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RESEARCH ARTICLE

The profitability of carry trades

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Abstract The uncovered interest parity (UIP) condition suggests that carry trades whereby investors borrow in the low interest rate currency and invest in the high interest rate currency should not result in excess profits over the long run. In this paper, we test the significance of the conventional empirical failure of UIP condition. Using the four bilateral pound parities we fail to detect significant excess carry trade profits for the yen, euro and swiss franc–pound parities. The only parity for which the carry trade consistently makes excess profits is the dollar–pound parity. This result is somewhat surprising as this is the currency pair with the lowest interest rate differential.

Keywords Carry-trade · Efficient market hypothesis · Profitability tests · Uncovered interest parity

JEL Classification F30 · F31 · F37

1 Introduction

There is a large literature based upon econometric regressions that has decisively rejected the UIP condition, see for example, Hodrick (1987), Froot and Thaler (1990), Engel (1996), Flood and Rose (2002), Baillie and Bollerslev (2000) and Sarno et al. (2006). The failure of UIP to hold empirically has in turn resulted in a large related

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offshoot literature that attempts to explain either theoretically or empirically the adverse econometric test results for UIP. Among the most popular explanations for the poor empirical test results for UIP are the existence of a risk premium, irrational speculation, the peso problem and nonlinearities in the exchange rate, or some mixture of these. Unfortunately none of these can be said to convincingly explain the failure of UIP. For example, the risk premium explanation is accepted by Cavaglia et al. (1994) and Taylor (1989) but rejected by Domowitz and Hakkio (1985), Cumby (1988) and Frankel and Froot (1989), the peso problem explanation is rejected by Lewis (1995), the possibility of nonlinearities in the exchange rate has been explored by Sarno et al. (2006) who show that deviations detected from UIP using linear regression can be misleading.

In this paper, we take the above conventional econometric failure of the UIP as given and do not concern ourselves with whether this failure is a statistical problem or a genuine departure from the theory of UIP. Instead, we explore the implications of deviations from UIP for the profitability of trading in the foreign exchange market. In particular, we investigate the empirical relevance of the failure of UIP for carry trades. While there have been numerous studies that look at the profitability of different filter and technical trading rules such as Sweeney (1986) and Levich and Thomas (1993) it is surprising that there has not been any investigation of the economic significance of the empirical failure of the UIP condition for the profitability of carry trades.

The paper is structured as follows: Sect. 2 looks at the conventional tests of the UIP condition. In Sect. 3 we show that the implied empirical failure of the UIP condition does not automatically mean there are excess returns to be had in holding onto one currency over another; indeed, we show that the returns on holding different currencies over time are remarkably similar as UIP would predict. The econometric failure of UIP suggests excess profits can be made from carry trades. However, we show in Sect. 4 that this is not necessarily the case, indeed we only detect excess profits on carry trades for the dollar–pound parity. The paper concludes with the implications of our results for UIP testing and the possible avenues for future research.

2 Conventional econometric testing of the uncovered interest rate parity condition

For the purposes of this paper we assume that the forward rate corresponds to the rate provided by the arbitrage inherent in the covered interest parity condition (CIP). This has the advantage of eliminating any timing mismatch between interest rates and exchange rates we use in the paper (1). The CIP condition is given by Eq. (1)

$$F_t = \frac{(1 + r_t^*)S_t}{(1 + r_r)} \tag{1}$$

where S_t is the spot exchange rate at time t defined as units of foreign currency per unit of domestic currency (UK pounds), F_t is the forward exchange rate at time t, r_t^* is the foreign interest rate and r_t the domestic (UK) interest rate (2). In this paper we

concentrate on the monthly forward exchange rate which involves using one month interest rates and making adjustments to reflect the CIP arbitrage condition.

According to the efficient market hypothesis, in the presence of rational expectations, risk neutrality, the absence of taxes on capital transfers and perfect capital mobility then forward rates will coincide with expected future spot rates, that is:

$$E[S_{t+1}] = F_t \tag{2}$$

where E$[S_{t+1}]$ is the expected spot exchange rate at time t for time $t+1$. Taking logs of Eq. (1) means that CIP can be approximated by Eq. (3):

$$f_t - s_t = r_t^* - r_t \tag{3}$$

with f_t and s_t the logs of the forward exchange rate and the spot exchange rate at time t, respectively. Also by using a first order Taylor expansion of log S_{t+1} around its expected value we obtain that $E[s_{t+1}] = f_t$, hence, the uncovered interest parity condition states that the interest rate differential is, on average, equal to the expected change in the log of the exchange rate as given by Eq. (4):

$$E[s_{t+1}] - s_t = r_t^* - r_t \tag{4}$$

where E$[s_{t+1}] - s_t$ is the expected rate of depreciation of the currency. With rational expectations then the exchange rate dynamics can be expressed by the formula:

$$s_{t+1} = E[s_{t+1}] + \varepsilon_{t+1} \tag{5}$$

where ε_{t+1} is a random error term with zero mean. Substituting Eq. (4) into Eq. (5) and using the approximation given in (3) we obtain a testable form of UIP given by Eq. (6):

$$s_{t+1} - s_t = (f_t - s_t) + \varepsilon_{t+1}. \tag{6}$$

For regression purposes this means that UIP can be tested by the following regression:

$$\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + \varepsilon_{t+1} \tag{7}$$

with Δs_{t+1} denoting $(s_{t+1} - s_t)$. The hypothesised value of the beta coefficient in such regressions is a figure of unity, a zero intercept and the error term should be white noise.

We test the UIP hypothesis using Eq. (7) for four major currencies against the pound; namely the dollar, euro (3), swiss franc, and yen. The dataset consists of monthly exchange rate and interest rate data covering the period March 1978 until January 2007. Table 1 shows our econometric estimates of Eq. (7).

The results reported in Table 1 are consistent with those of previous studies, such as Boothe and Longworth (1986), Maynard and Phillips (2001) and Froot and Thaler (1990) in showing that uncovered interest rate parity is decisively rejected for all four

Table 1 Estimates equation $\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + \varepsilon_{t+1}$

Currency	A	β	R^2	JB	SC-LM	ARCH
Dollar–pound	−0.005(0.12)	−1.94(0.01)	0.019	87.71(0.00)	0.64(0.53)	14.02(0.00)
Euro–pound	−0.007(0.02)	−1.42(0.02)	0.015	111.43(0.00)	0.95(0.46)	0.76(0.38)
Swfranc–pound	−0.021(0.00)	−4.55(0.00)	0.032	163.40(0.00)	0.55(0.58)	0.23(0.78)
Yen–pound	−0.003(0.14)	−0.87(0.15)	0.006	40.7(0.00)	1.63(0.01)	4.50(0.20)

p-values are in parentheses

parities. The negative beta coefficient usually reported in such regressions implies a rejection of UIP. This combined with the negative alpha coefficient suggests that currencies at a forward discount actually appreciated rather than depreciated as required by UIP. Since a currency at a forward discount is the high interest rate currency the regression results seemingly imply that one can expect the high interest rate currency to appreciate contrary to the UIP hypothesis. The regression estimates seem to imply that the carry trades will be profitable since it pays to borrow in low interest rate currencies which appear to depreciate and instead invest in high interest rate currencies that appear to appreciate.

3 Does a failure of UIP imply market inefficiency?

According to UIP there should be no systematic difference in the returns from holding capital in the domestic currency or the foreign currency. Indeed, econometric rejections of UIP have frequently been taken as evidence indicating that the foreign exchange market is inefficient. Despite the fact that there are numerous profitability studies of the foreign exchange market it is surprising that apart from the Burnside et al. (2006) study there have not been any rigorous investigations of whether the econometric failure of the UIP condition can actually be used to make excess returns. This oversight is important because if excess returns cannot be made then the econometric failure of UIP has no real economic meaning and cannot be taken as evidence of exchange market inefficiency.

Econometric rejections of UIP have almost universally been taken as evidence of the potential to make excess returns from currency speculation which may or may not be due to the existence of risk premia. We now proceed to look at the data set from a simple profitability perspective before looking at it from a slightly more sophisticated carry trade perspective. Crucially, if UIP holds, then the returns on each of the investment strategies that we analyse should not be consistently superior to those derived from other foreign exchange investment strategies or superior to just holding one's capital in pounds over time. While Levich and Thomas (1993) have conducted profitability tests of technical trading rules, there surpringly been little testing of the UIP condition from a profitability perspective. We now outline two basic tests of UIP before we look at two further tests based upon a carry trade perspective.

3.1 Strategy 1: invest in the foreign currency versus domestic returns

Strategy 1 is a simple profitability test of the UIP condition through testing the efficient market hypothesis. Under this strategy an investor is confronted with the possibility of investing at the risk free rate of interest in the UK or alternatively placing all his capital in the foreign currency to earn the foreign interest rate and then at the end of the month converting the capital sum back into pounds at the then prevailing exchange rate. If the foreign exchange market is efficient, the expected excess return on being in the foreign currency should be zero. This is expressed by the following equation:

$$E[R^*_{t+1}] - E[R_{t+1}] = 0 \tag{8}$$

where $E[R^*_{t+1}]$ is the expected return, conditional on information available at time t, in pound units, of holding capital in the foreign currency at the foreign rate of interest, and $E[R_{t+1}]$ is the expected return on holding capital at the UK interest rate. The latter rate of return is the same as the UK interest rate r_t, since the domestic strategy consists of investing in the risk free asset, and is known at the beginning of time t. The pound return on the investment of X pounds in the foreign currency R^*_{t+1}, is defined by:

$$R^*_{t+1} = \frac{S_t}{S_{t+1}}(1 + r^*_t) - 1 \tag{9}$$

Also, noting that $\mathrm{E}[R_{t+1}] = r_t$, Eq. (8) can be expressed as:

$$E[R^*_{t+1}] - r_t = 0. \tag{10}$$

By a first order Taylor expansion of $1/S_{t+1}$ about $\mathrm{E}[S_{t+1}]$ we observe that this condition is equivalent to the following:

$$S_t(1 + r^*_t) = E[S_{t+1}](1 + r_t). \tag{11}$$

When covered interest parity holds, $S_t(1+r^*_t) = F_t(1+r_t)$ and the foreign exchange market would be efficient if $F_t = \mathrm{E}[S_{t+1}]$. To make a testable version of this efficiency condition we propose the following simple econometric test:

$$R^*_{t+1} - R_{t+1} = \alpha + \varepsilon_{t+1}. \tag{12}$$

Market efficiency boils down to seeing if $\alpha = 0$ and the error term is a white noise. Note the regression is balanced if $R^*_{t+1} - R_{t+1}$ and the error term are stationary. If this is the case and the error term is a white noise then Ordinary Least Squares estimators provide consistent and efficient estimates of the parameters. Conversely, if $\alpha \neq 0$ there exists either a risk premium and/or market inefficiency between the currency pair. Our empirical test based on returns reported in Table 2 provides quite supportive results for the null hypothesis contrary to what we have observed from the conventional regression UIP results using an identical data set. In three of the four cases we do

Table 2 Estimated equation $R^*_{t+1} - R_{t+1} = \alpha + \varepsilon_{t+1}$

Currency	α	JB	ARCH
Dollar–pound*	−0.001(0.28)	12.77(0.00)	0.36(0.69)
Euro–pound*	−0.002(0.79)	106.86(0.00)	0.04(0.95)
Swfranc–pound*	−0.003(0.02)	168.00(0.00)	0.19(0.82)
Yen–pound*	−0.002(0.25)	209.07(0.00)	0.10(0.90)

p-values are in parentheses
*GARCH effects at the 5% significance level

not find evidence to reject the efficient market hypothesis. However, the Jarque Bera statistic suggests that we can reject the hypothesis that the residuals are normally distributed. The asterisks denote the presence of conditional heteroscedasticity in the error term at the 5% significance level. We have accounted for these effects by incorporating a GARCH(1,1) process in the modelling of the error term. After filtering for GARCH effects the error term is well behaved and depicts a white noise process. These results we report are supportive of UIP and are somewhat startling given the decisive rejections of UIP and the inference of foreign exchange market inefficiency in all four cases using the conventional regression approach.

3.2 Strategy 2: invest in the currency that yielded the highest return in the previous period versus domestic returns

The highest return or momentum strategy consists of investing in each period in the currency that yielded the highest return (interest and exchange rate movement) in the previous period. The investment rule is as follows, if $R^*_{t-1} - R_{t-1} < 0$ we invest for the current period in the UK market since this yielded the highest return in the previous period. Conversely, if $R^*_{t-1} - R_{t-1} > 0$ then the investor places his capital in the foreign currency for the current period. This rule is equivalent to investing in the UK pound if $S_t > F_{t-1}$ and in the foreign currency otherwise. If the market is efficient this momentum based strategy should not lead to any excess return compared to holding the capital in domestic currency. The appropriate regression test of the strategy is given by Eq. (13) which compares the realized returns of this momentum based strategy against just holding the capital to earn the domestic interest rate.

$$RHR_{t+1} - R_{t+1} = \alpha + \varepsilon_{t+1} \tag{13}$$

where RHR_{t+1} is the actual pound return from being in the previous period's highest return currency.

The results of this regression Eq. (13) are reported in Table 3. Once again the results are very supportive of UIP contrary to the impression created by the econometric regressions reported in Table 1. There is no significant difference to be had between an investment strategy of holding money in a currency that provided the highest return in the previous period than simply holding one's money in pounds, which is precisely what we would expect if UIP was holding.

Table 3 Estimated equation $RHR_{t+1} - R_{t+1} = \alpha + \varepsilon_{t+1}$

Currency	α	JB	ARCH
Dollar–pound*	0.000(0.80)	1570.0(0.00)	0.24 (0.78)
Euro–pound*	−0.001(0.12)	928.0(0.00)	0.10 (0.90)
Swfranc–pound*	−0.001(0.36)	1653.0(0.00)	0.13 (0.87)
Yen–pound*	−0.002(0.71)	1300.0(0.00)	1.16 (0.31)

p-values are in parentheses
*GARCH effects at the 5% significance level

4 Do carry trades generate excess profits?

Although tests 1 and 2 reported in Tables 2 and 3 are generally supportive of foreign exchange market efficiency the econometric results reported in Table 1 nonetheless suggest the possibility of excess returns to be made from carry trades. In a carry trade investors borrow money in the low interest rate currency and place it into a higher interest rate currency in the hope that the high interest rate currency will either appreciate or not depreciate more than the interest rate differential enabling an excess return to be made. Of course, the carry trade will prove unprofitable if the currency with the high interest rate depreciates by an amount greater than the interest rate differential over the relevant time horizon. If we were to take the results reported in Table 1 at their face value then they would suggest that it is best to be in the high interest rate currency and avoid investment in the low interest rate currency. The econometric rejections of UIP results imply that by being in the high interest rate currency an investor will also benefit from an appreciation (given the negative alpha and beta estimates) whilst being in the low interest rate results in an underperformance since one suffers from a depreciation of the currency.

Our high interest-low interest profitability test consists of comparing the pound returns of investing capital in the market with highest nominal interest rate to the pound denominated returns of investing capital in the currency with the lowest nominal interest rate. According to UIP there should be no excess returns from such a strategy. The relevant efficiency condition in this case is:

$$E[RH_{t+1}] - E[RL_{t+1}] = 0 \tag{14}$$

where E$[RH_{t+1}]$ is the expected pound return from being in the high interest rate currency and E$[RL_{t+1}]$ is the expected pound return from being in the low interest rate currency. The economic interpretation of this condition is that an investor does not obtain consistent excess profits by placing his capital in the high interest rate currency. The econometric test of the high interest rate-low interest rate strategy is given by the following equation:

$$RH_{t+1} - RL_{t+1} = \alpha + \varepsilon_{t+1} \tag{15}$$

Table 4 reports the outputs of the estimates of the preceding regression. As this table shows, only for the dollar–pound parity were we able to detect significant excess profits for the carry trade. For three of the four parities the euro, swiss franc and yen

Table 4 Estimated Equation $RH_{t+1} - RL_{t+1} = \alpha + \varepsilon_{t+1}$

Currency	α	JB	ARCH
Dollar–pound*	0.003 (0.04)	17.42 (0.00)	0.40 (0.66)
Euro–pound*	0.002 (0.06)	107 (0.00)	0.04 (0.95)
Swfranc–pound	0.002 (0.16)	532.0 (0.00)	0.09 (0.91)
Yen–pound	0.002 (0.25)	209.07 (0.00)	0.10 (0.90)

p-values are in parentheses
*GARCH effects at the 5% significance level

versus the pound, the alpha coefficient estimates are in fact indistinguishable from zero as one would expect if UIP holds. Our results are quite surprising given the decisive rejection of UIP in Table 1 for an identical data set. The results for the swiss franc, euro and the yen against the pound are particularly noteworthy as these three currencies had, generally speaking, much lower interest rates than the UK over the period under study. The average annualised monthly interest rate on the swiss franc was 3.76 and 3.69% on the yen, 5.45% on the euro, 6.85% on the dollar and 8.96% on the pound. If the carry trade were to generate excess profits as the econometric rejections of UIP suggest, we might have expected borrowing in euros, swiss francs and yen which all have much lower interest rates than the pound to be the most profitable, but we find no evidence for this over the time horizon under study. However, there is a decisive rejection of market efficiency and evidence of excess profits from being in the high interest rate currency in the case of the dollar–pound parity which is the one with the lowest interest rate differential. In other words, the carry trade is seen to work only for the two currencies namely the dollar–pound parity with the lowest interest rate differential. Our results for the other currency pairs indicate that UIP holds and by extension the carry trade fails to generate excess returns over the longer run.

As a further check on the robustness of our results we also looked at a modified version of the carry trade which uses the forward exchange rate for speculative purposes. The forward strategy involves the investor going long with all his capital plus the relevant UK interest rate during the holding period in the currency that is at a forward discount in the market. The idea of this strategy is that if one takes the negative or low positive (less than unity) beta coefficients from conventional regression analyses of UIP, the currency at a forward discount (i.e. the high interest rate currency) is actually likely to appreciate or at least not depreciate as much as the forward discount indicates. If this happens, then the realised exchange rate S_{t+1} will be less than the forward rate F_t and the investor will realise an excess return from the forward purchase of the high interest rate currency compared to just holding his capital at the domestic interest rate. This profitability strategy is the same as the high versus low interest rate strategy when the UK interest rate is the highest but differs when the UK interest rate is below the foreign interest rate. The relevant efficiency condition in this case is:

$$E[RF_{t+1}] - E[R_t] = 0 \tag{16}$$

where $E[RF_{t+1}]$ is the expected return from taking a long position in the currency at a forward discount (4). Table 5 reports the outputs of the estimates of the testing

Table 5 Estimated Equation $RF_{t+1} - R_{t+1} = \alpha + \varepsilon_{t+1}$

Currency	α	JB	ARCH
Dollar–pound*	0.003 (0.04)	17.42 (0.00)	0.40 (0.66)
Euro–pound*	0.002 (0.06)	107 (0.00)	0.05 (0.95)
Swfranc–pound*	0.003 (0.02)	167.0 (0.00)	0.19 (0.82)
Yen–pound	0.002 (0.25)	209.07 (0.00)	0.10 (0.90)

p-values are in parentheses
*GARCH effects at the 5% significance level

regression equation:

$$RF_{t+1} - R_{t+1} = \alpha + \varepsilon_{t+1}. \tag{17}$$

As we can see, we once again accept the efficient market hypothesis for the euro and yen parities but reject it in this case for the dollar–pound and swiss franc–pound parities. The hypothesis of white noise is not rejected although the residuals are not normally distributed.

The results of our two carry trade tests show that despite a decisive rejection of UIP using the conventional regression based approach, the foreign exchange market is nonetheless clearly efficient for two of the four parities studied, namely, the yen–pound and euro–pound parities. Only in the case of the dollar–pound parity is there evidence of consistent excess profits from being in the high interest rate currency. The profitability tests that we have proposed have a key advantage in distinguishing between bilateral parities where the foreign exchange market can be said to be efficient and parities where it may not have been so. Also, our results based upon excess returns seem to have better statistical properties than the conventional UIP regression results.

5 Conclusions

The results of this paper suggest that the conventional econometric breakdown of the UIP condition does not per se imply foreign market inefficiency as it is frequently inferred in the existing literature. Our profitability based tests of the UIP condition suggest that for the euro and yen parities against the pound there were no excess returns to be made from carry trades despite the usual decisive econometric rejections of the UIP condition. The dollar–pound parity, does, however, provide unambiguous evidence of excess returns attributable to the two carry trade strategies that we analyse. Our results suggest that the conventional overwhelming rejections of UIP may well be a statistical rather than economic phenomenon.

We would further argue that econometric rejections of UIP are only indirect tests of the efficient market hypothesis and that excess profitability is a more direct test and economically meaningful test of uncovered interest parity and with it market efficiency. The results we have obtained by using this profitability perspective are far more supportive of UIP than the traditional econometric based literature. The carry trade has been increasingly used in recent years by hedge funds, speculators and banks

despite the fact that UIP theory suggests that it will not produce excess returns in the long run.

Whilst the conventional econometric regressions seemingly suggest there are excess returns to be had from carry trades we were only able to detect excess returns for the two carry trade strategies in the case of dollar–pound parity and for the forward strategy in the case of swiss franc–pound. Our results are very surprising for two reasons: Firstly, the regression results are suggestive that the carry trade would work for all four parities but it actually only worked for at best two. Secondly, the carry trade in practice usually involves looking for currency pairs where there are large differences between the low and high interest rate currency but in this paper it actually only produced excess returns for the currency pair with the lowest interest rate differential, namely the dollar–pound parity.

Notes

1. It should be noted that the forward rates generated using CIP were extremely close to the actual forward rates we had data for.
2. The variables in the above equation needs to be modified according to whether one is looking at the 1, 3, 6 or 12 month time horizon using the appropriate eurocurrency interest rate to that time horizon. The relevant adjustments have been made for the purposes of this paper.
3. We have used the deutchmark-pound parity for data up to 31 December 1998 but thereafter calculated an artificial deutchmark-pound rate by using the fixed exchange rate of the deutchmark against the Euro. We use the term euro–pound rate even though it is in fact the deutchmark-pound rate.
4. When calculating the return from going long on the currency at a forward premium we have allowed investors to take a pound long or short position in the forward market equivalent to their capital at that point plus the relevant UK interest rate gain for the current position. Therefore, we can compare the profit/loss from the forward position easily against the return generated by just holding the capital in the pound to earn the UK interest rate.

Data sources

Eurodollar, eurosterling, euroyen, euroswiss franc and eurodeutschmark/euroeuro interest rates and spot exchange rates from globalfindata.com for the period November 1978 until January 2006. Forward rates were generated from this data using the covered interest parity condition and were found to be extremely close to the set of actual forward rates from the same data source.

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