UNCOVERED INTEREST PARITY: IT WORKS, BUT NOT FOR LONG

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Abstract: If an investor borrows in a low interest currency and invests in a high interest currency, the interest differential accrues in a lumpy manner. The investor will receive the interest differential discretely at the point when a position is rolled over from one day to the next. A position that is not held open overnight receives no interest differential because intradaily interest rates are zero. Using a large dataset of 5 minute exchange rate data, we run uncovered interest parity regressions over different short time intervals taking careful account of the settlement rules in the spot foreign exchange market. We find results that are supportive of the uncovered interest parity hypothesis over very short windows of data that span the time of the discrete interest payment.

1. Introduction

The empirical failure of the simple uncovered interest parity (UIP) relation has been a puzzle to economists working in international finance ever since the work of Fama (1984). The UIP relation postulates that the interest differential between two countries should equal the expected exchange rate change. As such, a regression of exchange rate returns on the interest differential should give an intercept of zero and a slope coefficient of unity. This hypothesis has however been consistently and decisively rejected in the data. A carry trade (in which the investor borrows in the currency with the low interest rate and invests in the currency with a high interest rate) is profitable on average. Most often, the estimated slope coefficient is negative, meaning that the currency with the *higher* interest rate tends to *appreciate*.

Many comprehensive surveys exist (e.g. Froot and Thaler (1990), Lewis (1995) and Engel (1996)) that list and discuss the explanations which economists have devised for the empirical failure of UIP. We do not attempt to review these, other than to note that the explanations include peso problems, learning effects, expectational errors, and the existence of a risk-premium (defined as the *ex-ante* expected profit on the carry trade) that is time-varying and correlated with the interest differential. Economists have not, however, had much success in explicitly modeling this risk premium, although attempts have been made to relate it to the relative cumulative current account balances of the two countries, or to the relative uncertainty in monetary policy in the two countries, among other things.

Meredith and Chinn (1998) and Fujii and Chinn (2001) have considered running the UIP regression over long horizons. Exchange rate returns from t to $t+m$ are regressed on the difference in yields on m-period government bonds at time t. These authors have found that as the horizon m increases, the rejection of the UIP hypothesis becomes less decisive. They interpret this as meaning that any risk premium is relatively stable over very long horizons.

In this paper, we are going in exactly the opposite direction, examining UIP over extremely short horizons. We will exploit the fact that interest is only paid on overnight positions. No interest is paid on intraday positions. Lyons and Rose (1995) is the only extant paper that has exploited this fact in looking at the relationship between interest differentials and exchange rates at high frequency, to the best of our knowledge. Lyons and Rose considered pairs of currencies in the now-defunct European Monetary System (EMS). They found that currencies which were under attack[1] actually appreciated intraday, if the currency was not in fact devalued. Their interpretation of this finding is that investors must be compensated for the risk of devaluation. Overnight, they can be compensated by an interest differential. Intraday, there are however no interest differentials. So, if the currency stays within the band, it must appreciate in order to compensate them for the risk of devaluation that might have occurred, but did not.

We focus instead on the flip-side of the argument of Lyons and Rose (1995). Instead of

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[1] Concretely, Lyons and Rose (1995) considered the French franc-mark and lira-mark bilateral exchange rates, and defined the franc or lira as being under attack on those days on which the interest differential was in the top decile.

looking at high frequency exchange rate movements over the intraday period when no interest is paid, we instead consider the overnight period when interest does accrue. Interest is paid on positions that are open at a particular point in time (17:00 New York time). If trading is liquid around this time, we should expect to see a jump in the exchange rate to offset the interest differential at this instant. Otherwise, an arbitrage opportunity exists as the investor can gain the interest differential while being exposed to exchange rate risk for an arbitrarily short period of time. This is entirely analogous to the discrete jump in a stock price when it goes ex-dividend. We therefore argue that an intraday UIP regression over a short period that spans 17:00 New York time may have the full interest differential, but a negligible risk premium. We test empirically whether or not this is the case, and find remarkably consistent affirmative results, using 15 years of high frequency exchange rate data on dollar bilateral exchange rates relative to the yen, mark/euro, Swiss franc, and pound. One contribution of our paper relative to that of Lyons and Rose is that we run conventional UIP regressions (regressions of the exchange rate return on the interest differential) over windows of time that bracket the discrete payment of interest, instead of looking at exchange rate movements during the intraday period when no interest is paid. Also, our results are not focussed only on EMS currencies under speculative attack.

The plan for the remainder of this paper is as follows. Section 2 lays out the implications of the discrete timing of interest payments for high frequency UIP regressions. Section 3 contains the empirical work. Section 4 concludes.

2. Implications of the Discrete Timing of Interest Payments

Let $s(t, h)$ denote the log exchange rate (foreign currency per dollar) on day t at time h. Intraday interest rates are zero - only positions that are open overnight attract interest. A position that is open at a certain cutoff time is deemed to be held overnight and so attracts interest. This cutoff time is 17:00 New York time[2]. We adopt the convention that this time is the end of day t and the start of day $t+1$. Liquidity is, however, very thin around this time - positions that are open at this time in practice usually remain open at least until trading gets going in Tokyo.

Settlement in the foreign exchange market is t+2[3]. More precisely, for dollar-mark, dollar-Swiss franc, dollar-yen, sterling-dollar and euro-dollar trades, the market convention is that settlement is on the second day after the day of the trade counting only days that are business days in both the United States and the foreign country[4]. There is moreover an exception that if the middle day is a holiday in the United States but not in the foreign

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[2] The 17:00 cutoff time (21:00 GMT during daylight savings time, 22:00 GMT at other times) is a rigid convention for EBS, the major electronic brokerage system. Any EBS quote flags whether the quote is before or after the cutoff time. In conversations with dealers, we have learned that the 17:00 convention was fairly rigidly followed before the advent of EBS. In any event, our empirical work is not depend crucially on an exact cutoff at 17:00 - what really matters is that trades at 16:30 and 19:00 are for different value dates.

[3] Parties to a trade are in principle free to fix settlement at any time they both agree to, but the two business day settlement lag is a very strong convention, for the currencies that we work with in the empirical part of this paper. Actually, settlement is t+1 for the Canadian dollar, but we do not consider the Canadian dollar in our empirical work.

[4] When we refer to a "holiday" we mean a day on which the national payments system is closed. In the euro area the TARGET payments system was set up in 1999. Only two public holidays are observed in all euro area countries (Christmas Day and New Year's Day) while of course an enormous number of holidays are observed in at least one member state. TARGET adopts a compromise holiday schedule as discussed in Deutsche Bundesbank (2002), and this is used to determine euro settlement dates.

country, then this does not cause settlement do be delayed. For example, if Wednesday is a holiday in Japan then a Tuesday dollar-yen trade will settle on Friday, whereas if Wednesday is a holiday in the United States but not in Japan, then a Tuesday dollar-yen trade will settle on Thursday. See Loopesko (1984), Walmsley (2000) and Stigum (1990) for a discussion of the determination of the settlement date for spot foreign exchange transactions.

Consider the self-financing strategy of going short the foreign currency on day t at time h_1, investing the proceeds in the domestic currency, and unwinding the position the next day at time h_2. The investor will receive the interest differential prevailing between the day of settlement for day t trades and the day of settlement for day $t+1$ trades, which we write as $i_t - i_t^*$ and assume to be known by the investor on day t - we shall discuss in section 3 exactly how to measure this interest differential. So we treat the return from the transaction of going short the foreign currency on day t at time h_1, investing the proceeds in the domestic currency, and unwinding the position the next day at time h_2 as

$$s(t+1,h_2) - s(t,h_1) - (i_t^* - i_t) \tag{1}$$

Define the expected return on this transaction *ex-ante* (i.e. on day t at time h_1) as the risk-premium $RP(t,h_1;t+1,h_2)$. By definition, in the equation

$$s(t+1,h_2) - s(t,h_1) - (i_t^* - i_t) = RP(t,h_1;t+1,h_2) + u_t \tag{2}$$

the error term must be orthogonal to anything in the information set on day t at time h_1, including the interest differential. Thus, in the equation

$$s(t+1,h_2) - s(t,h_1) = \alpha + \beta(i_t^* - i_t) + RP(t,h_1;t+1,h_2) + u_t \tag{3}$$

the intercept coefficient α is zero, and the slope coefficient β is one. As it stands, this equation is nothing more than an accounting identity. The UIP hypothesis however sets the risk premium to zero, requiring that the *ex-ante* expected return on the carry trade should always be zero, and so implies that in the regression

$$s(t+1,h_2) - s(t,h_1) = \alpha + \beta(i_t^* - i_t) + u_t \tag{4}$$

the intercept and slope coefficients should be zero and one, respectively. If we observe daily but not intradaily data - that is, we observe the exchange rate at only a fixed time h each day, then the regression equation simplifies further to

$$s(t+1,h) - s(t,h) = \alpha + \beta(i_t^* - i_t) + u_t \tag{5}$$

a UIP relation for daily data[5].

The hypothesis that the slope coefficient in the UIP regression is equal to one has been tested, and decisively rejected, over different horizons and for many currency pairs and sample periods. The standard interpretation of this result is that some risk premium exists which is time varying, and correlated with the interest differential. In this paper, we make no attempt to explicitly model the risk premium. We do however consider how to exploit

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[5] Here and throughout this paper, and in common with nearly all the UIP literature, we are neglecting a Jensen's inequality effect. This effect is numerically small, and is absorbed in the constant term, leaving the slope coefficient that is the primary object of interest unaffected.

high frequency intradaily data. Let λ denote the time elapsed between time h_1 on day t and time h_2 on day $t+1$. Our central assumption about the risk premium is that it is small over short intervals of time, specifically

$$lim_{\lambda \to 0} RP(t, h_1; t+1, h_2) = 0 \tag{6}$$

Crucially, however, no matter how little time elapses between time h_1 on day t and time h_2 on day $t+1$, the carry trade still involves a fixed interest differential. The combination of the accounting identity in equation (3) and the assumption in equation (6) imply that equation (4) must hold with $\alpha = 0$ and $\beta = 1$, in a sufficiently small window around the time of the discrete interest payment. That is, $\alpha = 0$ and $\beta = 1$ if time h_1 is sufficiently late on day t, and time h_2 is sufficiently early the next day[6]. Put another way, in equation (4), the bias in the least squares estimate of β is $\frac{Cov(RP(t,h_1;t+1,h_2),i_t^* - i_t)}{Var(i_t^* - i_t)}$. But if time h_1 is sufficiently late on day t, and time h_2 is sufficiently early the next day, this bias shrinks to zero under the assumption in equation (6) since the risk premium vanishes, but the interest differential does not.

Intuitively, the idea is to relate exchange rate movements to interest differentials only over those time intervals when interest differentials actually accrue, while ignoring exchange rate movements over other time intervals which cannot be associated with interest differen-

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[6] If we picked any arbitrarily short interval of time *not* spanning the time of the payment of the interest differential, we might also expect the risk premium to shrink to zero, meaning that expected exchange rate change over that period of time would shrink to zero. But over an arbitrarily short interval of time that *does* span the time of the payment of the interest differential, if the risk premium shrinks to zero, the expected exchange rate change is not zero, but rather a jump to offset the interest differential.

tials simply because there are no interest differentials over these other (intradaily) intervals.

Neglecting transactions costs, under the condition in equation (6), it must be true that the slope and intercept coefficients in equation (4) are 0 and 1, respectively, if time h_1 is sufficiently late on day t, and time h_2 is sufficiently early on day $t+1$. Otherwise an arbitrage opportunity exists. In this sense, testing this hypothesis is somewhat akin to a test of covered interest parity. The simple strategy of shorting the low-interest currency at the very end of day t and then unwinding the position at the start of day $t+1$ purely so as to pick up the interest differential is seldom likely to be profitable, because of transactions costs. In the interdealer market for major currency pairs, the bid-ask spread is often of the order of 2 basis points, in times of active trading (e.g. Lyons (1995)). The overnight interest differential is small – often of the order of 1 basis point (though it can be much larger especially when there are multiple days between the settlement day for day t trades and the settlement day for day $t+1$ trades, because of holidays and weekends). Still, the investor deciding whether to conduct a transaction at the very end of day t, or at the start of day $t+1$, should care about the interest differential, and should take this into account in his or her decision. The presence of transactions costs might well prevent us from accepting the UIP hypothesis in a short window around the time of the interest payment, but need not necessarily do so. It is to find out that we will turn to empirical analysis in the next section.

Most papers in the UIP literature have ignored the fact that settlement in the foreign exchange market occurs with a two-day lag, as described above. The issue is of course unimportant for low frequency analysis but is crucial for a high frequency analysis of the sort that we are undertaking in this paper. One paper that does take account of the settlement lag issue is Bekaert and Hodrick (1993). They considered UIP over a 30 day horizon, taking careful account of the settlement lag, but still rejected UIP.

3. Empirical Work

Our spot exchange rate data consist of the exchange value of the Japanese Yen, German Mark/Euro, Swiss Franc and Pound Sterling (relative to the US Dollar) provided by Olsen and Associates every 5 minutes, covering the entire calendar years 1988 to 2002, inclusive. To construct these data, Olsen and Associates record all Reuters quotes, average the bid and the ask, and then linearly interpolate the resulting series to get prices at exactly the required times[7]. We discard weekends, defined to be the time from 23:00 GMT on Friday to 22:55 GMT on Sunday, because there is virtually no foreign exchange trading during this time.

Measurement of the interest differential is tricky, although in practice very short term interest rates are highly correlated with each other. We want to measure the interest differential that applies between the value dates for day t and day $t+1$ trades, but we moreover

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[7] These are based on Reuters indicative quotes, not transaction prices. Danielsson and Payne (2002) compare Reuters indicative quotes and transactions prices, and find that the five-minute returns on the two series are very highly correlated.

want this interest differential to be in the investors information set on day t - otherwise the theory of why the slope coefficient in the UIP regression should be one does not exactly work. Strictly, then, the appropriate interest rates to be using are spot/next interest rates. A spot/next loan agreed to on day t is a loan for one business day, starting in two business days[8]. Using spot/next rates, the investor can fix on day t the interest rate that is to apply between the value dates for day t and day $t+1$ trades, and thus is to apply to the time between opening and closing the overnight position. We obtained spot/next interest rates for Japan, Germany, Switzerland and the United Kingdom, relative to spot/next US interest rates, from the BIS. These are expressed at annualized rates. In our regressions we then divide these annual interest rate differentials by 360, and scale this by the number of days between settlement for day t trades and settlement for day $t+1$ trades, to allow for weekends. In our regressions, for each US-foreign country pair, we simply discard days that are holidays in either the US or the foreign country, and all of the three preceding weekdays (the dates of holidays were obtained from Bloomberg). We do this because foreign exchange trading is unusually light on holidays, and because the spot/next interest differential may not in fact be the correct interest differential between the value dates for day t and day $t+1$ trades if there is a holiday coming up[9].

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[8] In money markets, an overnight loan is a loan from today until the next business day, a tomorrow-next loan is a loan from day t+1 to day t+2, and a spot-next loan is a loan from day t+2 to day t+3, where the interest rates on these loans are all agreed to on day t, and business days are defined as weekdays that are not holidays in the country of the currency in which the loan is denominated.

[9] For example, suppose that Thursday is a holiday in Japan only. On Monday, dollar-yen settlement will

Although we believe that the spot/next interest rates are the appropriate interest rates to use in this paper, we nevertheless also redid all the empirical work in this paper using one-week eurocurrency interest rates on day t (scaled by the number of days between the day t and $t+1$ value dates) instead. These gave very similar results (available from the authors on request), which is not surprising since very short term interest rates are highly correlated with each other.

We divide the sample into days when the interest differential that will accrue on an overnight position is for only one day (*single-day interest differential days*) and days when the interest differential that will accrue is for two or more days (*multi-day interest differential days*). The value dates for Wednesday and Thursday trades are Friday and the following Monday, respectively, so three times the daily interest differential will accrue between Wednesday and Thursday. Because we have cut out holidays, all multi-day interest differential days are Wednesdays. All single-day interest differential days are Mondays, Tuesdays, Thursdays or Fridays. The institutional rules of spot foreign exchange settlement mean that the interest differential is unusually large (in absolute magnitude) on Wednesday nights, though we find it hard to imagine a reason why the risk premia would by unusually important on Wednesday nights. This is the reason why we split out Wednesdays from the rest

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be on Wednesday. On Tuesday dollar-yen settlement will be on Friday. So the interest differential that we want would be from Wednesday to Friday. A yen-denominated spot/next loan agreed to on Monday will consist of a loan from Wednesday to Friday, but a dollar-denominated spot/next loan agreed to on Monday will instead consist of a loan from Wednesday to Thursday.

of the week.

We first ran the ordinary UIP regression with daily data, equation (5), regressing the exchange rate returns from day t to day $t+1$ on the overnight interest rate differential for each currency pair for single-day interest differential days. The exchange rate we took for each day is as of 16:30 New York time. Here and throughout this paper we use heteroskedasticity-robust White standard errors[10]. The results are reported in Table 1. For all currencies the estimated slope coefficient is negative, and is significantly different from one for all currencies except the pound. This rejection of UIP is similar to that found in the literature, in lower frequency regressions.

We next turned to running the proposed regression, as in equation (4), over a window from time h_1 to time h_2, for single-day interest differential days. In theory, as discussed in section 2, we would like to select these times so as to construct the smallest possible window around 17:00 New York time. In practice, however, we also want the markets to be liquid at these times. Also, we want to select the times h_1 and h_2 so that the data we use (based on linearly interpolated Reuters quotes) can be thought of as referring to prices *before* and *after* the rollover time as unambiguously as possible. We therefore set h_1 to 16:30 New York time (late afternoon trading in New York), and h_2 to 21:00 New York time (morning trading in

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[10] The standard errors are not autocorrelation-robust, because the holding periods for the carry trade are non-overlapping (except when we consider 7-day and 30-day horizon regressions below, when we use Newey-West heteroskedasticity and autocorrelation robust standard errors).

Tokyo[11]). The results, reported in Table 2, are very different from those in the ordinary UIP regression. In all cases except the yen, the slope coefficient is estimated to be positive and is not significantly different from one. Even for the yen, the estimated coefficient is higher than in the ordinary UIP regression with daily data. This is quite consistent with the idea of the risk premium being small in short windows around the time of the discrete interest payment, as discussed in the previous section. But it is not consistent with the general failure of UIP being due to simple expectational errors. Nor is it consistent with the usual rejection of the UIP hypothesis being an artifact of difficulties in statistical inference (as discussed by Baillie and Bollerslev (2000), among others).

Importantly, the regression is also much more precisely estimated over the period from 16:30 to 21:00. The reason why is simple. Over this period, the variance in the regressor (the interest differential) is the same as in the daily regression. The variance in the error term is, however, much lower. The signal-to-noise ratio is thereby more favorable to precise inference using the judiciously chosen intradaily interval that spans the actual interest payment. The error term u_t, like the risk premium, is of small order over this short period of time, but the interest differential is just the same as in an entire 24 hour period.

The slope coefficients in equation (4) setting h_1 to 16:30 New York time, and using various values of h_2 from 19:00 to 16:30 the next day (New York time) are plotted in Figure

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[11] Tokyo time is 13 hours ahead of New York in summer, and 14 hours in winter. So, 21:00 New York time is 10:00 Tokyo time in summer, or 11:00 Tokyo time in winter (Japan does not have daylight savings time).

1. A distinctive pattern can be seen in these plots, whereby the later h_2 is in the day, the lower the coefficient estimate is. Setting h_2 to 16:30 just gives a standard daily-frequency UIP regression. The pattern is especially dramatic for the mark/euro and the Swiss franc, but can also be observed for the pound and to a lesser extent for the yen. This figure shows the central finding in the paper graphically - on average, currencies do indeed move in the direction predicted by UIP in short windows around the time of the discrete interest payment, but then move back the other way, and the latter effect dominates at the daily frequency.

We repeated this analysis for the multi-day interest differential days. The daily UIP regressions, and UIP regressions over the window from 16:30 to 21:00, on multi-day interest differential days are reported in Tables 3 and 4 respectively. The slope coefficients setting h_1 to 16:30 New York time, and using various values of h_2 from 19:00 to 16:30 the next day (New York time) for multi-day interest differential days are plotted in Figure 2. For all four currencies, the null hypothesis that the slope coefficient is one is not rejected using either the 16:30 to 21:00 window or the daily window, though the standard errors are much larger in the latter case. Of course 24 hours is still a very short horizon for running a UIP regression.

These results are again consistent with the idea that UIP is most likely to work over short windows of time when the interest differential is unusually large: the variance of the interest differential on these days is so great that UIP is not rejected even at the daily frequency. Importantly, the reason why the interest differential is unusually large (in absolute magnitude) on multi-day interest differential days is purely because of the institutional fact that the value date jumps 3 days between Wednesdays and Thursdays, giving a multi-day interest differential, but we cannot imagine a reason to expect unusually large risk premia on Wednesday nights.

Note that the standard errors for the multi-day interest differential days (Figure 2) are smaller than for the single-day interest differential days (Figure 1), even though the sample size for the single-day interest differential days is much larger. This is simply because the variance of the regressor is so much bigger on the multi-day interest differential days.

3.1 *UIP and the Direction of the Exchange Rate Change*

As a simple robustness check, and to guard against results being driven by outliers, we calculated the proportion of times that the exchange rate change had the correct sign as predicted by UIP, both for single day and multi-day interest differentials, over the period from 16:30 New York time to time h_2 the next day, setting h_2 between 19:00 and 16:30 the next day. Where the foreign interest rate is greater than the US interest rate, UIP would call for the dollar to appreciate, and vice-versa. The percentage of days on which this prediction is in fact correct is plotted against h_2 in Figures 3 and 4, for single-day and multi-day interest differential days, respectively. Confidence intervals are included, which were constructed using the standard formula for the variance of a binomial distribution.

For the Swiss franc, mark/euro and yen, using data at the daily frequency (16:30-16:30) on single-day interest differential days (Figure 3), the estimated proportion of times that UIP predicts the correct sign is less than half. In other words UIP gets the sign wrong more often than it gets it right. However, over the short window from 16:30 to 21:00, UIP gets the sign right more than half the time for all currencies except the yen, and significantly more than half the time for the mark/euro and pound.

On multi-day interest differential days (Figure 4), the proportion of times that UIP calls the sign of the exchange rate movement correctly is greater than 0.5 over the 16:30 to 21:00 window, and this proportion is significantly greater than 0.5 at the 10% level or better for all four currencies. At the daily frequency, on these multi-day interest differential days, UIP predicts the correct sign of the exchange rate movement more than half the time for the Swiss franc and yen, but not for the mark/euro or pound and this proportion is not significantly different from 0.5 for any of the currencies.

Although UIP predicts the exchange rate movement significantly better than a coin toss over high frequency intervals where the interest differential is large, the exchange rate movement does still often go the wrong way even over these intervals. This just confirms that exchange rates are very noisy. We are able to do reasonably precise inference only because we have a sample spanning 15 years.

3.2 *Conventional UIP Regressions over this Period*

Flood and Rose (2002) found that the empirical evidence against UIP was a little less overwhelming in the 1990s than in earlier periods. This leads us to ask if our high-frequency results, which are unusually favorable to UIP, are in fact just the result of the sample period we consider.

To investigate this, we ran the conventional UIP regression at the weekly and monthly frequencies. That is, we regressed the 7-day and 30-day exchange rate changes on the interest differentials from the one-week eurocurrency market (as above) and the one-month British Bankers Association interest rates. We obtained the exchange rate data from the 16:30 New York Time exchange rates in the Olsen data, and ran the regressions over the same sample period (1987-2002). The results are reported in Table 5.

The slope coefficient in the UIP regression at both weekly and monthly frequencies is negative and significantly different from one (at the 10% level at least) for all currencies except the pound in this sample. These results are quite typical of the rejections of UIP in the literature. There is nothing unusual about our sample period. The regular UIP regression simply gives quite different results from a regression over a short window of data where the interest differential is unusually large relative to the length of the window because of the settlement rules in the spot foreign exchange market. We make no claim to have "solved" the UIP puzzle - only to have found that UIP appears to work much better over these particular high frequency intervals where the interest differential swamps the risk premium.

4. Conclusion

No interest is paid on intradaily positions. Rather, interest is paid discretely, at the point when a position is rolled over from one day to the next. The number of days interest that accrues depends on how many days the value date moves when a position is rolled over.

The common rollover time is determined by market convention. This practice has potential implications for high-frequency exchange rate movements that we exploit in this paper.

The basic idea in this paper is to relate exchange rate movements to interest differentials only over the time intervals where these interest differentials actually accrue, without being contaminated by exchange rate movements over other time intervals which cannot be associated with interest differentials simply because there are no interest differentials over these other intradaily intervals.

Uncovered interest parity is both central to theoretical models, and an enormous empirical failure. Using a large dataset of high frequency exchange rate data, covering mark/euro, yen, pound and Swiss franc exchange rates vis-a-vis the US dollar, we run uncovered interest parity regressions over different time intervals. Over short windows of high frequency data that span the time of the discrete interest payment, the slope coefficient in the UIP regression is close to one, and precisely estimated. Our results are supportive of UIP when run over the shortest windows, and over windows where settlement conventions lead to unusually large interest differentials. Nevertheless, we reject UIP for three of the four currencies we consider when the regression is run over a daily horizon, omitting those days when settlement conventions cause exceptionally large interest differentials to accrue. We also reject UIP for these same three currencies when we run the UIP regression over one-week and one-month horizons.

The usual rejection of UIP can be ascribed to the existence of a risk premium. The size of this risk premium may, however, shrink to zero over sufficiently small intervals of time. In contrast, because of the market practice of discrete interest payments, the size of the interest differential remains fixed over any interval that covers the time of the discrete interest payment, no matter how short the interval. Over the shortest windows with the largest interest differentials, the interest differential swamps the risk premium. An interpretation of this sort says nothing about the nature of the risk premium, and it remains a puzzle that it is sufficiently large and time-varying as to lead to the rejection of UIP in conventional UIP regressions. But it does argue against the idea that the usual rejection of uncovered interest parity represents an arbitrage opportunity resulting from simple expectational errors.

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Table 1: UIP Regressions for Daily Data on U.S.-foreign bilateral exchange rate
Single-Day Interest Differential Days
Coefficient Estimates (Standard Errors in Parentheses)

Currency	Intercept	Slope
Swiss Franc	-0.007	-4.86
	(0.018)	(2.03)
Mark/Euro	0.017	-3.45
	(0.014)	(1.97)
Pound	0.028	-1.07
	(0.016)	(2.21)
Yen	-0.009	-3.46
	(0.021)	(2.16)

Notes: This table reports the results of the UIP regression with daily data, measured at 16:30 New York time each day, i.e. the regression in equation (5) with h set to 16:30 New York Time. White standard errors are reported.

Table 2: UIP Regressions from 16:30 to 21:00 New York Time
Single-Day Interest Differential Days
Coefficient Estimates (Standard Errors in Parentheses)

Currency	Intercept	Slope
Swiss Franc	0.002	0.79
	(0.006)	(0.69)
Mark/Euro	0.007	1.02
	(0.005)	(0.73)
Pound	0.013	1.44
	(0.004)	(0.72)
Yen	0.008	-1.00
	(0.008)	(0.84)

Notes: This table reports the results of the UIP regression with intradaily data, from 16:30 to 21:00 New York time each day, i.e. the regression in equation (4) with h_1 and h_2 set to 16:30 and 21:00 New York Time, respectively. White standard errors are reported.

Table 3: UIP Regressions for Daily Data on U.S.-foreign bilateral exchange rate
Multi-Day Interest Differential Days
Coefficient Estimates (Standard Errors in Parentheses)

Currency	Intercept	Slope
Swiss Franc	-0.036	1.58
	(0.040)	(1.50)
Mark/Euro	-0.037	2.60
	(0.030)	(1.33)
Pound	-0.088	2.70
	(0.033)	(1.40)
Yen	-0.037	1.26
	(0.046)	(1.51)

Notes: As for Table 1.

Table 4: UIP Regressions from 16:30 to 21:00 New York Time
Multi-Day Interest Differential Days
Coefficient Estimates (Standard Errors in Parentheses)

Currency	Intercept	Slope
Swiss Franc	0.001	0.87
	(0.008)	(0.31)
Mark/Euro	0.000	1.02
	(0.007)	(0.29)
Pound	0.001	0.94
	(0.007)	(0.36)
Yen	-0.016	0.59
	(0.013)	(0.46)

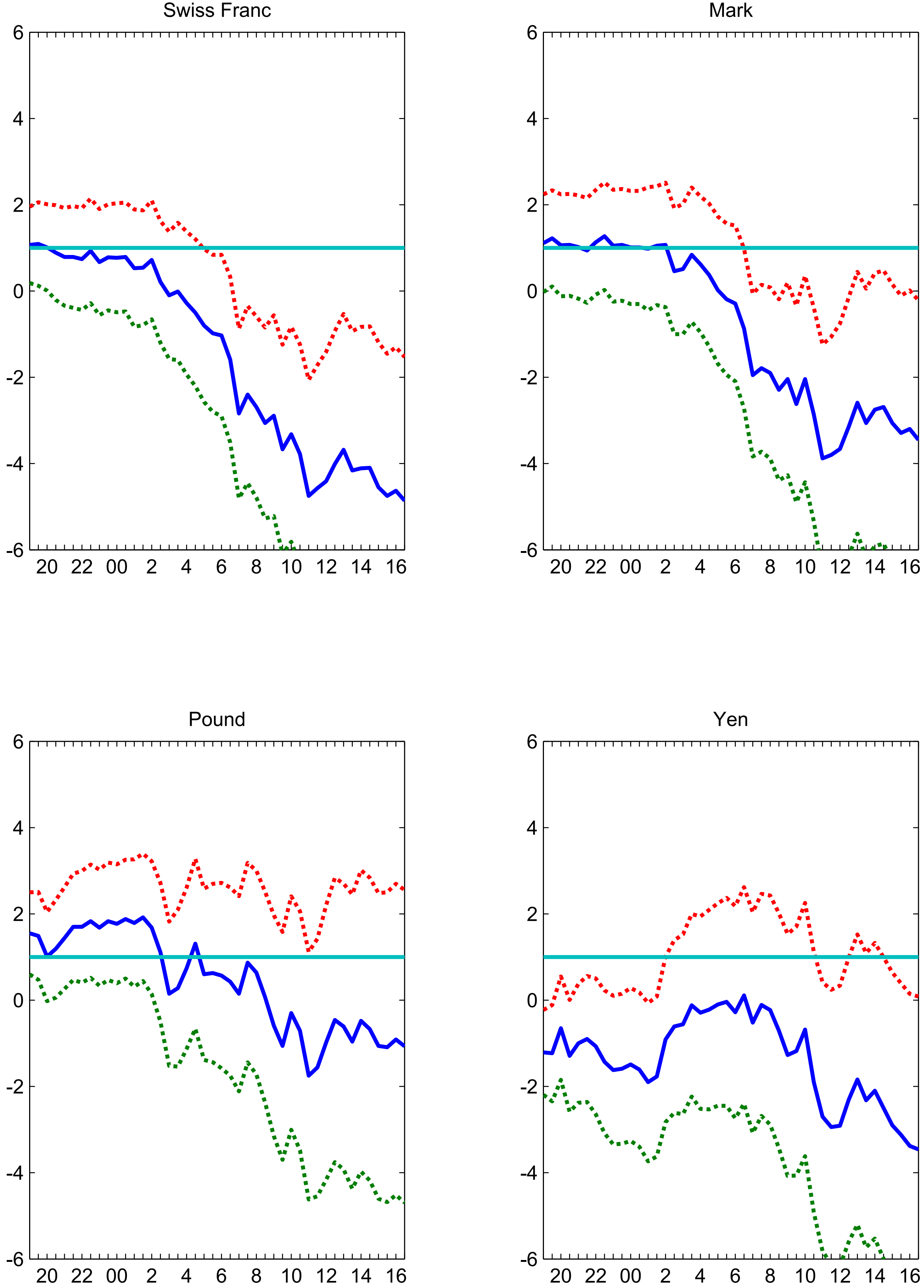
Notes: As for Table 2.

Table 5: Conventional UIP Regressions at Weekly/Monthly Frequency
Slope Coefficient Estimates (Newey-West Standard Errors in Parentheses)

Currency	Intercept	Slope
Swiss Franc	-1.94	-1.53
	(1.03)	(1.25)
Mark/Euro	-1.03	-0.85
	(1.01)	(1.10)
Pound	0.42	0.33
	(1.33)	(1.53)
Yen	-1.96	-2.29
	(0.99)	(1.13)

Notes: This table reports the results of the conventional UIP regression with daily data, measured at 16:30 New York time each day, over horizons of one-week and one-month. That is, the exchange rate change from day t to 7/30 calendar days later is regressed on the one-week/one-month interest differential on day t. The regression is run over all weekdays such that neither day t nor the day at the end of the one-week/one-month horizon is a holiday in either country. The annualized interest rate differential is divided by 360/7 and 12 to get weekly and monthly differentials, respectively.

Fig. 1: Estimate of β in Equation 4, with 90% Confidence Interval, from 16:30 to time h_2, plotted against h_2
Estimated over Single-Day Interest Differential Days



Swiss Franc

Mark

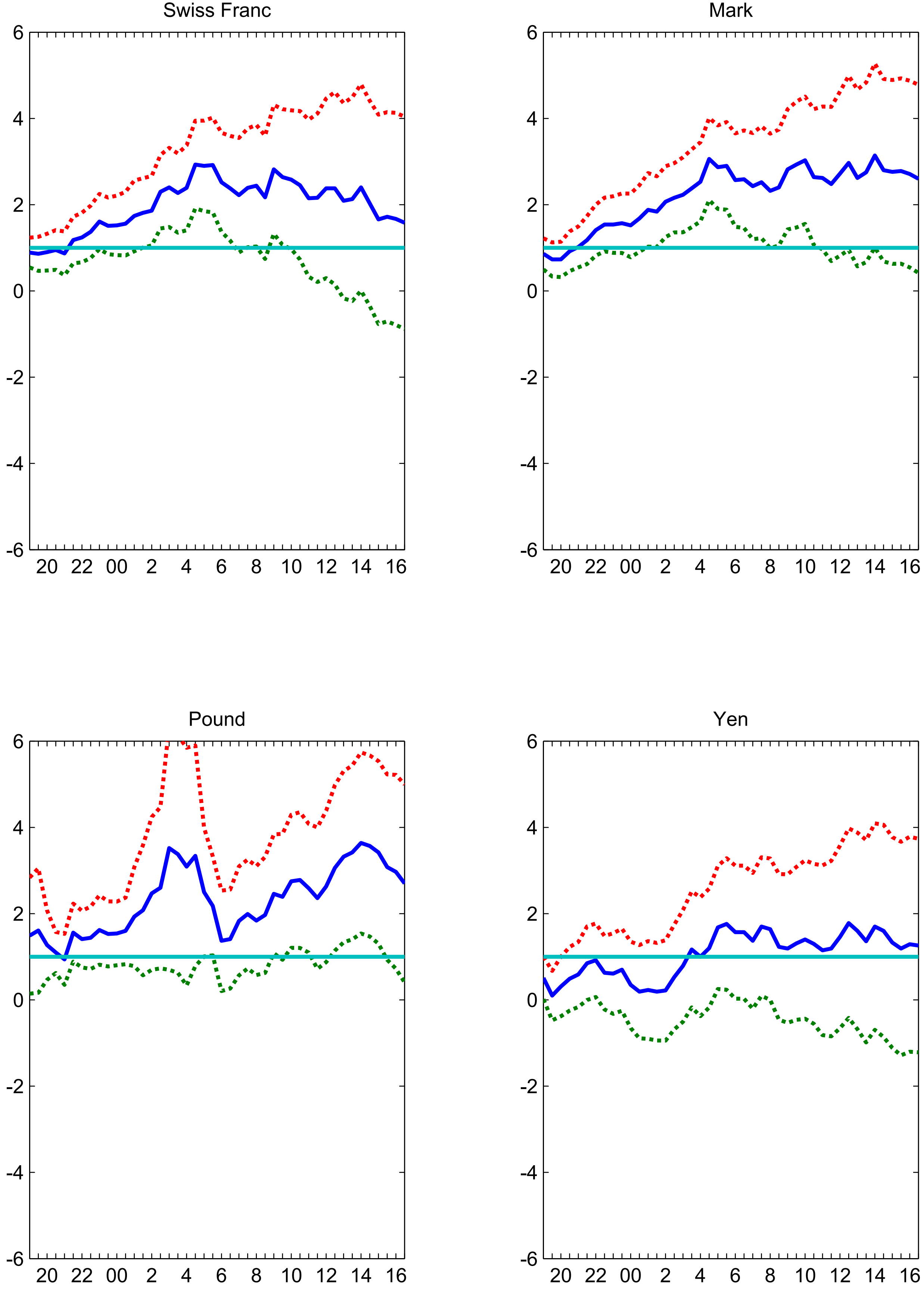
Pound

Yen

Notes: Time shown is New York Time

Fig. 2: Estimate of β in Equation 4, with 90% Confidence Interval, from 16:30 to time h_2, plotted against h_2

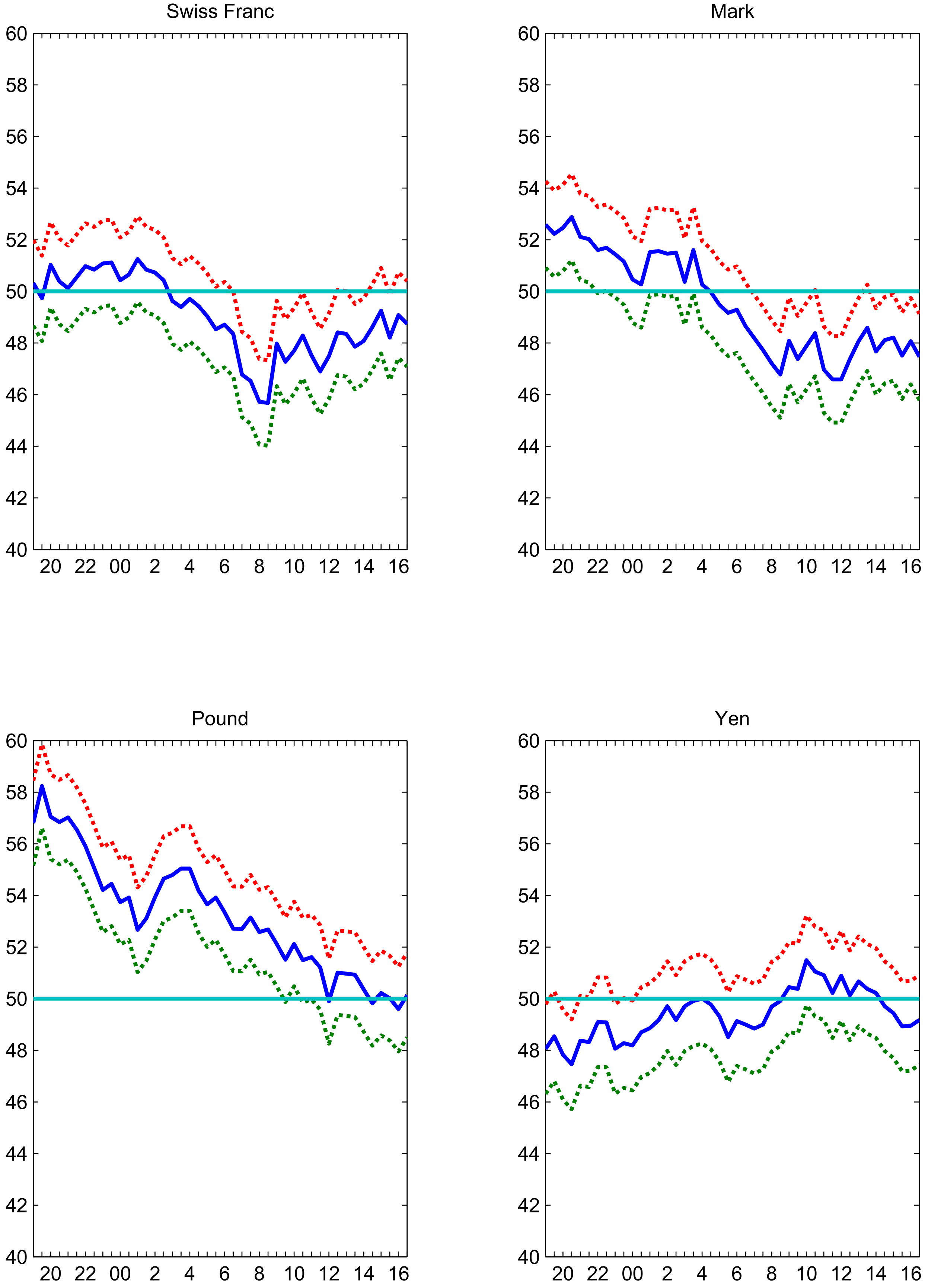
Estimated over Multi-Day Interest Differential Days



Notes: Time shown is New York Time

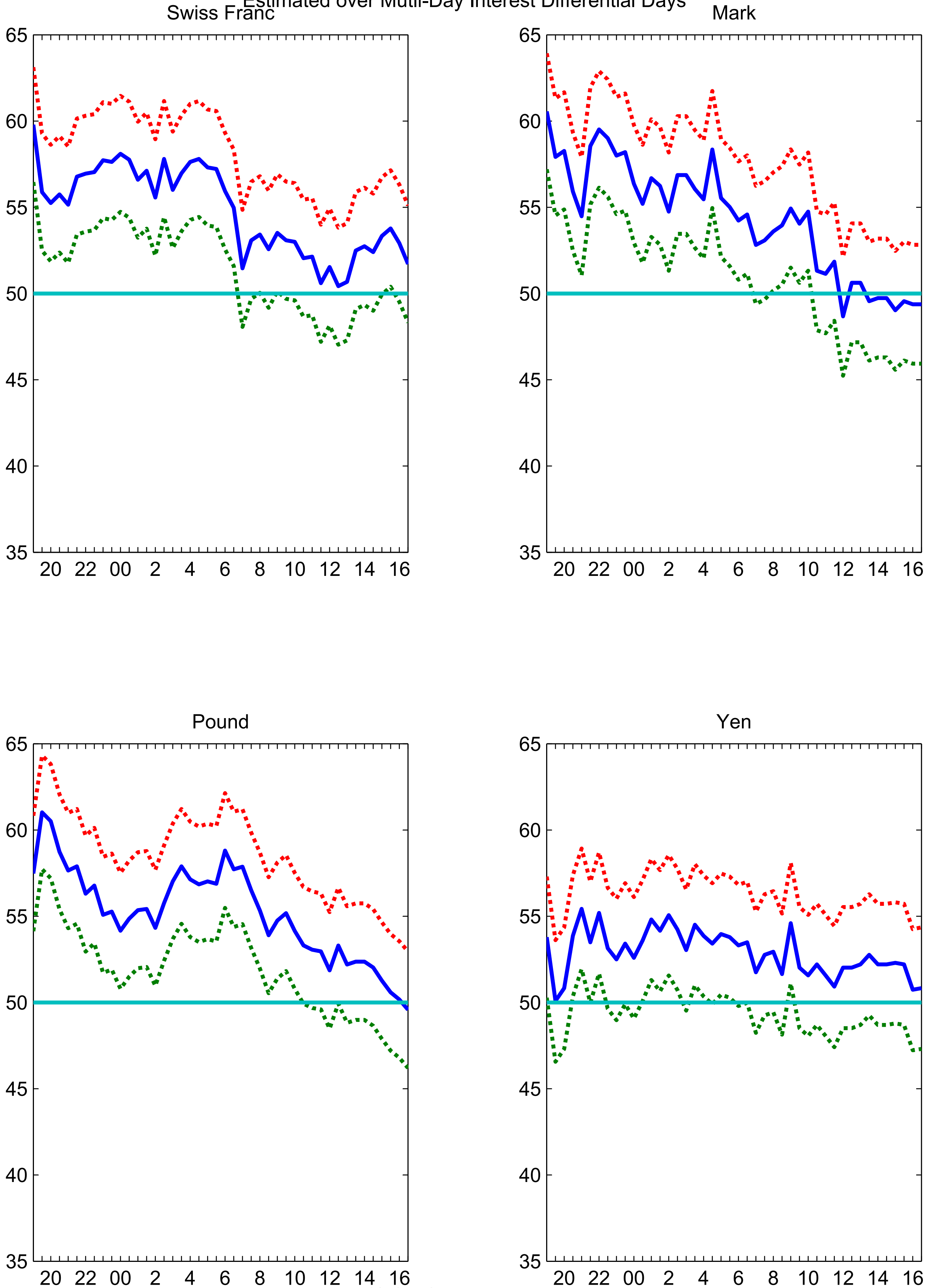
Fig. 3: Percentage of Days UIP Predicts Correct Sign of Exchange Rates, from 16:30 to time h_2, plotted against h_2

Estimated over Single-Day Interest Differential Days



Notes: Time shown is New York Time. 90% Confidence Intervals Also Included

Fig. 4: Percentage of Days UIP Predicts Correct Sign of Exchange Rates, from 16:30 to time h_2, plotted against h_2
Estimated over Mutli-Day Interest Differential Days



Notes: Time shown is New York Time. 90% Confidence Intervals Also Included