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Comment

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The carry trade in currencies is an investment strategy whereby an investor borrows funds in a low interest rate currency in order to lend in a high interest rate currency. If uncovered interest rate parity (UIP) held, the investor would expect to make zero profits on average, because the interest differential would reflect the expected depreciation of the high interest rate currency against the low interest rate currency. UIP has been studied by many researchers in international economics and has been widely rejected. Contrary to what the UIP condition predicts, on average, high interest rate currencies tend to appreciate against low interest rate currencies, at least when the currencies being studied are those of advanced economies with relatively low inflation. Perhaps not surprisingly, therefore, the carry trade is a profitable investment strategy. As Burnside et al. (2008) report, the average excess return of a simple carry trade strategy based on up to 20 currencies and executed monthly over the period 1976–2007 was close to 5% per year. More surprisingly, the annualized Sharpe ratio of this strategy was 0.97, more than double that of the value-weighted U.S. stock market over the same period.

Some research in international economics has tried to directly tackle the UIP puzzle. Other research tries to explain the apparent profitability of the carry trade. Clearly any explanation of one is likely to provide insights into the other. As a result, Brunnermeier, Nagel, and Pedersen's paper, which focuses on the carry trade as an investment strategy, is of interest not only to researchers in finance but also to a wider audience of macroeconomists.

The contribution of Brunnermeier et al.'s paper is the novelty of the empirical work. They provide an interesting collection of new facts that, at least informally, provide support for the theoretical "liquidity

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spirals" model in Brunnermeier and Pedersen (2009). In my view the key findings are fourfold.

1. Speculative activity in currencies rises persistently when interest differentials widen.
2. The negative skewness of carry trade returns increases conditional on a wider interest differential.
3. When measures of market volatility (interpreted as changes in investor risk appetite) go up, speculative activity and carry trade returns go down.
4. Indicators of tightening interbank liquidity predict carry trade losses.

I will discuss the meaning and importance of these findings in more detail below, but they provide loose support for the following story. Suppose the interest differential between two currencies widens. As a result, speculation increases, but, due to liquidity frictions, it does not rise quickly enough and with enough volume to immediately eliminate deviations from UIP. Furthermore, perceived downside risk (skewness) increases, raising the cost of crash insurance, and these effects together dampen investors' willingness to speculate. In the face of shocks, including those to risk preferences, market liquidity goes down, speculators unwind positions, and this can precipitate large shifts in exchange rates.

Should a model with liquidity frictions be the model of choice? Models with financial market imperfections and other frictions have long been considered candidate explanations of the UIP puzzle, so Brunnermeier et al. are in good company. Their paper contributes to a long-lived area of research in international finance.[1] Another reason to consider models of financial frictions is, in my view, the empirical failure of other leading explanations of the UIP puzzle. As I discuss in more detail below, standard risk-based stories do not hold up when confronted by the data. Another recurrent explanation that has received attention in the literature is the "peso problem."[2] Making reference to Burnside et al.'s (2008) empirical findings, however, I argue that for major currencies the evidence for peso problems as an explanation of the UIP puzzle is weak. Therefore, there is a strong case for research into other potential explanations.

Brunnermeier et al.'s findings suggest that models with liquidity frictions deserve a closer look. My main criticism of the paper is that the links between theory and empirics are loose enough that we do not get a firm sense of the quantitative success of the model. As I mentioned above, a simple carry trade strategy earned a 5% mean excess return between 1976 and 2007. Can a liquidity-based story explain this excess return? If so, how much skewness in carry trade returns is required to make the story work? Is this degree of skewness consistent with what we see in the data? Future research should tackle these questions.

In the rest of this comment, I first describe the carry trade in more detail and explain how its profitability relates to the failure of UIP. I then briefly review the evidence against risk-based and peso-problem-based explanations of the UIP puzzle, while referring the reader to Burnside et al. (2008) for more details. Finally, I return to the authors' contribution and discuss their empirical findings in more detail.

I. The Carry Trade and UIP

Consider three simple investment strategies. One is to lend in the domestic money market. The gross return of this strategy in local currency units is

$$1 + i_t, \tag{1}$$

where i_t is the domestic interest rate. The second strategy is to convert local currency (U.S. dollars) to foreign currency and lend it in the foreign money market. The return of this strategy in dollars is

$$(1 + i_t^*)\frac{S_{t+1}}{S_t}, \tag{2}$$

where i_t^* is the foreign interest rate and S_t is the spot exchange rate at time t measured in dollars per foreign currency unit (FCU). The third strategy is like the second, except that the investor lending in foreign currency hedges his exchange rate risk by buying dollars in the forward market at the rate F_t. His return is

$$(1 + i_t^*)\frac{F_t}{S_t}. \tag{3}$$

Since the strategy of lending dollars and the strategy of lending FCUs combined with a forward hedge are both nominally riskless (in dollars), the returns given in (1) and (3) must be equal, implying the covered interest parity (CIP) condition:

$$\frac{1 + i_t}{1 + i_t^*} = \frac{F_t}{S_t}. \tag{4}$$

Standard asset-pricing theory implies that there exists a stochastic discount factor, M_t, that prices dollar payoffs. That is, there exists an M_t such that

$$1 = E_t[R_{t+1}M_{t+1}], \tag{5}$$

where R_t is the time-t realization of the gross return of any investment strategy and E_t is the conditional expectations operator given information available at time t. Combining (2), (4), and (5) and using the fact that (5) implies that $1 + i_t = 1/E_tM_{t+1}$, we obtain

$$\frac{F_t}{S_t}E_tM_{t+1} = E_t\left(M_{t+1}\frac{S_{t+1}}{S_t}\right). \tag{6}$$

Some simple rearrangement of (6) leads to

$$E_t\delta_{t+1} = f_t - \underbrace{\frac{\text{Cov}_t(M_{t+1}\,\delta_{t+1})}{E_tM_{t+1}}}_{p_t}, \tag{7}$$

where $\delta_t \equiv (S_t - S_{t-1})/(S_{t-1})$ and $f_t = (F_t - S_t)/S_t$. Here, p_t represents a "risk premium." A version of (7) for interest rates holds approximately and can be derived using (4):

$$E_t\,\delta_{t+1} \cong i_t^* - i_t - p_t. \tag{8}$$

The unbiasedness hypothesis, that the forward rate, F_t, is an unbiased predictor of the future spot rate, S_{t+1}, is that the condition (7) holds without the "risk premium" term: $p_t = 0$. Equivalently, the UIP hypothesis is that (8) holds for $p_t = 0$. A standard test of this hypothesis is to run the regression

$$\delta_{t+1} = a + bf_t + \epsilon_{t+1} \tag{9}$$

testing the null hypothesis that $a = 0$, $b = 1$.[3] Burnside et al. (2008) study a panel of 20 major currencies observed on a monthly basis against the U.S. dollar over the period 1976–2007. For most of these currencies the estimate of b is negative and lies significantly below one. In a few cases, it lies significantly below zero.

The carry trade in currencies is motivated by this failure of UIP. It is important to note that this motivation does not rely on the precise estimate of b. Instead, the key fact is that currencies at a forward premium do not, on average, depreciate by the amount of the forward premium. Given this fact, a strategy of borrowing cheap currencies and lending expensive ones should be profitable. Equivalently, selling currencies forward when they are at a forward premium should be profitable.

Measuring the profitability of the carry trade and other currency strategies offers a way of measuring the economic significance of the failure of UIP.[4] Burnside et al. (2008) report that over the period 1976–2007 an equally weighted carry trade portfolio, executed monthly using up to 20 currencies, earned an average annual excess return of about 5%.[5] (In what follows, I refer to this strategy as the CT strategy.) This return is statistically significant but smaller than the average excess return of the stock market over the same period (about 7%). On the other hand, carry trade returns are much less variable than stock returns, with an annualized standard deviation of about 5% (compared to about 15% for stocks). As a result the Sharpe ratio of the carry trade is double that of stocks.

II. Risk-Based Explanations

The failure of UIP has received a great deal of attention in the literature, and it is not my intention to thoroughly survey that literature here. A number of theories have been proposed. Perhaps the most conventional of these theories is that the failure of UIP is rationalized by the behavior of the risk premium, p_t, in (7) (see Fama 1984). One approach to measuring the risk premium is to assume that the exchange rate is a random walk, $E_t\delta_{t+1} = 0$, since it is well known that this is a reasonably good approximation to the behavior of many exchange rates. Given this assumption, $p_t = f_t$; the forward premium *is* the risk premium. The problem with this approach to measuring the risk premium is that it is purely mechanical and lacks economic content.[6] By construction, it can be used to "explain" the returns on any asset, but it tells us nothing about the economic sources of risk. To do that we need an economically meaningful stochastic discount factor, M_{t+1}, such that

$$p_t = \frac{\mathrm{Cov}_t(M_{t+1},\ \delta_{t+1})}{E_t M_{t+1}}.$$

This is much more challenging and has been an elusive goal in the literature. For example, Burnside et al. (2006, 2008) build stochastic discount factors from conventional measures of risk such as consumption growth, stock returns, and so forth, and find that these do not explain the real excess returns of the carry trade. The basis of their argument is straightforward. If R_t^e is the real excess return of some asset, standard asset-pricing theory implies the existence of a stochastic discount factor, m_t, such that

$$E(R_t^e m_t) = 0. \tag{10}$$

If the stochastic discount factor, m_t, is linear in a vector of risk factors, f_t, we can write $m_t = 1 - (f_t - \mu)'b$, where $\mu = E(f_t)$. With this definition of m_t, (10) implies that

$$E(R_t^e) = \mathrm{Cov}(R_t^e, f_t)b. \tag{11}$$

Equation (11) states that if an asset's expected excess return is nonzero, the asset's return must covary with f_t. Burnside et al. (2008) show that the excess return of the CT strategy is positive and significantly different from zero yet is statistically uncorrelated with every risk factor and vector of risk factors in their data set. The same is true for carry trade portfolios sorted on the basis of the size of the absolute value of the forward premium. Without covariance, a risk-based story cannot work.[7]

III. Skewness of Carry Trade Payoffs

The failure of conventional risk models has led to a wide variety of alternative explanations of the returns to the carry trade or, equivalently, the UIP puzzle. Some stories center on the properties of the higher-ordered moments of the distributions of carry trade payoffs.

Exchange rate speculation is often viewed as being especially risky in that the returns to common trading strategies are highly skewed and have fat-tailed distributions. Investors might limit their positions in foreign exchange because of this, and this might explain what look like unexploited profit opportunities.

While it is true that the payoffs to carry trades carried out for individual pairs of currencies are highly variable and skewed, the view that exchange rates display particularly severe skewness and kurtosis is far from fair. As Burnside et al. (2008) show, the excess returns to the CT strategy from 1976 through 2007 are skewed (–0.66) and kurtotic (6.73), but the degree of skewness is not statistically significant.

IV. Peso Problems

One argument in defense of skewness as an explanation of exchange rate puzzles is that there is a peso problem. Originally, the "peso problem" referred to the possibility that market participants put positive probability on rare switches in monetary policy that are infrequently observed.[8] In particular, the Mexican peso traded at a forward discount in the early 1970s despite being pegged to the dollar, presumably because market participants feared a policy-driven devaluation of the peso. But this devaluation did not occur until 1976. As a result, over a long period of time the forward discount appeared to be a poor predictor of the change in the value of the peso. Put differently, unobserved skewness might explain the returns to the carry trade even if observed skewness cannot. Recently, a related literature has developed that explores the notion that "rare disasters" (infrequent events leading to big negative payoffs) can explain puzzles in equity markets.[9] Farhi and Gabaix (2008) argue that a calibrated rare disasters model can explain the UIP puzzle.

Do peso problems or rare disasters explain the profitability of the carry trade? Burnside et al. (2008) argue against pure peso problem explanations, because the average payoff of a hedged CT strategy is close to the average payoff of a plain CT strategy. The plausibility of rare disasters, in contrast, rests on the stochastic discount factor being very large in the disaster state.

V. Liquidity Frictions

As I mentioned in my introduction, Brunnermeier et al.'s paper is mainly empirical, but their empirical work is guided by the theoretical model in Brunnermeier and Pedersen (2009) in which liquidity frictions play a key role. One reason this model is interesting is that it offers an explanation of the carry trade puzzle that relies neither on a conventional risk mechanism nor on peso problems. The main mechanism in the model is a liquidity friction that prevents a rapid and immediate response by investors to shocks affecting the value of an exchange rate. In a conventional exchange rate model a sudden increase in a central bank interest rate, for example, would lead to an instantaneous appreciation of the currency, to be followed by an expected depreciation. In a model with a liquidity friction investors respond to the interest rate increase but their response takes time, so the appreciation of the currency is protracted. In the meantime, carry trade in the currency is profitable. Liquidity frictions also play a role in currency crashes. In models with these frictions, small shocks or time variation in investors' risk aversion can lead to shortages of available liquidity and the unwinding of carry positions. The consequence is that exchange rates can "crash" and the returns to the carry trade can turn negative.

I will now elaborate on, and discuss the significance of, the four key empirical findings in Brunnermeier et al.'s paper that I highlighted earlier. The first finding is that the volume of currency speculation, measured by the net futures position of noncommercial traders in foreign currency, rises persistently when interest differentials (forward premia) against the U.S. dollar widen. This result is consistent with the notion that market frictions slow the response of exchange rates to fundamental shocks.[10] So when forward premia widen, speculators initiate carry trades, but these carry trades remain profitable over extended periods of time.

Second, the degree of negative conditional skewness in carry trade returns increases when interest differentials (forward premia) rise. Brunnermeier et al. provide two measures of conditional skewness at month t. One is a purely empirical measure: the within-sample skewness in daily exchange rate changes (normalized by the sign of the forward premium) in month $t+1$. The other is a theoretical or implied measure of skewness backed out from risk reversals.[11] Brunnermeier et al. find that increasing forward premia predict increased skewness using either measure. This suggests that while profit opportunities are created by widening forward premia, downside risk also increases. Unfortunately, the relationship between the forward premium and skewness is statistically stronger with realized skewness than it is with implied skewness. Consequently, it is not completely clear that changes in skewness are anticipated by speculators and reflected in option prices. Finding this link would strengthen the case for the liquidity story.

Third, the volume of speculative trading and the returns to the carry trade go down when there is an increase in the implied volatility of the S&P 500, as measured by the VIX index. Changes in implied volatility measures for options are sometimes interpreted as changes in the risk appetite of investors.[12] Interpreted this way, the association of decreased speculation with higher VIX volatility suggests that as investors lose their general appetite for risk they unwind their carry trade positions. In a model with liquidity frictions this has spillover effects on other speculators, making them more likely to unwind their positions as well. Alternatively, changes in implied volatility are sometimes interpreted as changes in the perceived or actual volatility of the asset underlying the option. Given this interpretation, the link between speculative activity in currency markets and VIX volatility would be less clear.

The fourth fact is that a rise of the spread between LIBOR rates and short-run T-Bills (TED) is correlated with current and 1-week-ahead carry trade losses. This spread is often interpreted as an indicator of liquidity in interbank markets. The negative correlation between this spread and carry payoffs, of course, provides a very suggestive link to the liquidity mechanism in the Brunnermeier and Pedersen (2009) model.

Taken together, the empirical facts provide some support for the story I told in the introduction. One thing that concerns me, however, is that time variation in the conditional skewness of carry trade returns plays a central role. As I mentioned above, the degree of observed unconditional skewness in the data is less than dramatic. Also, evidence in Burnside et al. (2008) regarding the returns to hedged carry trade positions suggests that unobserved perceived skewness may not be that much larger. None of this, of course, rules out the possibility that conditional skewness works, but we are left with several open questions: Does conditional skewness occasionally increase sharply? If so, how much? Also, how much conditional or unconditional skewness is needed in the Brunnermeier and Pedersen (2009) model to explain the returns to the carry trade? Is a lot of skewness needed, or does the model structure magnify the importance of a given degree of skewness?[13] I would love to see quantitative answers to these questions.

The results relating to VIX implied volatility and the TED spread are, to me, the most intriguing. In weekly data, both variables are negatively contemporaneously correlated with carry trade payoffs, while the TED spread has strong negative predictive power for carry trade payoffs a week ahead. Also, both variables have marginal predictive power (beyond that of the forward premium) in regressions that predict carry trade returns at the quarterly frequency. This hints at a quantitative solution to the UIP puzzle or, put differently, a better understanding of the "risk premium" in equation (7). Again, the issue is whether the quantitative significance of VIX and TED adds up to a significant portion of the mean excess return to carry trade.

To sum up, the authors have written a very creative paper with new empirical findings that shed light on a central puzzle in international finance. I think their paper represents a big step forward in our understanding of how foreign exchange markets work, and at the very least they have provided a whole new set of facts that future researchers in international finance will need to grapple with. Moving forward, as I have suggested several times in this comment, the next question is whether the excess return to the carry trade can be fully explained by volatility measures and liquidity spreads.

Endnotes

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1. Financial market frictions are emphasized in an early review article by Froot and Thaler (1990).
2. Rogoff (1980) is an early contribution.
3. Early examples include Fama (1975, 1984), Bilson (1981), and, in a GMM context, Hansen and Hodrick (1980).

4. An early example is Levich (1979). More recently, Villanueva (2007) and Burnside et al. (2006, 2008) have examined the profitability of the carry trade and regression-based trading strategies.

5. Burnside et al. (2008) form the equally weighted portfolio by selling forward $1/(Fn)$ units of each currency for which $F > S$ and buying forward $1/(Fn)$ units of each currency for which $F < S$, where n is the number of currencies with available data at each date. This ensures that currency by currency the amount bet on each currency is equivalent to $1/n$ U.S. dollars.

6. The exercise can be repeated with any forecasting model, but this does not change the mechanical nature of the calculation.

7. Lustig and Verdelhan (2007) argue that conventional consumption-based risk factors explain the returns to portfolios of long positions in foreign currencies sorted on the basis of the interest differential with the United States. Burnside (2007) argues, however, that the correlation between their portfolio returns and the risk factors is very weak, consistent with Burnside et al.'s (2008) findings. Furthermore, the weak correlation between factors and returns implies that the particular models being estimated are weakly identified, making asymptotic inference unreliable. Finally, a common-to-all-assets pricing error is introduced to the model as an additional parameter yet is not included in the pricing error when the model is tested. Lustig, Roussanov, and Verdelhan (2008) also favor a risk-based explanation of the returns to the carry trade. They argue that two carry trade portfolios explain the cross-sectional distribution of the expected returns to sorted carry trade portfolios. While potentially interesting, this result does not explain why the two core portfolios themselves have positive expected returns.

8. Early treatments of the peso problem are Rogoff (1980) and Krasker (1980). Lewis (1995) provides a useful review.

9. An early example is Rietz (1988), who argues that the equity risk premium can be explained as long as aggregate crash risk is taken into account. Recent examples are Barro (2006) and Gabaix (2007).

10. A related, but somewhat different, model is presented by Bachetta and van Wincoop (2007). In their model, infrequent portfolio optimization by investors can rationalize the UIP puzzle.

11. The Black-Scholes option-pricing formula assumes that the log exchange rate follows a Brownian motion, possibly with drift, with constant volatility σ. Given an option price, the "implied volatility" can be backed out from the formula. The theory underlying the formula assumes a symmetric distribution for exchange rate changes around the drift, so in theory implied volatility does not vary with the strike price of the option, but this is not true in practice. Deviations from constant implied volatility such as volatility smiles and smirks are often interpreted as indicators of skewness and kurtosis in the true underlying distribution of exchange rate changes. A risk reversal is the difference in implied volatility between an out-of-the-money put option and a symmetrically out-of-the-money call option and is sometimes interpreted as an indicator of market-perceived skewness.

12. The Black-Scholes option-pricing formula relates the price of the option to the volatility of the price of the underlying asset. Given an option price, the "implied volatility" can be backed out from the formula. In reality, changes in implied volatility could reflect changes in the volatility of the underlying asset price, but they could also reflect other factors, such as changes in the risk aversion of market participants.

13. One mechanism may be that because the returns to the carry trade are on average lower than those on stocks, carry traders may be more highly leveraged than equity investors. Also, the role of liquidity emphasized by Brunnermeier et al. may be more important in the markets where carry trades are executed.

References

Bachetta, Philippe, and Eric van Wincoop. 2007. "Incomplete Information Processing: A Solution to the Forward Discount Puzzle." Unpublished manuscript, University of Virginia.

Barro, Robert. 2006. "Rare Disasters and Asset Markets in the Twentieth Century." *Quarterly Journal of Economics* 121:823–66.

Bilson, John F. O. 1981. “The ‘Speculative Efficiency’ Hypothesis.” *Journal of Business* 54, no. 3 (July): 435–51.

Brunnermeier, Markus K., and Lasse H. Pedersen. 2009. “Market Liquidity and Funding Liquidity.” *Review of Economic Studies*, forthcoming.

Burnside, Craig. 2007. “The Cross-Section of Foreign Currency Risk Premia and Consumption Growth Risk: A Comment.” Working Paper no. 13129, NBER, Cambridge, MA.

Burnside, Craig, Martin Eichenbaum, Isaac Kleshchelski, and Sergio Rebelo. 2006. “The Returns to Currency Speculation.” Working Paper no. 12489, NBER, Cambridge, MA.

———. 2008. “Do Peso Problems Explain the Returns to the Carry Trade?” Working Paper no. 14054, NBER, Cambridge, MA.

Fama, Eugene F. 1975. “Short Term Interest Rates as Predictors of Inflation.” *American Economic Review* 65:269–82.

———. 1984. “Forward and Spot Exchange Rates.” *Journal of Monetary Economics* 14:319–38.

Farhi, Emmanuel, and Xavier Gabaix. 2008. “Rare Disasters and Exchange Rates.” Working Paper no. 13805, NBER, Cambridge, MA.

Froot, Kenneth A., and Richard H. Thaler. 1990. “Anomalies: Foreign Exchange.” *Journal of Economic Perspectives* 4, no. 3:179–92.

Gabaix, Xavier. 2007. “Variable Rare Disasters: An Exactly Solved Framework for Ten Puzzles in Macro-Finance.” Working Paper no. 13724, NBER, Cambridge, MA.

Hansen, Lars Peter, and Robert J. Hodrick. 1980. “Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis.” *Journal of Political Economy* 88, no. 5:829–53.

Krasker, William S. 1980. “The ‘Peso Problem’ in Testing the Efficiency of Forward Exchange Markets.” *Journal of Monetary Economics* 6:269–76.

Levich, Richard M. 1979. “On the Efficiency of Markets for Foreign Exchange.” In *International Economic Policy: Theory and Evidence*, ed. Rudiger Dornbusch and Jacob Frenkel. Baltimore: Johns Hopkins University Press.

Lewis, Karen. 1995. “Puzzles in International Financial Markets.” In *Handbook of International Economics*, vol. 3, ed. Gene M. Grossman and Kenneth Rogoff, 1913–71. Amsterdam: North-Holland.

Lustig, Hanno, Nikolai Roussanov, and Adrien Verdelhan. 2008. “Common Risk Factors in Currency Markets.” Working Paper no. 14082, NBER, Cambridge, MA.

Lustig, Hanno, and Adrien Verdelhan. 2007. “The Cross-Section of Foreign Currency Risk Premia and Consumption Growth Risk.” *American Economic Review* 97:89–117.

Rietz, Thomas A. 1988. “The Equity Risk Premium: A Solution.” *Journal of Monetary Economics* 22:117–31.

Rogoff, Kenneth S. 1980. “Essays on Expectations and Exchange Rate Volatility.” PhD diss., Massachusetts Institute of Technology.

Villanueva, O. Miguel. 2007. “Forecasting Currency Excess Returns: Can the Forward Bias Be Exploited?” *Journal of Financial and Quantitative Analysis* 42 (December): 963–90.