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Uncovered interest parity: The long and the short of it

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ABSTRACT

Uncovered interest rate parity (UIP) is a theoretical relation linking changes in exchange rates and corresponding interest rate differentials. Despite its considerable intellectual appeal, uncovered interest rate parity has very often been found wanting empirically. I reinvestigate this relation using a 17-country panel of historical time series data at its longest—for the US–UK country pair—spanning 217 years. I find results that are largely consistent with theory: over the long term, in most countries, bond yields expressed in common currency bear a positive relationship to one another as UIP predicts. This is in contrast to the very nearly opposite findings reported in much of the literature and now taken as a stylized fact.

1. Introduction

According to the uncovered interest rate parity (UIP) relation, countries with high interest rates should have depreciating currencies relative to currencies of countries with low interest rates. Most studies, however, have found the opposite. High interest rate countries over quite lengthy periods have often experienced currency *appreciation* rather than depreciation. This in turn has come to be known in the literature as the "forward premium puzzle". The proof of the pudding has also been found in the eating. Among practitioners, the phenomenon of "carry trades"—an implicit bet against UIP in which traders borrow low interest rate currencies (the "funding currencies") and invest in high interest rate currencies (the "target" or "investment currencies")—has become common.[1]

In this study, I re-examine the performance of UIP using an even richer body of long-term historical data. These data span 16 foreign countries and the United States and periods ranging from 90 to 217 years. I find results that are largely consistent with theory: in most countries bond yields expressed in common currency bear a positive relationship to one another as UIP predicts. This is in contrast to the very nearly opposite findings reported in much of the literature and now taken as a stylized fact.

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[1] The recent literature on carry trades is extensive. See for example, Boudoukh et al., forthcoming, Brunnermeier, et al. (2009), Clarida et al. (2009), Menkhoff et al. (2012), Moore and Roche (2012) and Doskov and Swinkels (2015).

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2. Data and theory

The data that I have constructed are for a multi-country panel encompassing 17 countries and over two centuries. These data are for annual US dollar exchange rates and annual long-term bond yields for Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the United Kingdom and the United States. At their longest, for the UK–US country pair, the data span 217 years; at their shortest, for Finland–US, they span 92 years and on average, 157 years. Table 1 contains a list showing the lengths of the data series for 17 countries.

A major reason for focusing on yields of long-term bonds as opposed to yields on short-term money market instruments is data availability. For many countries, short-term money market interest rates simply are not available for very lengthy periods. A secondary, but not unimportant, reason for doing so is that over the longer horizons relevant to bonds, as Chinn and Meredith (2004) have argued, economic “fundamentals,” become more important. Hence, the UIP relation is less apt to be disturbed by idiosyncratic and accidental influences.

Using very long samples does, however, come with some potential costs. One is that the data are not all exact matches. The bond yields are long-term and not homogeneous across countries and in many instances not completely homogenous over time within the various countries.[2] There are, moreover, wartime disruptions to markets in both bonds and currencies and in several cases missing observations for such periods and observations marred by the controls and the liquidity limitations that come with the thin markets characteristic of wartimes and their immediate aftermaths.

Uncovered interest parity posits a link between the exchange rate currencies two countries' and their respective interest rates of the following form:

$$E\left[\Delta s_{t+1}\right]_t = i_t - i_t*, \tag{1}$$

where $E[\Delta s_{t+1}]$ is the expected change from time t to $t+1$ in the log spot exchange rate, conditional on information at time t, and expressed as the foreign-currency price of a unit of the home currency, i_t is the one-period foreign interest rate and i_t* is the one-period home interest rate. If there is a forward market in currencies and covered interest parity is assumed to hold, this equation can be replaced by an equation linking the expected change in the exchange rate to the forward premium:

$$E\left[\Delta s_{t+1}\right] = f_t - s_t, \tag{2}$$

where f_t is the log forward exchange rate.

The bulk of the literature features tests using a regression equation based on (2), like:

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

where $s_{t+1} - s_t$ is the rate of depreciation of the log spot exchange rate, α captures risk premia and possibly other disturbing factors and $E[e_{t+1}] = 0$, $E[e_{t+1}^2] = \sigma^2$, $E[e_t e_s]$, $t \neq s$.

A test of unbiasedness in the absence of risk premia is $(\alpha, \beta) = (0, 1)$.

An alternative is to focus on UIP directly and use the interest differential in place of the forward premium as a predictor of the exchange rate change. Because of the long sub-periods in which exchange rates were fixed in the countries in this paper, and because of concerns about resultant errors-in-variables problems, the regressions that I run are based on a variant of this approach that relates the exchange-rate adjusted interest rate in the foreign country to the US interest rate[3]:

$$i_{j,t} - (s_{t+1} - s_t) = \alpha + \beta i_t * + e_{t+1}, \tag{4}$$

where $i_{,j,t}$ is the long-term bond yield for the jth-country, i_t* is the long-term home country (US) bond yield and $s_{t+1} - s_t$, the one-period change in the log of the spot jth-country vs. USD exchange rate. The null hypothesis of uncovered interest rate parity is $(\alpha, \beta) = (0, 1)$ and a lack of serial correlation in e_{t+1}.

The rationale here is that investments in domestic and foreign bonds on average should generate the same return when denominated in the same currency. Investing in a US bond and holding it to maturity will result in a certain return of i_t*, while investing in a foreign bond, holding it to maturity and converting the proceeds back into the domestic currency, will generate a return of $i_{j,t} - (s_{t+1} - s_t)$, the sum of the foreign yield, which also is certain at time t, plus the currency appreciation or depreciation return, which is uncertain at time t and only becomes known at time $t+1$, the maturity date of the bond.

In the first two decades following the advent of floating rates, there was an outpouring of studies based on Eq. (3) or its UIP variant. The upshot of this research was that the forward rate was a biased predictor of the future spot rate and that UIP was violated. To make matters worse, estimates of the regression slopes, β, were generally found to be negative rather than positive. Hodrick (1987), Lewis (1995) and Engel (1996) summarize this early research. Froot and Thaler (1990) report results of a survey of empirical results obtained in 75 of these studies. In very few cases are the estimates of β positive; on average they are −.88.

[2] The yield data are for varying maturities both across countries and over time within countries. Most are for 10-year maturities or longer. The exceptions are Finland (5 years), Germany (8 to 15 years) and Japan (7 years).

[3] See the discussion in Lothian and Wu (2011) on the problem of errors in variables in standard UIP regressions when exchange rates are fixed.

Table 1
Number of observations by country.

Country	Years
Australia	156
Belgium	182
Canada	156
Denmark	150
Finland	92
France	215
Germany	176
Italy	152
Japan	133
Netherlands	200
New Zealand	109
Norway	150
Spain	182
Sweden	147
Switzerland	100
UK	217
US	217
Mean	157.3

The phrases "forward premium puzzle" and "UIP failure" came into being to describe these findings. Replications of these studies and searches for explanations have continued. Miller (2014) contains a review of this literature as well as much of the earlier literature.

Most of the recent empirical studies use developed country data for various parts of the period from the breakdown of Bretton Woods and advent of floating exchange rates in the early 1970s until recently. Much of this period, however, was dominated by sizable and persistent fluctuations in the US dollar and somewhat later by similar fluctuations in the Euro, suggesting in turn that the negative results may be driven in part by the unique features of this period. A number of studies using data for the early 1920s have reported similarly anomalous behavior, rejecting the hypothesis of forward rate unbiasedness in most instances. See as examples McFarland et al. (1994), Phillips et al. (1996) and Choudhry (2013). Diamandis et al. (2008) do get results more favorable to the forward rate unbiasedness hypothesis for countries that did not experience substantial financial turmoil during that period.

If small sample problems have in fact distorted the earlier results, then an obvious solution is to turn to longer bodies of data in which even fairly long-lived events are not nearly so dominant. This was the principal motivation behind the Lothian and Wu article (2011), which used two-century-long time series data on UIP for France-UK and US-UK. The results of that study were much more in accord with UIP than those typically reported in the literature. Flood and Taylor (1996) and Lothian and Simaan (1998) provide similar evidence using cross-country averaged data. Lothian, Pownall and Koedijk (2013) report additional evidence supporting UIP using both long-term UK vs. US time series data and a recent sample of multi-country cross-section data. See Moosa and Bhatti (1997) and Lambelet and Mihailov (2007) for further supportive evidence of UIP in the context of the three international parity conditions.

A number of researchers, beginning with Huisman et al. (1998), have focused on non-linearities, in the UIP relation. These researchers generally find that large interest rate differentials have much better forecasting power for currency movements than small interest rate differentials. The studies here include Chaboud and Wright (2005), Sarno, et al. (2006), Baillie and Kilic (2006) and Lothian and Wu, (2011).

Other researchers have examined the temporal stability of UIP regressions. A common finding here is that periods in which estimates of β are positive and closer to the theoretical value of unity alternate with periods in which the estimates are close to zero or negative. See here Bansal (1997), Baillie and Bollerslev (2000), Bansal and Dahlquist (2000), Baillie and Kilic (2006), Lothian and Wu, (2011) and Baillie and Cho (2014).

Another strain of the literature focuses on differences in the volatility and levels of underlying economic variables as influences on the behavior of UIP, On the effects of differences in volatility see Brunnermeier et al. (2009), Moore and Roche (2012), Menkhoff, et al. (2012), and Coudert and Mignon (2013). Bansal and Dahlquist (2000) using a broad cross section of countries find that the negative correlation between the expected rate of currency depreciation and the interest- rate differential is confined to developed economies in situations in which the US interest rate is greater than the foreign interest rate, They find that differences among country pairs bear a systematic relationship to per capita GNP, the level and variability of inflation.

The potential importance of various idiosyncratic factors in disturbing the UIP relation goes back to Irving Fisher's Appreciation and Interest (1896).[4]

[4] See Lothian et al. (2013) for discussion of Fisher's theoretical and empirical work on UIP including his peso-problem type explanation for empirical violations of the relationship between interest rates and exchange rates.

Friedman and Schwartz (1983, pp. 556–557), in the course of their analysis of interest rate behavior, provide an illuminating more recent discussion of this phenomenon in the context of US historical experience. They write:

> One way that [the rational expectations hypothesis] has been made operational is by regarding rationality of expectations as requiring that on average the expectations are correct and hence by testing rationality of expectations by the direct or indirect comparisons of expectations with the actual subsequent values of variables about which expectations were formed.

But doing so, they argue, can be quite problematic. As a case in point, they cite the period from 1880 to 1896 in the United States:

> It was surely not irrational by a commonsense interpretation of [the] term [rational expectations] for participants in the financial markets to fear that a growing political support for free silver would lead the United States to depart from the gold standard and to experience subsequent inflation—and this despite actual deflation during the period…
>
> As it happened, the departure from gold was avoided. That does not prove that the persons who bet the other way were wrong—any more than losing a two-to-one wager that a fair coin will turn up heads proves that it was wrong to take the short side of that wager. Given a sufficiently long sequence of events, of course, it could be maintained that all such events will average out, that in the century our data cover, for example, there are enough independent episodes so that it is appropriate to test rationality of expectations by their average accuracy. But that is cold comfort, since few studies cover so long a period, and our aim is surely to derive propositions that can be applied to shorter periods. Moreover, one hundred years only contain six periods as long as that from 1880 to 1896, hardly a sufficiently large sample to assure "averaging out."

Indeed that is the major reason for my choice of data for this study, to see whether when all is said and done the tendency for UIP to assert itself over the long term would in fact emerge in the broader body of data used here. Strengthening my belief that this might be the case were the studies of purchasing power parity (PPP) that I and others have conducted. See, for example, Lothian and Taylor (1996) and Lothian and Simaan (1998). In the shorter spans of post-Bretton Woods data used to investigate purchasing power parity in the 1970s and 1980s, purchasing power parity seemed not to hold at all. New tests using much longer data series, however, pointed to mean reversion of real exchange rates.

3. Empirical results

Table 1 provides a list showing the number of observations by country. These figures exclude missing observations for a number of the countries due to wartime and other disruptions. Table 2 reports the results of the regressions of adjusted foreign returns on US returns for the 16 foreign countries in the sample. These regressions all took the form of equation (4). Shown in the table are the coefficient estimates and their standard errors directly beneath them, conventional t statistics for tests of the hypothesis that the coefficient are zero are in parentheses below the standard errors, additional *t* statistics for tests of the hypothesis that $\beta = 1$ are in brackets. Also shown are the R^2s and standard errors of the regressions.

Two features of these regressions in particular stand out. The first is the sign and magnitude of the slope coefficients in the regressions. Fig. 1 shows the frequency distribution of these estimates. All of these estimates are positive. Three fourths of them, moreover, are in the .75 to 1.25 range. Their average is 1.05.

In all but two instances, we can reject the hypothesis that $\beta = 0$ at levels of significance of .05 or better. The exceptions are Finland, for which we can only reject at the .10 level and Switzerland for which we cannot reject at any conventional level. In no instance can we reject the related hypothesis that the regression intercept term is zero at the .05 level of significance.

Table 3 shows the results of two regressions run on the pooled data. The first regression is a regression with a single intercept for all of the countries. The second includes country-fixed effects. These regressions tell virtually the same story as those reported in Table 2. The slope coefficients in both regressions are very close to unity and the intercept in the first regression is not significantly different from zero. Returns expressed in the same currency, therefore, are related positively and in most instances close to one-to-one. The UIP relation, therefore, does in fact appear to hold over the long run.

If over the short run idiosyncratic factors of various sorts have played a role in disturbing the UIP relation, it seems likely that their effects would be broad based and not simply confined to one or two currency pairs. The late nineteenth century free-silver episode that Friedman and Schwartz describe is a good example. In the data used here, in which the United States is the country of reference, the effects of that episode almost certainly extended beyond the US and UK bond markets analyzed by Friedman and Schwartz. But it would also very likely be the case for a shock emanating from one of the other countries in the sample given the close links among these countries over much of the sample period.

To investigate this phenomenon, I computed the pairwise correlations of the residuals from the pooled regression with the single intercept for the subsample of countries for which I had full data for the past 150 years, Australia, Belgium, Canada, Denmark, France, Italy, the Netherlands, Norway, and the UK and for Sweden versus the other nine countries, for 147 years. All 45 of these correlations are positive and all but one is statistically significant at .05 or better. The mean of the 45 correlations is .46.

The other notable feature of the regression results is the very low R^2 obtained in virtually every one of the individual currency-pair regressions as well as in the pooled regressions. In the individual currency-pair regressions, the average R^2 is only .054 and in

Table 2
Results of returns regressions.

Country	n_{obs}	α	β	R/SEE
Australia	156	−0.267	0.941	0.047
		2.029	0.342	9.516
		(−0.131)	(2.753)	
			[0.173]	
Belgium	182	−2.003	1.082	0.039
		2.375	0.401	11.265
		(−0.843)	(2.695)	
			[−0.204}	
Canada	156	0.088	0.887	0.182
		0.900	0.152	4.220
		(0.098)	(5.851)	
			[0.747]	
Denmark	150	−1.427	1.269	0.072
		2.212	0.373	10.348
		(−0.645)	(3.399)	
			[−0.721]	
Finland	92	−3.848	1.365	0.034
		4.961	0.764	19.697
		(−0.776)	(1.786)	
			[−0.477]	
France	215	−8.598	2.054	0.044
		3.982	0.656	19.402
		(−2.159)	(3.132)	
			[−1.607]	
Germany	176	−0.205	0.870	0.023
		2.635	0.427	11.067
		(−0.078)	(2.039)	
			[0.305]	
Italy	152	−7.863	1.900	.052
		3.923	.663	18.370
		(−2.004)	(2.866)	
			[−1.358]	
Japan	133	0.155	0.918	0.054
		2.038	0.335	8.682
		(0.076)	(2.743)	
			[0.244]	
Netherlands	200	0.212	0.771	0.041
		1.580	0.266	7.595
		(0.134)	(2.901)	
			[0.860]	
New Zealand	109	0.499	0.744	0.038
		2.237	0.365	9.868
		(0.223)	(2.042)	
			[0.701]	
Norway	150	−0.451	0.951	0.047
		2.083	0.352	9.745
		(−0.216)	(2.704)	
			[0.139]	
Spain	182	−0.298	1.112	0.037
		2.542	0.426	11.675
		(−0.117)	(2.612)	
			[−0.264]	
Sweden	147	0.884	0.700	0.031
		1.908	0.323	8.927
		(0.463)	(2.166)	
			[0.930]	
Switzerland	100	2.570	0.530	0.018
		2.507	0.394	10.360
		(1.025)	(1.347)	
			[1.193]	
UK	217	−.340	.740	.049.
		1.358	.222	6.659.
		(−.253)	(3.327)	
			[1.171]	

Notes: Regressions took the form $i_{j,t} - (s_{t+1} - s_t) = \alpha + \beta i_t{}^* + e_{t+1}$, where $i_{j,t}$ is the long-term government bond yield for the jth-country, $i_t{}^*$ is the long-term home country (US) government bond yield and $s_{t+1} - s_t$ is the one-period change in the log of the spot jth-country vs. USD exchange rate. The figures in the first and second lines below the coefficient estimates are standard errors of the coefficients and in parentheses conventional t values, respectively. The figures in the bottom lines in brackets are t values for tests of the hypothesis $\beta = 1$.

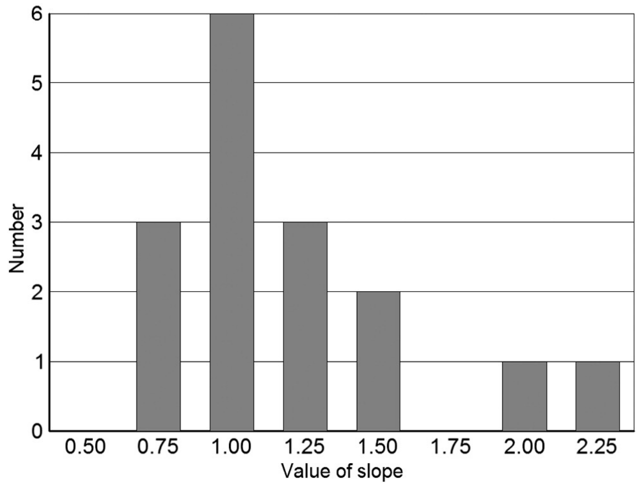

Fig. 1. Frequency distribution of slope coefficient estimates in Table 2.

Table 3
Results of returns regressions with pooled data.

Regression	n_{obs}	α	β	R^2/SEE
Pooled, single intercept	2651	−1.306	1.048	0.038
		0.618	0.102	11.632
		(−2.113)	(10.235)	
			[−0.471]	
Pooled, country intercepts	2651		1.031	0.044
			0.089	11.631
			(11.638)	
			[−0.351]	

Note: See Table 2.

only in the case of Canada is the R^2 greater than .10. In the pooled regression with a single intercept, it is .038 and with fixed effects it is .044. So while UIP receives support in these regressions, it nevertheless explains very little, as Lothian and Wu (2011) previously documented.

4. Conclusions

Replication of experiments is part of any science. In this paper, I replicate the earlier work by Lothian and Wu (2011) that used ultra-long time series for UK-France and UK- and the extension of that work for UK-US by Lothian et al. (2013). To do so I constructed a multi-country panel of similarly long historical series that includes an additional 14 countries. The results that I get are in line with those reported in those two earlier studies and quite different from those reported in most of the literature. Here, the UIP puzzle, as conventionally defined, disappears. The longer sample period used in this study and in the two earlier studies appears to be the reason. In principle, it allows small-sample departures to cancel one another out and they apparently do so.

The issue, I believe, now becomes one of short- vs. long-run validity of the theory rather than validity per se. This, in turn, can inform future research and help redirect thinking with regard to the reasons for the poor performance of UIP over shorter periods.

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