Uncovered Interest Rate Parity over the Past Two Centuries*

James R. Lothian† and Liuren Wu‡

Graduate School of Business, Fordham University

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†113 West 60th Street, New York, NY 10023; tel: (212) 636-6147; fax: (212) 765-5573; jrmlothian@aol.com.

‡113 West 60th Street, New York, NY 10023; tel: (212) 636-6117; fax: (212) 765-5573; wu@fordham.edu.

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ABSTRACT

Uncovered interest rate parity (UIP) is one of three key theoretical relations used in analytical work in both international finance and international monetary economics. The problem, however, is that UIP does not seem to hold up well empirically. In this paper, we argue that the failures of UIP that have been so widely documented are a coincidence of two empirical artifacts: (1) the unique sample period of the 1980s and (2) the noise induced by small UIP deviations. We control for these empirical artifacts by constructing an ultra long time series that spans two centuries and by running regressions conditional on large deviations from UIP. We find that traditional regressions yield positive slope estimates over the whole sample period and become negative only when the sample is dominated by the period of 1980s. We argue that the negative estimates during this sample period are mainly the result of a failure of expectations to adjust quickly to the regime changes in monetary policy that took place in both the United Kingdom and the United States. We also find that large interest rate differentials have significantly stronger forecasting powers for currency movements than small interest rate differentials. Finally, a historical account of expected and realized regime changes further illustrates how the expectation hypothesis holds over the very long haul but can be deviated from for a long period of time due to slow adjustment of expectations to actual regime changes or to anticipations for extended periods of regime changes or other big events that never materialize.

JEL CLASSIFICATION CODES: G12, F31.

KEY WORDS: Uncovered interest rate parity, expectation hypothesis, regime changes, small sample problem, Peso problem, extreme sampling.

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I. Introduction

Uncovered interest rate parity (UIP) is one of three key international financial relations that are used repeatedly in the fields of international finance and open-economy macroeconomics in both model construction and other analytical work. The other two, purchasing power parity (PPP) and real interest rate equality, which a decade ago appeared to be of questionable empirical applicability, have now been al least somewhat rehabilitated. Uncovered interest rate parity, however, has not been nearly so fortunate.

Indeed, one of the most puzzling feature of exchange-rate behavior since the advent of floating exchange rates in the early 1970s is the tendency for countries with high interest rates to see their currencies appreciate rather than depreciate as UIP would suggest. This UIP puzzle, known in its other guise as "the forward premium puzzle," is now so well documented that it has taken on the aura of a stylized fact and as a result has spawned a second generation of papers attempting to account for its existence. See, for instance, Bakshi and Naka (1997), Bekaert (1995), Bekaert, Wei, and Xing (2003), Canova and Marrinan (1995), Engel (1996), Flood and Rose (1996), Hodrick (1987), Phillips and McFarland (1997), and Wu and Zhang (1997).

Most of the empirical investigation uses the U.S. dollar as the numeraire currency and focuses on the sample period of the late 1970s and the 1980s, a period dominated by the persistent appreciation of the dollar. Thus, we conjecture that the negative results are in part driven by the unique features of this sample period. We further conjecture that while the market tolerates small deviations from UIP for a relatively long period of time due to market frictions such as transaction costs, UIP — like PPP — will hold much better over the long run and reversions to the parity condition will become more obvious and hence stronger when the deviations are large.

We test these hypotheses with a careful selection of both data and methodology. First, we construct an ultra-long time series that spans two centuries so that our tests will be free from any local features of a short sample period. Equipped with these long data series, we then go on to perform the tests using rolling windows so that we can see how the test results are affected by the choice of sample periods. Second, we choose two pairs of currencies: the French franc versus the pound sterling and the U.S. dollar versus sterling. Since the first pair does not involve the U.S. dollar, domino effects from the United States will be absent. By comparing the two pairs of currencies, we can therefore get a better understanding of how factors specific to the United States may be affecting the test results and of the ways in which those factors have operated. Third, to test the hypothesis that small deviations from UIP are tolerated while large deviations are likely to be followed by reversions to parity, we apply the principle of extreme sampling and run regressions conditional on large and small UIP deviations to detect differences in the regression slopes. We investigate these phenomena further using non-linear estimation techniques that allow smooth transitions from small to large deviations.

The results confirm our hypotheses. First, we run traditional linear regressions of depreciation rates on nominal interest rate differentials. UIP implies that the regression slope should be one while traditional evidence often generates negative estimates. Our regressions over the long time series generate results much more in accord with the expectation hypothesis: the regressions slopes are positive for both pairs of countries and the slope estimate is not significantly different from one for the first pair, franc-sterling. Hence, when the time series is long enough and when the U.S. dollar is not one of the currencies, uncovered interest parity cannot be rejected.

Second, our rolling window regressions confirm our conjecture that the negative slope estimates are mainly a special feature of the late 1970s and the 1980s. Indeed, once the start of the sample period switches to the early 1970s, the regression slope estimate becomes negative even for franc-sterling, with no presence of the U.S. dollar. In all three countries, this was a period of substantial inflation, the culmination of an historically unprecedented three-decade period in which inflation trended up continually and reached historic peacetime highs. The first break in the process came in 1979 in the UK following the Thatcher election and the ensuing move to much tighter monetary policies. A similar shift began in the US shortly after Paul Volcker became Federal Reserve Chairman and gained momentum following the 1980 Reagan election. The shift in France came several years later. Nevertheless, in all three countries, the public remained skeptical several years after the actual policy changes. Expected inflation rates remained high several years after the actual inflation rates had decreased significantly.

Therefore, we argue that the negative regression slopes during this sample period are mainly a result of a failure of expectations to adjust over an extended period of time to the regime switch.

Third, when we run regressions conditional on large deviations, the regression slopes for both pairs of currencies are not significantly different from unity, thus confirming our conjecture that while the market may tolerate small deviations from UIP for a relatively long period of time, UIP holds over the long run and the reversions to parity becomes stronger when the initial deviation is large.

Finally, to better understand the persistent departure from UIP during the past two centuries, we decompose the UIP deviation into two components: (1) the deviation from real interest rate equality and (2) the deviation from purchasing power parity. A historical account of the major UIP deviations indicates that during the nineteenth century these deviations are mainly due to deviations from real interest rate equality, but the UIP deviations during the more modern period are mainly driven by deviations from purchasing power parity. Furthermore, no matter whether they are from nominal or real factors, most of the deviations can be attributed to one of the two following problems: (1) a peso problem, where the investors are anticipating a large event that only materializes after the specific sample period and hence can only be captured by an ultra long sample, or (2) a missed expectation problem, e.g, a regime or policy switch that investors fail to realize is happening for an extended period of time. Both problems become severe when the data set only covers a relatively short period. The most efficient way to deal with them lies in the construction of an ultra long sample, which is what we have done this paper.

In an influential paper, Fama (1984) attributes the behavior of forward and spot exchange rates to a time-varying risk premium. Fama shows that a negative slope estimate from the UIP regression implies that the risk premium on a currency must (1) be negatively correlated with its expected rate of depreciation and (2) have greater variance. Modern currency pricing models, e.g., Backus, Foresi, and Telmer (2001) and Leippold and Wu (2003), can accommodate flexible enough risk premium specifications to generate a negative regression slope, but the implied market price of risk often varies too much to seem plausible. Our empirical investigation indicates that it is not the market price of risk that varies wildly over time, but the regression estimates based on short samples that we cannot rely on.

Nevertheless, even with the ultra long sample and with nonlinear regression or extreme sampling techniques, we find that the overall predictive performance of UIP is rather poor, especially over shorter periods and for small interest differentials. Thus, if there is a UIP puzzle, it is not as commonly believed the anomalous negative relationship between the interest differential and the rate of exchange rate depreciation observed in the 1980s, but the fact that there is very often little relationship one way or the other.

In related literature, Baillie and Bollerslev (2000), Bekaert and Hodrick (2001), and Bekaert, Wei, and Xing (2003) show how small sample can bias the regression tests to overwhelmingly reject the expectation hypothesis even when it holds. Bekaert (1995) shows that violations of UIP are also strong for currencies that do not involve the U.S. dollar. Hallwood, MacDonald, and Marsh (2000) and Lewis (1988) argue how the "peso problem" in a short sample can dramatically alter the results on expectation hypothesis regressions.

The remainder of the paper is organized as follows. The next section describes the construction of the long data series. Section III presents the empirical results based on traditional regressions. Section IV considers the extreme sampling and smooth-transition nonlinear regressions. In Section V, we perform a historical analysis over the past two centuries. Section VI concludes.

II. Data Construction

The data set consists of annual observations of dollar-sterling and franc-sterling exchange rates, as well as long-term and short-term interest rates for France, the United Kingdom, and the United States. The dollar-sterling exchange rate data span more than two centuries (209 years) between 1791 and 1999. The franc-sterling exchange rate starts in 1802 with 198 years of data. The interest rate data span just two centuries between 1800 to 1999.

The interest rate and exchange rate data are constructed from several sources. Refer to Appendix A and Lothian and Taylor (1996) for details of the exchange rate series and Lothian (2000) for details of the interest-rate series. The long-term interest rates for all three countries and the short-term series

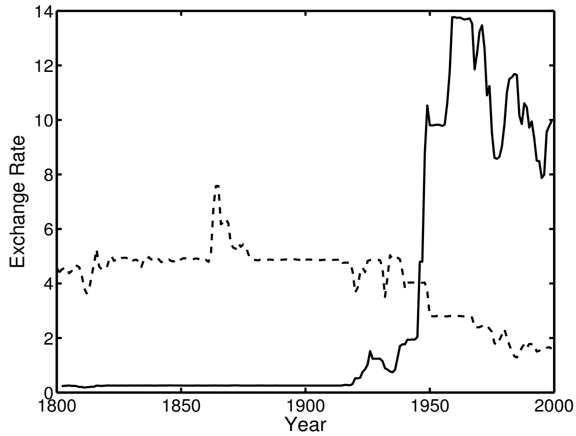

FIG. 1. Exchange rates over the past two centuries. The solid line denotes the time series of the franc-sterling exchange rate, and the dashed line denotes that of dollar-sterling, from 1800 to 1999. Refer to Appendix A for the sources of the exchange rates.

for UK and France all start in 1800. The short-term series for the United States starts in 1831. The short-term interest rate series for France has missing observations from 1914 through 1924.

Figure 1 plots the two exchange rate series for the past two centuries. Prior to 1914, franc-sterling shows almost no movement. This stability is a product of the specie standards to which both countries adhered — in the case of France, a bimetallic standard pre-1875 and gold thereafter, and in the case of the UK, gold from 1821 on. Dollar-sterling over this period is more variable, but this is due chiefly to behavior in two wartime episodes — the lower US than UK inflation during the Napoleonic Wars and the higher US than UK inflation during the Civil War. Over most of the rest of the period, dollar-sterling appears as stable as franc-sterling. As the twentieth century wears on, the picture changes dramatically. During the two World Wars and their aftermaths, the Interwar years, and under the post-Bretton-Wood's float, exchange-rate variability is markedly greater.

Figure 2 plots the time series for both the short-term (solid lines) and the long-term (dashed lines) interest rates. Interest rates for all countries were abnormally high during late 1970s and early 1980s, but came down in the 1990s. Overall, the interest rates, especially the long-term rates, follow similar patterns of movement among the three countries. In general, the short-term rates are more volatile than the long-term rates, but they follow each other closely. The one major exception is the short-term rate for the United States during the nineteenth century. Between 1831 and 1873, short-term US interest rates are much higher and much more volatile than the long-term counterparts. These rates also deviate from interest rates in the other two countries. This is a period in which a number of severe banking panics took place in the United States. The anomalous behavior of the United States short-term rates is probably a result of this fact. The U.S. short-term rates are for commercial paper and hence may include a portion of credit premium, which can become very significant during crisis-laden periods.

Table 1 reports the summary statistics of the exchange rate and long-term interest rate data. Since we have missing data for the France short-term interest rates during the First World War and the years immediately thereafter, we compute the summary statistics excluding those missing data points. Due to the telescoping property of the log exchange rates, we measure the mean depreciation rates through a simple regression of log exchanges rates over time. The standard deviation measures the standard error of this regression slope estimate. Over the past two centuries, sterling appreciates about 2.46 percent per year against the French franc, and depreciates about 0.45 percent per year against the US dollar, but as is obvious from Figure 1, this trend is mainly due to the realignments of both the sterling and the franc relative to the dollar in 1949. While the magnitudes do not exactly match, the differentials in long-term rates are in line with this trend. For example, on average, the French long-term rate is 0.38 percentage point higher than the UK long rate, partially compensating for the currency depreciation of the franc. Correspondingly, the US dollar long-term rate is slightly lower than the UK rate, in line with the slight appreciation of the dollar. The direction of the short-term interest rate differentials, however, is counter to intuition. On average, the appreciating currency also has a higher short-term interest rates. There are at least two potential reasons for this. First, the short-term rate does not forecast currency movements as well as the long-term interest rate. Second, in the U.S. case, due to the data that is used, the short-term interest rate series may also contain a significant portion of credit premium that contaminates any relation between the interest rates and currency movements.

Both currency depreciation rates exhibit moderate mean reversion. The annual first order autocorrelation is 0.21 for the France-Sterling depreciate rate and 0.22 for the US-Sterling depreciate rate. Assuming a first-order autoregressive process, we also compute the half life, the length of time by which the autocorrelation declines by half of its first-order autocorrelation value. The half lives for both depreciation rates are less than six months. In contrast, the interest rates are much more persistent, with annual autocorrelations between 0.78 and 0.91, and half lives ranging from three to thirty years.

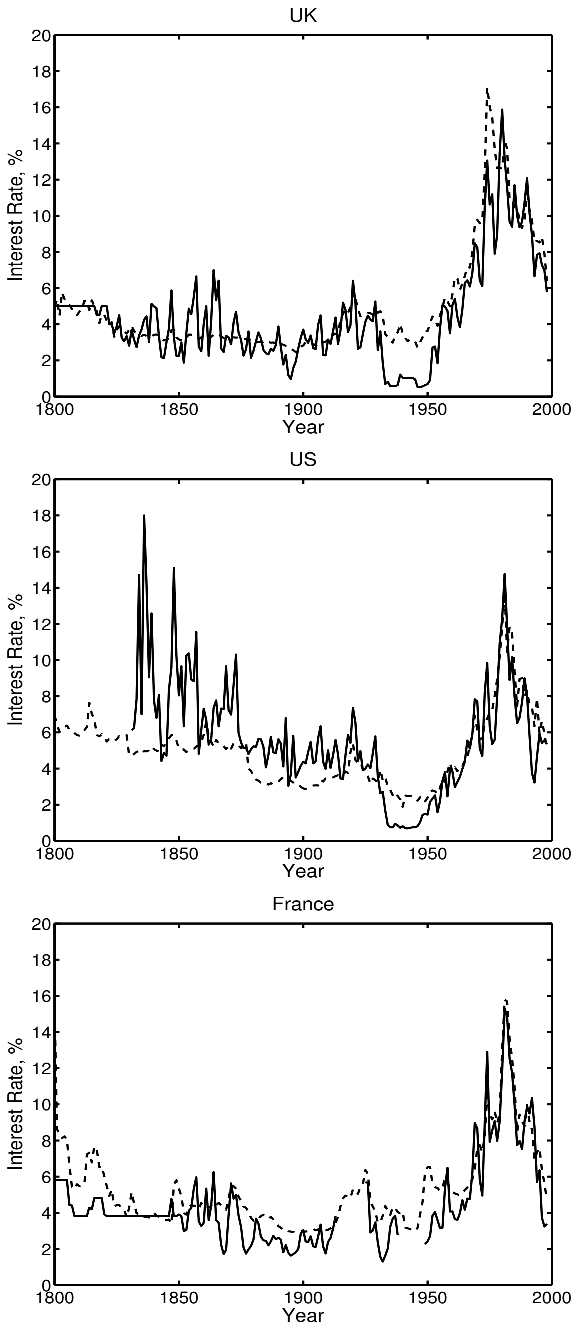

FIG. 2. short and long-term interest rates over the past two centuries. The solid lines in each panel denotes the short-term interest rates while the dashed lines denote the long-term interest rates. Refer to Appendix A for the sources and definitions of these interest rates.

The most persistent series is the long-term interest rate in UK, least is the short rate from US. Overall, the long rates are more persistent than the short rates and the interest rate differentials are less persistent than the interest rates themselves.

III. Uncovered Interest Rate Parity

A. Evidence from the Traditional Regression

Based on the martingale hypothesis, the forward exchange rate should be an unbiased forecast of the future exchange rate. A popular forecasting relation is formulated as

$$s_{t+1} - s_t = \alpha + \beta (f_t - s_t) + e_{t+1}, \tag{1}$$

where s_t denotes the logarithm of the exchange rate and f_t denotes the one-period-ahead forward exchange rate. Under the martingale hypothesis, $\beta = 1$. By covered interest rate parity, we have

$$f_t - s_t = r_t - r_t^*, \tag{2}$$

where r_t and r_t^* denote, respectively, the domestic and foreign interest rate on a one-period zero coupon bond. Combining (1) and (2), we have

$$s_{t+1} - s_t = \alpha + \beta (r_t - r_t^*) + e_{t+1}. \tag{3}$$

A test of the hypothesis $\beta = 1$ is a test of uncovered interest parity. Under the UIP hypothesis, if the return on a domestic n-period zero coupon bond is one percentage point per annum higher than that on a foreign bond, one would expect, on average, the foreign currency to appreciate by one percent over the next n periods. In practice, one often finds the hypothesis grossly violated. Most puzzling of all, however, is that the estimate for β is often negative.

We run the above regression on both pairs of currencies. Since neither the short-term interest rates nor the long-term interest rates match the required maturity of one year, we perform alternate sets of regressions using first short rates and then long rates as the right-hand-side variable. Table 2 reports the results of these regressions. First, in contrast to most of the results in the literature, the regression slope estimates for β are positive for all four regressions. Second, while the slope estimates of $\beta = 0.38$ (long rate) and 0.14 (short rate) for dollar-sterling are significantly different from the null hypothesis of $\beta = 1$, the estimates for the franc-sterling regression $\beta = 0.73$ (long rates) and 0.97 (short rates) are not statistically different from one. Finally, none of the intercept estimates for α are significantly different from zero. Thus, we find that the UIP puzzle disappears when we perform the tests over our ultra long sample period. UIP may be violated during a particular short period, but it holds much better over the long haul, especially for a currency that does not involve the US as the benchmark.

Comparing the regression results based on long-term interest rates and short-term interest rates, we find that the regressions with the long-term rates generate results closer to the expectation hypothesis. In the case of the France/UK pair, the slope estimate with the short-term rates is closer to one in magnitude, but the standard error of the estimate is also significantly larger. As a result, the estimate of 0.97 is neither significantly different from zero nor from one. In contrast, the regression slope of 0.73 based on the long-term interest rates is significantly different from zero, but not significantly different from the null of one. In the case of US/UK, the slope estimate becomes closer to zero when using the short-term rates instead of the long-term rates. Therefore, the long-term rates do a better job of forecasting the currency movement than do the short-term rates. Both the instruments used and the term mismatch very likely play a role in this result, particularly for the United States given our use of a commercial paper rate. The commercial paper rate doubtlessly contains some component due to credit risk, which can be both sizable and highly volatile during years of financial crisis. Furthermore, the slope and curvature of a yield curve is mainly generated with rates within two years of maturity.[1] Hence, on average, the difference between the one-year rate and three-month rate can be larger than that between one year and ten year rates. Both data issues generate measurement errors, which as Bekaert and Hodrick (1993) show can bias the regression slope toward zero. After correction for these biases, the regression slope estimates should be even closer to one, the null value.

[1] See, for example, the stylized evidence documented in Backus, Foresi, and Telmer (1998)

B. Subperiod Analysis

To analyze the robustness of the results, we divide the sample into three subperiods and perform analysis within each subperiod. The three subperiods roughly correspond to three different broad regimes: (1) 1800-1913, the varied regimes of the early nineteenth century, the U.S. Civil War period, and the heyday of the classical gold standard; (2) 1914-1949, the War and Interwar years, periods of substantial inflation punctuated by the economic dislocations of the 1920s and 1930s; and (3) 1950-1999, the post-WWII period characterized by the quasi-fixed exchange rates of Bretton Woods and the managed float and, in the case of France, the recent move to the Euro.

Table 3 reports the summary statistics for the depreciation rates and interest rate differentials, as well as the forward premium regression in equation (3) for the three subperiods. For comparison, we also report the corresponding statistics for the full sample in the last two rows of each panel. We observe again that the results based on the long-term interest rates conform to the hypothesis much better than those based on the short-term series. The regression slope estimates are positive in all subperiods when using the long-term rates, but become negative in some cases when the short-term interest rates are used.

The slope estimates for the subperiod regressions exhibit large fluctuations around the null value from period to period. Thus, while the expectations hypothesis holds approximately over the whole sample, the regression slope estimates can vary dramatically from the null value in any given subperiod, illustrating the potential danger of drawing conclusions based on a short sample.

Unconditionally, the mean values of the deprecation rates and the interest rate differentials move mostly in the same direction. For example, during the nineteenth century, sterling appreciates against both the dollar and the franc, but the UK interest rates are on average lower than those of the other two countries. We also find that the mean interest rate differentials are much larger than the exchange rate changes. This, however, is expected, given that the exchange rates are mostly fixed during this period, with only occasional realignments.

During the World Wars and Inter-war Period, sterling on average depreciates against the dollar, but appreciates (dramatically) against the franc. Correspondingly, the mean interest rate differential is negative between the US and UK, but positive between France and the UK, again consistent with expectations. During this period, the average depreciation rate of sterling against dollar is close to the average of the interest rate differential between the two countries in magnitude. The franc, in contrast, experienced a dramatic depreciation against UK, much bigger than the mean interest rate differential.

Finally, during the last period of floating exchange rates, sterling depreciates against both dollar and franc. At the same time, UK interest rates are higher than those of the other two countries.

In summary, the violation of the uncovered interest rate parity is much smaller than generally portrayed in the literature, especially when we take an ultra long perspective and use a more stable interest rate series. Nevertheless, during any particular subperiod, the regression slope can deviate dramatically from the null value of one. This general alignment of UIP, with sharp short term deviations, can also be seen from a simple graphical analysis. Figure 3 plots the long-term temporal behavior of the exchange rate depreciation rates (solid lines) and the interest rate differentials (dashed lines), and the difference between the two, the deviation from UIP (dotted lines). To capture the long-term trend, we apply centered nine-year moving average to the annual figures. The broad-brush picture painted by the charts is consistent with the full-sample regression results. In both comparisons, the exchange rate changes and the interest rate differentials move together over the very long term, which is precisely what the whole sample regressions have shown. What become clearer in the charts are the details of the at times sharp divergences between the two series over shorter but nevertheless still quite lengthy periods.

C. Rolling Regressions

To investigate further the influence of the sampling period on the slope estimate, we re-run the above regression with a rolling window. We fix the ending period of the regression at the last observation (1999), but move the starting period progressively forward from 1802 to 1989. Figure 4 plots the regression slope estimates (solid lines) of the rolling regression, as well as the 95 percent confidence intervals (dashed lines), as a function of the starting period. In the case of franc-sterling (left panel), the regression slopes are not significantly different from one (the null value) until the starting period moves into the mid 1970s. Similar findings apply to the case of dollar-sterling (the right panel). The slope estimates are positive when the regression is run on the whole sample period but begin to become negative when the start of the sample period is after the early 1970s. Interestingly, the slope estimate

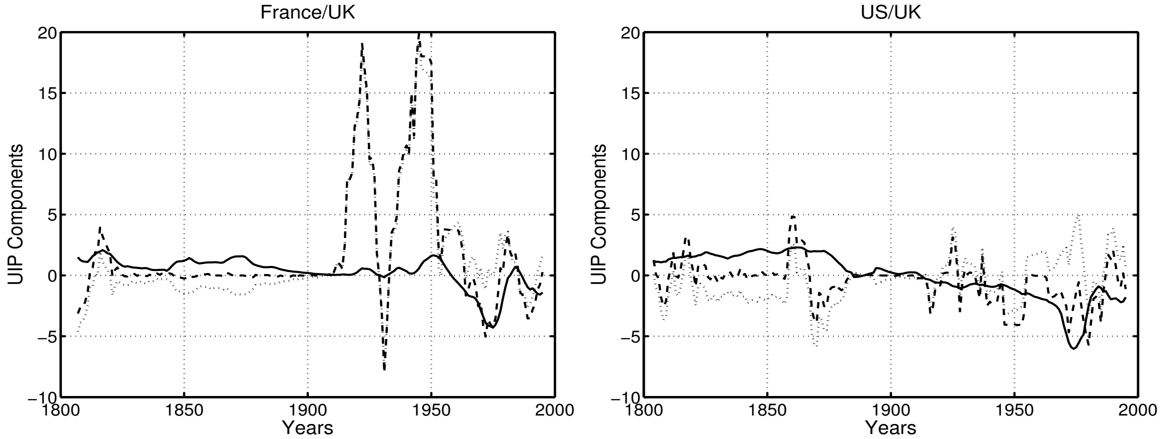

FIG. 3. Nominal interest differentials and exchange rate changes: long-term movements over two centuries. Shown in the charts are nine-year centered moving averages of foreign vs. UK long-term nominal interest rate differentials (dashed lines) and percentage rates of change of nominal foreign vs. pound sterling exchange rates (solid lines).

becomes positive again when the regression focuses on the 1990s, a finding also documented in Flood and Rose (2001). Indeed, most of the traditional evidence on negative regression slopes is based on samples dominated by late 1970s and early 1980s, with the U.S. dollar as the numeraire. Nevertheless, the negative slopes on franc-sterling during this sample period indicate that the violations of the expectation hypothesis during this sample period not only applies to currencies benchmarked to the U.S. dollar, but also to other exchange rates without the involvement of dollar. Bekaert (1995) present similar findings.

In all three countries, this was a period of substantial inflation, the culmination of a historically unprecedented three-decade period of inflation. By the end of the 1970s, inflation, which on a long-term average basis had trended up steadily since the 1950s, reached historic peacetime highs in all three countries. The first break in the process came in 1979 in the UK following the Thatcher election and the ensuing move to much tighter monetary policies. A similar shift began in the US shortly after Paul Volcker became Federal Reserve Chairman and gained momentum following the 1980 Reagan election. In France, the shift came several years later.

In each instance, a series of announcements accompanied these moves to less inflationary policy, but these announcements did not do much initially to alter market expectations on the inflation rates. In

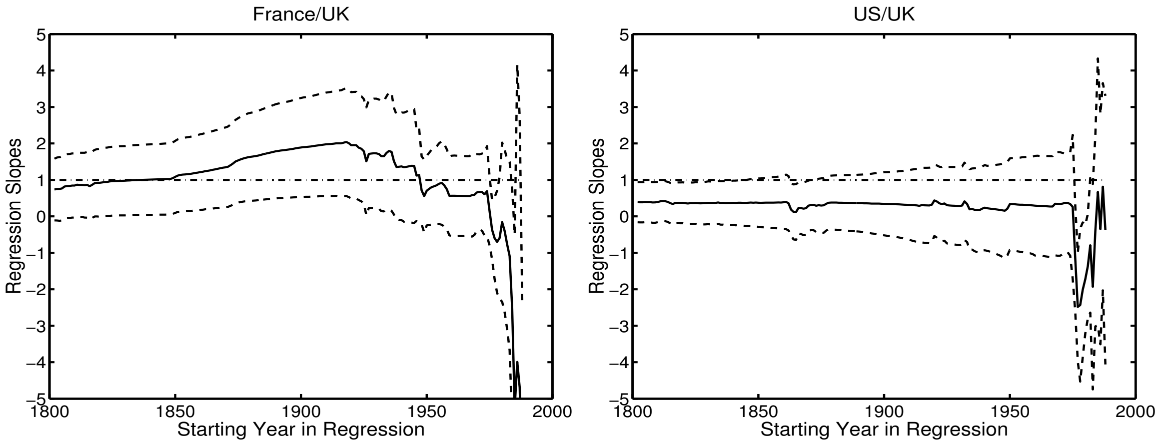

FIG. 4. Rolling regression slope estimates over the past two centuries. The solid lines are the slope estimates for the UIP regression on franc-sterling on the left panel and dollar-sterling on the right panel. The dashed lines are the 95 percent confidence intervals, constructed according to Newey and West (1987) with three lags. The dash-dotted lines represent the null value of one. Data are annual. The regressions are rolling forward from 1802 to 1989. The x-axis shows the starting period of each regression, with the ending period fixed at 1999.

the UK, many otherwise perspicacious observers even several years after the fact argued that no policy change had occurred and that inflation could be expected to increase rather than decrease. A major cause of this skepticism was the behavior of the broad monetary aggregate that the Bank of England had chosen as its target. This aggregate had accelerated for reasons that had nothing to do with policy and had no implications for price and spending behavior. Nevertheless, this acceleration created a false perception among the public such that the expected inflation rate remained high for several years after the actual inflation came down, thus creating an extended periods of missed targets between the forecasts and the realization in inflation rates. In this connection, see the discussion in Darby and Lothian (1983) and the papers by Sargent and by Batchelor and Griffiths cited therein.

A similarly slow adjustment of expectations also took place in the United States. An interesting bit of evidence in this regard is provided by the ten-year inflation forecasts collected by the Federal Reserve Bank of Philadelphia.[2] Figure 5 plots the inflation forecasts (dashed line) and the realized inflation rates (solid line), with the difference given by the dash-dotted line. We observe that inflation

[2]Federal Reserve Bank of Philadelphia, 2003, “Long-term inflation forecasts: Expected inflation over the next 10 years.” http://www.phil.frb.org/files/spf/cpie10.txt.

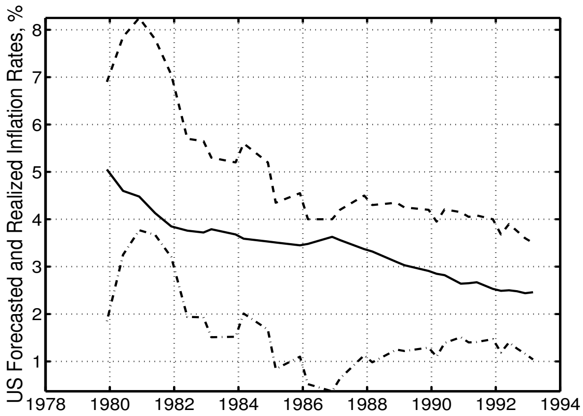

FIG. 5. U.S. forecasted and realized inflation. The dashed line denotes the ten-year inflation forecasts, the solid line denotes the realized inflation rate, and the dash-dotted line denotes the forecasting error, the difference between forecasted and realized inflation rates.

forecasts made throughout the 1980s are systematically higher than the rates actually realized. Such evidence points to failing expectations with respect to the regime switch, rather than time-varying risk premia as suggested by Fama (1984), as the key reason for the negative slope estimates of the UIP regression during this sample period.

IV. Extreme Sampling and Nonlinear Forecasting Relations

Due to inherent market frictions such as transaction costs, exchange rate adjustment may not follow the interest rate differentials (forward premiums) instantaneously. In particular, relatively small magnitudes of interest rate differentials may be tolerated in the market without inducing any directional movement on the exchange rate. Large interest rate differentials, however, are less likely to persist without inducing corresponding movements in the exchange rate. A second, but not mutually exclusive, explanation for such behavior revolves around measurement error (see Bekaert and Hodrick (1993)). In the presence of such errors, large and persistent interest rate differentials have a much higher signal to noise ratio and hence are much more likely to contain the market's view on how the exchange rate will move in the future. As a result, uncovered interest parity should hold better during periods of large interest rate differentials.

To test this hypothesis, we propose two specifications. The first applies the principles of extreme sampling and the second relies on the smooth transition in between different regimes. We elaborate on both in the following two subsections.

A. *Extreme Sampling*

The idea of extreme sampling is to run regressions conditional on the absolute magnitude of a signal being large. For our application, we use the absolute value of the interest rate differential as the criterion for conditioning and run the following regression,

$$s_{+1} - s_t = \alpha + \beta^S (r_t - r_t^*) I_{t \in S} + \beta^L (r_t - r_t^*) I_{t \in L} + e_{t+1}, \tag{4}$$

where the superscripts S and L refer to small and large absolute realizations of the interest rate differential, respectively. The term $I_{t \in S}$ is an indicator function that equals one if period t has a small interest rate differential and zero otherwise. $I_{t \in L}$ is analogously defined for large interest rate differential periods. A similar extreme sampling technique has been applied in Huisman, Koedijk, Kool, and Nissen (1998). Sercu and Vandebroek (2003) shows from a statistical analysis how this extreme sampling technique can improve the signal to noise ratio when the missing variable has a thin-tailed distribution.

We run the regression in (4) based on different extreme sampling criteria. We define the criteria based on percentiles of the data. Specifically, we sort the absolute value of the interest rate differential and then identify the cut-off value for different percentiles from 90 percentile to 99 percentile. We then define interest rate differentials with absolute magnitude higher than this cut-off value as extreme periods (L) and those smaller as normal observations (S). Table 4 reports the regression estimates based on the different percentile criteria. Since we have found that the long-term interest rate differential forecasts the currency movement better than the short-term interest rate differential, we only report extreme sampling analysis results based on the long-term interest rate data. For each coefficient, we report its estimate in the first column and the standard error in the second column. Under $\|dr\|$, we report the cut-off values on the absolute value of the interest rate differential that corresponds to each percentile.

We find that as we increase the percentile and hence make the criteria for large observations more stringent, the estimate for β^S declines and becomes closer to zero while the estimate for β^L increases and becomes more positive. For example, for the France/UK case, at a 90 percentile criterion, $\beta^S = 1.44$ is actually bigger than $\beta^L = 0.30$ and hence runs against the extreme sampling hypothesis. But once we increase the criterion to 99 percentile, $\beta^S = 0.34$ becomes insignificantly different from zero while $\beta^L = 2.33$, which is even significantly greater than one. The same pattern applies to the US/UK case. As the percentile increases, β^S declines and becomes insignificantly different from zero while β^L increases and becomes more positive.

This phenomenon is vividly captured by the graphics in Figure 6, in which we plot the estimates of β^L (solid lines) and β^S (dashed lines) as a function of the extreme sampling criteria in terms of percentiles. As the percentile increases and hence the criterion becomes more stringent for large interest rate differentials, the slope estimate for the large realization (β^L) increases while the slope estimate for the small realization (β^S) decreases. Thus, as we have conjectured, larger interest rate differentials have a bigger impact, or more significant forecasting power, on the currency movement.

At the extreme case of 99 percentile, we have only two sample points where the absolute magnitude of the interest rate differentials are "large" for both pairs of currencies and these two sample points refer to the large interest rate differentials in 1974 and 1975 for both pairs. For France/UK, the interest rate differentials are -0.92 and -1.17 in 1974 and 1975, respectively. The next year's exchange rate depreciation rates are respectively -16.87 and -9.86, respectively. For US/UK, the interest rate differentials are -2.23 and -2.63 for these two years, and the following years exchange rate depreciation rates are -5.20 and -20.70. For both pairs, the realized exchange rate depreciation rates not only have the same sign as the interest rate differentials, but also exhibit a larger magnitude of change than the interest rate differentials, thus generating slope estimates of β^L greater than one.

As we increase the percentile, we find that the R-squares of the regressions also improve. At 99 percentile extreme sampling, the R-square is 2.1 percent for France/UK and 4.0 percent for US/UK, higher than the R-squares from the linear regressions (about one percent for both exchange rates). Nevertheless, the overall forecasting power remains extremely small, even with the help of extreme sampling.

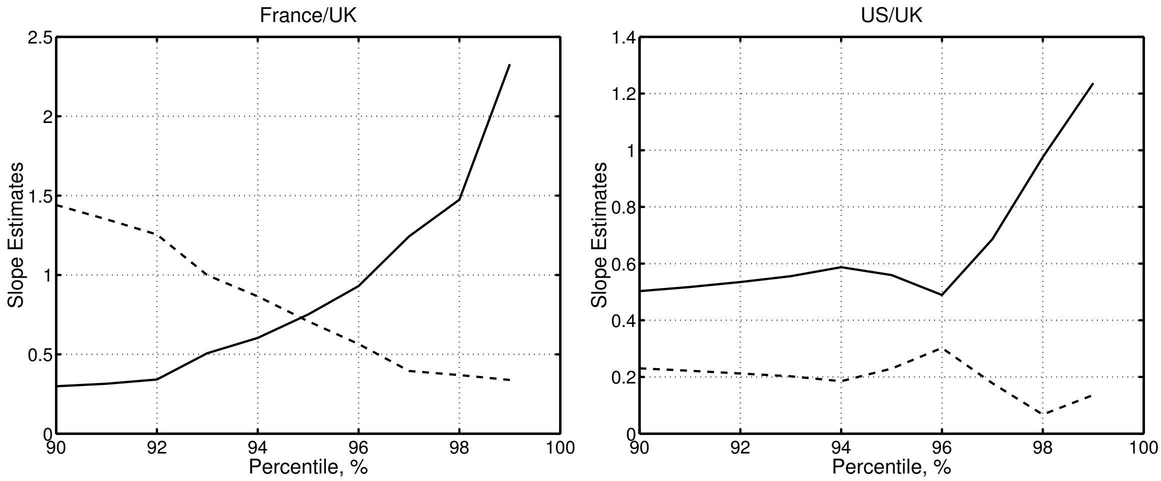

FIG. 6. Regression slopes under different extreme sampling criteria. Lines represent slope estimates of the following extreme sampling regression under different sampling criteria:

$$s_{+1} - s_t = \alpha + \beta^S (r_t - r_t^*) I_{t\in S} + \beta^L (r_t - r_t^*) I_{t\in L} + e_{t+1},$$

where S denotes the sample periods with the absolute value of the interest rate differential ($\|dr\|$) is within a critical value and L denote the sample periods when the interest rate differential is outside this critical value. The critical value on the absolute interest rate differential is based on the percentile of the data. The lines denote the slope estimates under different percentiles. In particular, the solid lines represent the estimates for β^L and the dashed lines represent the estimates for β^S.

B. A Smooth Transition Nonlinear Regressive Model

The extreme sampling analysis shows that the relation between the rate of exchange rate depreciation and the interest rate differential is inherently nonlinear. One particular statistical characterization of nonlinear adjustment that appears to work well for exchange rates is the smooth transition nonlinear regression model (Granger and Terasvirta 1993). In these models, adjustment takes place in every period but the speed of adjustment varies with the magnitude of the interest rate differential. A particularly simple formulation that is applicable to our case can be specified as follows,

$$s_{+1} - s_t = \alpha + \beta\left(r_t - r_t^* - \mu\right) + \gamma\left(1 - e^{-\lambda\left(r_t - r_t^* - \mu\right)^2}\right)\left(r_t - r_t^* - \mu\right) + e_{t+1}, \tag{5}$$

where μ denotes a long run mean of the interest rate differential, the transition function $\phi = 1 - e^{-\lambda(r_t - r_t^* - \mu)^2}, \lambda > 0$ is between zero and one as the deviation of the interest rate differential increases from zero to infinity. The transition function is centered around a mean interest rate differential level μ. The transition parameter λ determines the speed of transition between the two extreme regimes, with lower values of λ implying slower transition. The inner regime corresponds to $r_t - r_t^* = \mu$ so that $\phi = 0$ and equation (5) becomes a linear forecasting relation,

$$s_{+1} - s_t = \alpha + \beta\left(r_t - r_t^* - \mu\right) + e_{t+1}. \tag{6}$$

The outer regime corresponds to the case when $r_t - r_t^* - \mu \to \infty$ and $\phi = 1$ so that equation (5) becomes a different linear forecasting relation,

$$s_{+1} - s_t = \alpha + (\beta + \gamma)\left(r_t - r_t^* - \mu\right) + e_{t+1}, \tag{7}$$

with a different regression slope. Thus, equation (5) provides a smooth transition between these two limiting cases (regimes) and can be regarded as a smoother version of extreme sampling. The slope coefficient β represents the response of the exchange rate to small interest rate differential and the coefficient $(\beta + \gamma)$ corresponds to the response to large interest rate differentials.

The nonlinear regression in (5) is estimated by minimizing the mean squared error of the regression residuals using numerical nonlinear least square packages. The estimation results are reported in

Table 5. For both exchange rates, the estimates for β are negative, but the estimates for γ are large and positive. These results are consistent with our findings from the extreme sampling analysis. Exchange rate movements only respond to large (extreme) interest rate differentials, but not to small ones.

Compared to the linear regression, the percentage of explained variance (R-square) increases to 2.2 percent for France/UK and 3.9 percent for US/UK, similar to the performance of the extreme sampling regression. Thus again, while the forecasting performance can increase slightly via a nonlinear, and hence more flexible specification, the overall forecasting power of interest rate differentials on currency movement is still very low.

V. A Historical Account of UIP Deviations

The upshot of the findings reported so far is that over the long term, the UIP puzzle largely disappears. In that sense, UIP "works." The problem, however, is that it does not work all that well as a forecasting relation. The standard deviations of the UIP regression residuals are large relative to the standard deviations of exchange rate changes. In this section, we try to uncover the reasons why this is the case. To do so, we divide the sample into subperiods that correspond to historical regimes and analyze the properties of exchange rates and interest rates under each regime.

To understand the source of UIP deviations under different historical periods, we decompose the deviation from UIP into a real component and a nominal component. The real component captures the real interest rate differential, while the nominal component captures the deviation from the purchasing power parity. To understand this decomposition, consider the following open economy Fisher equation:

$$dr = d\rho + \overline{d\pi}, \tag{8}$$

where $d\rho$ denotes the difference between real interest rates in the two countries and $\overline{d\pi}$ denotes the difference between the relevant anticipated rates of inflation in the two countries.[3] Adding the anticipated depreciation rate $\overline{ds}$ to both sides of the Fisher equation results in,

$$\overline{ds} - dr = \overline{ds} - \overline{d\pi} - d\rho. \tag{9}$$

The left hand side is the anticipated deviation from UIP, which we label as $\overline{dUIP}$. The first two terms on the right hand side constitutes the anticipated deviation from PPP, which we denote as $\overline{dPPP}$. Thus, we can decompose the anticipated deviation from UIP into two components: (1) the anticipated deviation from purchasing power parity and (2) the difference between the real interest rates of the two countries,

$$\overline{dUIP} = \overline{dPPP} - d\rho. \tag{10}$$

Similar decomposition can also be found in Gokey (1994) and Hollifield and Yaron (2001).

Since PPP is being expressed in growth-rate form, the on-going debate concerning the existence and size of a permanent component in the real exchange rate is beside the point. No economist to our knowledge has argued that the real exchange rate is I(2). We would expect, therefore, that the anticipated exchange rate depreciation rates $\overline{ds}$ and the anticipated inflation rates $\overline{d\pi}$ converge even if the levels of nominal exchange rates and relative prices did not. Deviations from growth rate PPP would require the existence of recurrent real shocks, or factors producing recurrent shifts in exchange-rate expectations. An example of the former case is continually faster productivity growth in one country over the other; an example for the latter case is continually increasing or decreasing fears about future inflation in one of the two countries. Evidence presented in Lothian and Simaan (1998) suggests that such factors have little empirical relevance over the longer term.

The differential between the real interest rates in the two countries can be further decomposed into two components: (1) the differential between the real returns on real assets internationally and (2) the differential between the differentials in the real returns on real assets and on nominal assets (bonds) in the two countries domestically (Friedman and Schwartz, 1982, page 513 forward). The first

[3] We use the overline to denote anticipated rates, in contrast to the ex post realized rates.

component reflects factors affecting the degree of arbitrage among countries such as capital controls. The second component reflects either incomplete financial intermediation within countries, differences in the quality of the two financial assets (risk premia), or measurement or expectation error.

Table 6 reports subperiod averages of exchange rate depreciation rates (ds), interest rate differentials (dr), the deviations from UIP ($dUIP = ds - dr$), as well as four additional variables that are related to the above decompositions: inflation differentials ($d\pi$), real interest rate differentials ($d\rho = dr - d\pi$), deviations from PPP in growth rate form ($dPPP = ds - d\pi$), and real GDP grow rate differentials (dy). Equipped with these sample averages of UIP deviations and the relevant real and nominal components and variables, we proceed to analyze the fundamental source of UIP deviation under each sample period. We first divide the past two centuries into two broad periods, with 1914 the dividing line. We show that UIP deviations before and after 1914 are generated from different sources.

A. The Nineteenth and Early Twentieth Centuries

In the case of France versus the UK, the behavior of the interest rate differential (dr) and the currency depreciation rate (ds) was fairly homogeneous over the course of the century following the end of the Napoleonic Wars. The gap between dr and ds was positive but averaged only a bit over 80 basis points. This gap was traceable arithmetically to the gap between the two countries' real interest rates. Purchasing power parity for its part held almost perfectly over the period, with the average deviation merely two basis points per annum. Underlying the high French real interest rates, according to Homer and Sylla (1996), were risk premia resulting from the uncertainties surrounding the French political situation during this period, the occasional major changes in regime that took place in the first half century or so and the subsequent tensions with Germany that resulted in the Franco-Prussian War in 1870.

Viewed in a purely technical sense, however, UIP was violated. A British investor and his heirs who bought French rentes at the end of the Napoleonic Wars and held them until the start of World War I would have averaged 80 basis points per year more than on an equivalent investment in British consols. He would, however, have borne the political risk alluded to above and had he held the rentes until 1920 would have seen the additional return over the previous century more than fully eroded by the depreciation of the franc relative to sterling during WWI and its immediate aftermath.

The experience of the United States versus the United Kingdom over the same long period was similar on average to that of France versus the United Kingdom, but differed greatly in the details. Again the interest rate differential *dr* exceeded the currency depreciation rate *ds* and in this instance by more than one percentage point per annum. Again this was the arithmetic result of a difference in real interest rates between the two countries rather than a deviation from PPP.

As in the France-UK case, PPP again held almost perfectly over the period as a whole. Unlike the French case, in which political risk appeared to have been responsible for the real-interest rate gap, the higher US than UK real interest rates appear due to higher real returns to investment in real assets in the United States. Real GDP growth (*dy*), our proxy for such returns, was roughly two percentage points per annum faster in the United States than in the United Kingdom over the period, while for France versus the United Kingdom the real growth differential was actually reversed.

The other noticeable difference between the two cases was the much greater variability of both *dr* and *ds* and of the difference between the two, the deviation from UIP, in the US-UK case. This greater variability was largely the result of greater variability in two episodes — the US Civil War period and the early part of the Greenback period that followed it and the decade or so surrounding the Napoleonic Wars and the War of 1812. Interestingly, however, in both of these episodes *ds* and *dr* do track one another reasonably well in terms of broad movements, even though the magnitude of the differential between the two at times widens dramatically.

B. The Twentieth Century from 1914 to 1999

In 1914 the world changed. This certainly was true for monetary behavior, and not surprisingly, it carried over into both exchange-rate and price-level behavior. In the nineteenth century, suspension of specie payments during wartime and exchange rate depreciation were followed by resumption and appreciation. Wartime price level increases were followed by post-war decreases. The gold standard, as Bordo and Kydland (1995) have argued, was a commitment mechanism and investors for the most part caught on. Late nineteenth century US experience was the exception that proved the rule. Fears that the US would leave gold caused the spread between US and UK interest rates to widen. When these fears proved unfounded, US interest rates fell and, as it turned out, proved too low given the somewhat higher US than UK inflation over the next decade and a half. See the discussions of this episode in Friedman and Schwartz (1963, 1982) and the subsequent econometric analysis of Hallwood, MacDonald, and Marsh (2000).

Only in the UK following World War I did this nineteenth-century pattern of inflation followed by deflation continue. In 1925, the United Kingdom returned to gold at the pre-war parity as a conscious policy decision. In France in the early interwar years, in contrast, the severe inflation of World War I actually was followed by further inflation. As a result, the price level and the nominal franc-sterling exchange rate wandered even further from their nineteenth century levels. In the United States, the price level eventually did come back to earlier levels, but mostly as a result of the Great Depression.

Over the full period from 1914 to 1999, the average annual deviations from UIP for franc-sterling were markedly greater than the average deviation from 1803 to 1913 (4.73 versus -0.83 percentage point), but were actually quite a bit less for dollar-sterling (0.46 versus -1.14 percentage points). The franc-sterling result, as data for the subperiods indicate, was heavily influenced by behavior in the wartime and interwar periods. In all three of these episodes, expectations of inflation clearly were out of sync with what eventually transpired. French nominal interest rates averaged higher than their UK counterparts but the differentials were small in comparison to the realized differentials in inflation. Ex post real interest rates, therefore, were highly negative. Exchange rates did, however, change roughly in line with the inflation differentials so that deviations from PPP for both currencies continued to be small over the full period on average.

The disparity between differentials in nominal interest rates and movements in exchange rates in the two war periods in part may reflect the controls that governments at various times placed on interest rates. A more important source of divergences, we suspect, were problems of expectations formation. If the war-related inflations were unanticipated, or expected to have only transient effects on price levels, nominal interest rates would generally have been too low before the fact and nominal interest differentials, therefore, a poor predictor of subsequent changes in exchange rates, which is in fact what we observe.

Similar problems of expectations formation appear to have surrounded the moves to lower inflation regimes in the early 1980s in the United Kingdom and United States. As we argued in a previous section, such peso-like problems very likely account for much of the seemingly anomalous behavior of nominal interest rates and exchange rates relative to one another and to realized inflation rates in the late 1970s and early 1980s in both the United States and the United Kingdom.

During this period, we see an average deviation from UIP for dollar-sterling considerably above its twentieth century non-war average and an average deviation from UIP for franc-sterling slightly greater than its non-war average. In both cases, these are accompanied by deviations from PPP that are large both in comparison to twentieth century experience as a whole and to the UIP deviations. This positive association between UIP and PPP deviations has been documented previously by Gokey (1994), Marston (1997), and Tanner (1998). A plausible explanation for the association between the two, as Lewis (1988), Marston (1997), and Peruga (1996) have argued, revolves around learning. As inflation fell and learning set in, nominal exchange rates and short-term interest rates adjusted with a lag and long-term interest rates with greater lags still. Sizable deviations from both UIP and PPP were the end result.

Our long-term evidence as well as the results of several studies utilizing cross-country data for recent decades (Flood and Taylor (1996); Lothian and Simaan (1998)) suggests that in the end such problems disappear.

VI. Conclusion

Uncovered interest parity is one of three theoretical relations that are used repeatedly in analytical work in international finance and international monetary economics. Stated in its simplest form, the conclusion to which UIP gives rise is that countries with high nominal interest rates relative to interest rates abroad are countries with depreciating currencies. The problem, however, is that over the past several decades we very often have seen the exact opposite taking place.

In this paper, we attribute these widely documented UIP failures to the coincidence of two empirical artifacts: (1) the unique features of the late 1970s and the 1980s and (2) the noise induced by small UIP deviations. We control for both by constructing an ultra long time series spanning two centuries and by running regressions conditional on large deviations from UIP. We find that traditional regressions yield positive slope estimates over the whole sample period and that these estimates only become negative when the 1980s make up a major portion of the sample period. We find in addition that large interest rate differentials have stronger forecasting powers for currency movements than small interest rate differentials. Finally, a historical account of expected and realized regime changes illustrates how the expectation hypothesis underlying UIP holds over the very long haul but can be deviated from for long period of time otherwise, due either to failures of expectations to adjust quickly enough to regime and other broad-based policy changes or to anticipations over extended periods of large events that in the end never actually materialize.

These are the positive findings, the parts of the glass, so to speak that are full. There is also a truly major part that is empty. This is the overall poor predictive performance of UIP over shorter periods and for small interest differentials. If there is a UIP puzzle, it is not as commonly believed the anomalous negative relationship between the interest differential and the rate of exchange rate depreciation observed in the 1980s, but the fact that there is very often little relationship one way or the other.

Small sample and "peso problems" are well-known issues that bias the slope estimates of expectation hypothesis regressions. The construction of an ultra long sample constitutes the most direct remedy for both. Similar to the documented deviations to the uncovered interest rate parity, strong violations of the expectation hypothesis have also been repeatedly documented on the term structure of interest rates, e.g., Backus, Foresi, Mozumdar, and Wu (2001), Bekaert, Hodrick, and Marshall (1997), Campbell (1995), Campbell and Shiller (1991), and Evans and Lewis (1994). A line for future research is to apply the the same technique used in this paper to the various forms of expectation hypothesis regressions on the term structure of interest rates. The construction of an ultra long sample would resolve the issue on small samples and peso problems and identify how much of the violation is really due to time varying risk premium.

Appendix: Data Sources

The data are constructed from a variety of sources, including:

1. Board of Governors of the Federal Reserve System, Federal Reserve Bulletin, various issues.
2. Michael D. Bordo, "The Bretton Woods International Monetary System: An Historical Overview," in Michael D. Bordo and Barry Eichengreen, eds., A Retrospective on the Bretton Woods System, Chicago: University of Chicago Press for the NBER, 1993 [and associated data diskettes].
3. Michael D. Bordo and Lars Jonung, The Long-Run Behaviour of the Velocity of Circulation, The International Evidence, New York: Cambridge University Press, 1987 [and associated data diskettes].
4. Milton Friedman and Anna J. Schwartz, Monetary Trends in the United States and the United Kingdom, Chicago: University of Chicago Press for the NBER, 1982.
5. Sydney Homer, A History of Interest Rates, 2nd ed. New Brunswick, NJ: Rutgers University Press, 1977.
6. International Monetary Fund, International Financial Statistics (IFS), various issues, and companion CD ROM.

United Kingdom

Short-term interest rate:

1831-1844, Overend-Guerney average annual rate for first-class 3-month bills from Mitchell (1988), table entitled "Financial Institutions 15. The Market Rate of Discount - 1824-1980."

1845-1869, average annual rate for 3-month bank bills from the same source.

1870-1986, average annual rate for 3-month bank bills from Bordo and Jonung (1987) and Bordo (1993).

1987-1999, average annual money market rate from International Financial Statistics.

Long-term bond yields:

1791-1869, average annual yields on three percent consols for from Mitchell, table entitled "Financial Institutions 13. Yield on Consols."

1870-1975, average annual yields on three percent consols from Bordo and Jonung (1987).

1976-1994, average annual government bond yield from IFS.

United States

Short-term interest rates:

1831-1899, average annual commercial paper rate from Homer (1977), Table 44.

1900-1975, average annual prime 60-90 day commercial paper rate from Homer (1977), Table 51.

1976-1999, average annual prime 60-90 day commercial paper rate from various issues of the Federal Reserve Bulletin.

Long-term bonds yields:

These are U.S. treasury bonds for the most part. They are a mixture of maturities. A rough guess as to the average is 15-20 years prior to 1977 after which it is 30 years. The data were taken from Global Financial Data.

Exchange Rate:

1791-1796, annual averages of the White exchange rate series in the form of percent deviations of sterling from parity (in dollars per pound) from Table Appendix Table 1, pp. 610-12 in Officer (1983) adjusted by the parity values in his Table 5.

1797-1820, annual averages of the White exchange rate series in the form of percent deviations of sterling from parity inclusive of U.K. paper currency depreciation from worksheets provided by Lawrence Officer, adjusted by parity values in Officer (1983), Table 5.

1821, annual average of the White series inclusive of paper currency depreciation (first quarter) and the Appendix Table 1 (remaining three quarters) adjusted by the parity values in Officer (1983), Table 5.

1822-1829, same construction as for 1791-96.

1830-99, annual averages of percent deviations of sterling from parity from Officer (1985), pp. 563-65, adjusted by the parity values in Officer (1983), Table 5 (which are variable until 1837 and fixed at 4.8666 thereafter) and further adjusted in the years 1837-1843, 1857 and 1862-1878 for U.S. currency depreciation on the basis of the estimates reported in Warren and Pearson, (1935), Table 2, p. 154; 1900-1985, Friedman and Schwartz (1982), Table 4.9, pp.130-37; 1976-1990, IFS.

France

Short-term interest rates:

1863-1899, average annual open-market discount rate from Homer (1977), Table 27.

1900-1913, average annual open-market discount rate from Homer (1977) Table 61.

1925-1948, average annual private discount rate from Homer, Table 61.

1949-1994, average annual money market rate from IFS.

Long-term bond yields:

1800-1825, average annual yield on five percent French government rentes minus 67 basis points, the difference between the yield on the five percent rentes and the yield on three percent rentes in 1826), from Table 25.

1826-1899, average annual yield on three percent rentes, from Table 25;

1900-1948, average annual yield on three percent perpetual rentes, Table 60.

1949-1994, average annual government bond yield from IFS.

Exchange Rate:

1803-1940 and 1945-80, Paris franc/sterling exchange rate from British Historical Statistics (BHS), table entitled "Financial Institutions 22. Foreign Exchange Rates-1609-1980," pp. 702-3, adjusted for a break in 1931 by taking a weighted average of the 124.06 rate prevailing for the first three quarters of that year and the 94.02 rate in the last quarter.

1941-1944, derived as a cross rate using New York dollar/sterling rates and Swiss quotations of franc/dollar rates graciously provided by Phillipe Jorion.

1981 on, derived as a cross rate from yearly average dollar/sterling and franc/dollar rates from the IFS.

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TABLE 1
SUMMARY STATISTICS OF EXCHANGE RATE AND INTEREST RATES

		Long Term Rates			Short Term Rates		
	ds	r	$r*$	dr	r	$r*$	dr
				Home=France; Foreign=UK			
Mean	2.46	5.33	4.94	0.38	4.45	4.40	-0.18
Std Dev	0.10	2.40	2.90	1.71	2.52	2.78	1.34
Auto	0.21	0.89	0.98	0.79	0.90	0.91	0.60
Half life	0.44	6.20	31.67	2.92	6.65	6.95	1.34
Skewness	3.84	2.03	2.05	-0.16	1.90	1.40	-0.08
Kurtosis	22.65	5.15	3.86	9.40	4.17	2.38	0.70
				Home=US; Foreign=UK			
Mean	-0.45	4.94	4.94	-0.01	5.66	4.40	1.28
Std Dev	0.03	1.96	2.90	2.04	3.12	2.78	3.01
Auto	0.22	0.95	0.98	0.93	0.78	0.91	0.79
Half life	0.46	14.92	31.67	9.01	2.77	6.95	2.88
Skewness	-0.44	1.34	2.05	-1.68	0.95	1.40	0.90
Kurtosis	5.34	3.09	3.86	5.16	1.73	2.38	2.53

NOTE. — Entries report the summary statistics of exchange rate depreciation rates, interest rates, and interest rate differentials. We use ds to denote the exchange rate annual depreciation rates in percentages and r and $r*$ to denote domestic (France or US) and foreign (UK) interest rates, also in annualized percentages. The column under dr denotes the interest rate differential $dr = r - r^*$. Data are annual, starting in 1800 for US dollar and UK sterling and 1803 for French franc (FF).

TABLE 2
FORWARD PREMIA REGRESSION

	France/UK				US/UK			
	Long Rates		Short Rates		Long Rates		Short Rates	
	α	β	α	β	α	β	α	β
Estimates	0.02	0.73	0.00	0.97	-0.01	0.39	-0.01	0.14
Std Error	0.01	0.43	0.01	0.86	0.00	0.28	0.01	0.16
t-statistics	1.65	-0.63	0.73	-0.03	-1.08	-2.21	-1.27	-5.27
p-value	0.10	0.53	0.46	0.97	0.28	0.03	0.20	0.00
R^2, N	0.01	197	0.03	176	0.01	199	0.00	168

NOTE. — Entries report summary properties of the uncovered interest parity regression:

$$s_{t+1} - s_t = \alpha + \beta(r_t - r_t^*) + e_{t+1}.$$

Standard errors are constructed based on Newey and West (1987) with three lags. The number of lags is optimally chosen based on Andrews (1991) with a VAR(1) specification on the residuals. The t-statistics and p-value are constructed based on the hypothesis: $\alpha = 0, \beta = 1$. Data are annual from 1800 to 1999. In the last row, we report the R-squares on the left cell and the number of actual observations on the right cell, for each regression.

TABLE 3

SUBPERIOD ANALYSIS OF UNCOVERED INTEREST RATE PARITY

		Long Term Rates				Short Term Rates			
	ds	dr	α	β	(N,R^2)	dr	α	β	(N,R^2)
A. Home=France; Foreign=UK									
1800-1913	0.08	1.03	0.00	0.35	111	-0.11	0.00	-0.05	111
	0.02	1.21	0.00	0.26	0.01	0.86	0.00	0.35	0.00
1914-1949	7.95	0.30	0.08	10.05	35	0.63	-0.01	7.21	14
	0.64	0.71	0.04	3.63	0.10	1.82	0.03	1.77	0.42
1950-1999	-0.50	-1.09	0.01	0.70	49	-0.59	0.00	-0.18	49
	0.15	2.20	0.01	0.49	0.05	1.89	0.01	0.56	0.00
Whole	2.46	0.38	0.02	0.73	197	-0.18	0.00	0.97	176
	0.10	1.71	0.01	0.43	0.01	1.34	0.01	0.86	0.03
B. Home=US; Foreign=UK									
1800-1913	0.10	1.32	0.00	0.42	113.00	3.44	0.00	-0.02	82
	0.03	0.79	0.01	0.73	0.00	2.53	0.01	0.15	0.00
1914-1949	-0.44	-0.75	0.00	1.36	35.00	0.38	-0.01	1.18	35
	0.15	0.46	0.02	2.67	0.01	0.89	0.01	2.20	0.01
1950-1999	-1.58	-2.50	0.00	0.32	49.00	-1.68	-0.01	-0.08	49
	0.11	2.16	0.02	0.64	0.01	1.63	0.02	0.94	0.00
Whole	-0.45	-0.01	-0.01	0.39	199	1.28	-0.01	0.14	168
	0.03	2.04	0.00	0.28	0.01	3.01	0.01	0.16	0.00

NOTE. — Entries report summary properties of annul depreciation rates ($ds = s_{t+1} - s_t$, in percentage), interest rate differentials ($dr = r - r^*$, in percentage), and the estimates of the following uncovered interest parity regression:

$$s_{t+1} - s_t = \alpha + \beta(r_t - r_t^*) + e_{t+1},$$

under each subperiod. For each subperiod, the first row reports the estimates and the second row reports the standard errors. Under the column labeled "(N,R^2)," we report the number of available observations for the regression under each subperiod under the first row and the R-square of the regression under the second row. Standard errors for the regression estimates are constructed based on Newey and West (1987) with three lags.

TABLE 4
UNCOVERED INTEREST RATE PARITY UNDER EXTREME SAMPLING

Percentile	α		β^S		β^L		$\|dr\|$	R^2
			A. Home=France; Foreign=UK					
90	1.42	(1.01)	1.44	(0.81)	0.30	(0.57)	2.44	0.016
91	1.42	(1.02)	1.35	(0.77)	0.31	(0.59)	2.49	0.015
92	1.43	(1.03)	1.26	(0.74)	0.34	(0.61)	2.55	0.014
93	1.53	(1.05)	1.00	(0.68)	0.51	(0.57)	2.69	0.011
94	1.59	(1.07)	0.86	(0.66)	0.60	(0.58)	2.76	0.010
95	1.68	(1.09)	0.71	(0.65)	0.75	(0.56)	2.86	0.010
96	1.77	(1.09)	0.57	(0.60)	0.93	(0.54)	3.03	0.011
97	1.87	(1.06)	0.39	(0.55)	1.24	(0.36)	3.67	0.013
98	1.91	(1.06)	0.37	(0.50)	1.47	(0.30)	4.06	0.015
99	1.92	(1.02)	0.34	(0.40)	2.33	(0.21)	6.27	0.021
			B. Home=US; Foreign=UK					
90	-0.43	(0.51)	0.23	(0.39)	0.50	(0.33)	2.52	0.021
91	-0.43	(0.50)	0.22	(0.37)	0.52	(0.34)	2.57	0.021
92	-0.42	(0.50)	0.21	(0.35)	0.54	(0.34)	2.63	0.022
93	-0.42	(0.49)	0.20	(0.33)	0.56	(0.35)	2.81	0.022
94	-0.41	(0.50)	0.19	(0.36)	0.59	(0.34)	2.91	0.023
95	-0.43	(0.49)	0.23	(0.36)	0.56	(0.36)	3.23	0.022
96	-0.47	(0.51)	0.30	(0.36)	0.49	(0.39)	3.62	0.020
97	-0.41	(0.51)	0.18	(0.35)	0.69	(0.26)	3.98	0.025
98	-0.37	(0.51)	0.07	(0.36)	0.98	(0.14)	5.63	0.037
99	-0.42	(0.49)	0.14	(0.30)	1.24	(0.27)	8.20	0.040

NOTE. — Entries report estimates of the following extreme sampling regression:

$$s_{+1} - s_t = \alpha + \beta^S (r_t - r_t^*) I_{t \in S} + \beta^L (r_t - r_t^*) I_{t \in L} + e_{t+1},$$

where S and L denote small and large realizations on the absolute value of the interest rate differentials, respectively. The differentiation between small and large is based on the percentiles of the data, as shown in the first column of the table. The column under $\|dr\|$ reports the critical value of the interest rate differential to make this differentiation for each regression. The last column reports the R-square of each regression. For each estimate $(\alpha, \beta^S, \beta^L)$, the left column reports the regression estimate while the right column reports its standard error in parentheses, which is constructed based on Newey and West (1987) with three lags. The regressions are based on long-term interest rates. Refer to Appendix A for data sources.

TABLE 5
SMOOTH TRANSITION NONLINEAR UIP REGRESSION MODEL

	France/UK		US/UK	
Parameters	Estimates	Std Err	Estimates	Std Err
α	0.014	(0.030)	-0.003	(0.008)
β	-2.544	(2.775)	-0.715	(0.697)
μ	0.022	(0.016)	-0.020	(0.009)
γ	3.183	(2.555)	2.355	(1.924)
$\ln(\lambda)$	7.828	(2.136)	5.731	(1.814)
R-square	0.022		0.039	

NOTE. — Entries report the estimates of the following nonlinear forecasting relation:

$$s_{+1} - s_t = \alpha + \beta (r_t - r_t^* - \mu) + \gamma \left(1 - e^{-\lambda (r_t - r_t^* - \mu)^2}\right) (r_t - r_t^* - \mu) + e_{t+1},$$

The estimates are based on long-term interest rates. Refer to Appendix A for data source.

TABLE 6
HISTORICAL DECOMPOSITION OF UIP DEVIATIONS

Subperiods	dr	ds	$dUIP$	$d\pi$	$d\rho$	$dPPP$	dy
			A. Home=France; Foreign=UK				
1803-1913	**0.89**	**0.07**	**-0.83**	**0.09**	**0.81**	**-0.02**	**-0.25**
1803-1815	1.71	0.42	-1.29	0.51	1.19	-0.10	0.63
1816-1874	0.82	-0.03	-0.85	0.15	0.67	-0.18	-0.48
1875-1913	0.40	0.02	-0.39	0.14	0.26	-0.12	-0.38
1914-1999	**-0.47**	**4.26**	**4.73**	**3.82**	**-4.29**	**0.44**	**0.52**
1914-1925	0.38	11.58	11.20	10.11	-9.74	1.46	1.05
1926-1939	0.20	3.89	3.68	4.07	-3.87	-0.19	-0.63
1940-1949	0.57	17.85	17.28	20.49	-19.92	-2.64	-1.31
1950-1999	-1.07	-0.11	0.96	-1.10	0.03	0.99	1.08
1950-1973	-0.60	0.14	0.74	0.88	-1.48	-0.74	2.07
1974-1999	-1.51	-0.35	1.16	-2.93	1.42	2.58	0.17
			B. Home=US; Foreign=UK				
1800-1913	**1.28**	**0.14**	**-1.14**	**0.19**	**1.09**	**-0.05**	**2.19**
1800-1815	1.29	0.80	-0.49	1.62	-0.32	-0.82	1.65
1816-1860	1.79	0.07	-1.72	-0.63	2.42	0.70	2.21
1861-1874	2.12	0.67	-1.45	1.96	0.16	-1.28	2.99
1875-1913	0.39	-0.24	-0.63	-0.08	0.47	-0.16	2.10
1914-1999	**-1.75**	**-1.28**	**0.46**	**-1.53**	**-0.21**	**0.25**	**1.13**
1914-1925	-0.54	-0.07	0.47	-0.63	0.09	0.56	2.61
1926-1939	-0.91	-0.61	0.30	0.66	-1.58	-1.27	-0.66
1940-1949	-0.84	-1.85	-1.01	-1.26	0.42	-0.59	2.87
1950-1999	-2.45	-1.65	0.80	-2.42	-0.03	0.76	0.92
1950-1973	-2.25	-1.70	0.55	-1.63	-0.62	-0.07	1.10
1974-1999	-2.63	-1.61	1.02	-3.14	0.51	1.53	0.76

NOTE. — The symbols dr, ds, $dUIP$, $d\pi$, $d\rho$, $dPPP$ and dy denote, respectively, the nominal long-term interest rate differential, the percentage change in the nominal exchange rate, the deviation from UIP ($dUIP = ds - dr$), the inflation rate differential, the real interest rate differential ($d\rho = dr - d\pi$), the deviation from PPP ($dPPP = ds - d\pi$), and the real GDP growth rate differential. All figures are expressed in percentage per annum terms. The United Kingdom is the numeraire in all instances.