a reasonable description of the data only in four cases. First, Bansal and Dahlquist (2000) show that UIP is not rejected at high inflation levels, and likewise Huisman et al. (1998) find that UIP holds for very large forward premia. Second, Chaboud and Wright (2005) show that UIP is valid at very short horizons but is rejected for horizons above a few hours. Third, Meredith and Chinn (2005) find that UIP cannot be rejected at horizons above 5 years. Finally, Lothian and Wu (2005) find positive UIP slope coefficients for France/UK and U.S./UK exchange rates on annual data over 1800–1999, because of the 1914–49 subsample. Engel (1996) and Chinn (2006) provide recent surveys of UIP tests. Such UIP regressions suffer from small sample bias and persistence in the right-hand-side variables, but Liu and Maynard (2005) and Maynard (2006) show that these biases can only explain a small part of the results.

4. We use 1-month currency excess returns built using and ranked on 1-month forward contracts. Yet, forward contracts are available at longer maturities of 2, 3, 6, and 12 months. The currencies in our sample are reported in the data appendix.

5. See Brandt, Cochrane, and Santa-Clara (2006) for a detailed analysis of this equation and its implications for risk sharing across countries.

6. Without lognormality, the conditional risk premium on shorting the foreign currency is given by the half the spread in conditional moments of log pricing kernels:

$$p_t = .5(\mu_{2,t} - \mu^*_{2t}) + (1/6)(\mu_{3,t} - \mu^*_{3,t}) + \ldots .$$

Define the conditional skewness of the pricing kernel:

$$\mu_{3,t} = \text{skewness}_t[\log M_{t+1}] \times \text{SD}_t[\log M_{t+1}]^3.$$

We need strong negative correlation between interest rate spreads and differences in conditional skewness of log pricing kernels to replicate the pattern in the data. The conditional skewness of the rate of depreciation is not the spread in the conditional skewness of the log pricing kernels:

$$\begin{aligned}\text{skewness}_t[s_{t+1} - s_t] &= \text{skewness}_t[\log M_{t+1} - \log M^*_{t+1}] \\ &\neq \text{skewness}_t[\log M_{t+1}] - \text{skewness}_t[\log M^*_{t+1}].\end{aligned}$$

There is no obvious connection between the skewness of the rate of depreciation and the risk premium.

7. See Lustig and Verdelhan (2006) for a detailed explanation and more examples.

8. HML_{FX} is strongly related to macroeconomic risk; it has a U.S. consumption growth beta between 1 and 1.5, consistent with the findings of Lustig and Verdelhan (2007). In recent related work, DeSantis and Fornati (2008) provide more evidence that currency returns compensate investors for systematic, business cycle risk.

9. Standard macro asset-pricing models can replicate the negative slope in the UIP time-series regressions and, with some modification, the carry trade premium that we document. Recent contributions to the risk-based literature offer three types of fully specified models of the forward premium puzzle: Verdelhan (forthcoming) uses habit preferences in the vein of Campbell and Cochrane (1999), Bansal and Shaliastovich (2007) build on the long-run risk model pioneered by Bansal and Yaron (2004), and Farhi and Gabaix (2007) augment the standard consumption-based model with disaster risk following Barro (2006). These three models have two elements in common: a persistent variable drives the volatility of the log stochastic discount factor, and this variable co-moves negatively with the country's risk-free interest rate.

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