Uncovered Interest Parity in a Partially Dollarized Developing Country: Does UIP Hold in Bolivia? (And If Not, Why Not?)*

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Abstract

According to the Uncovered Interest Parity (UIP) condition, interest rate differentials compensate for expected exchange rate changes, equalizing the expected returns from holding assets which only differ in terms of currency denomination. In the previous literature, there are many tests of UIP for industrialized countries, and, more recently, some tests for emerging economies. However, due to data availability problems, poorer developing countries have not been studied. This paper tests UIP in a partially dollarized economy, Bolivia, where bank accounts only differ in terms of currency denomination (U.S. dollars or bolivianos). I find that UIP does not hold in Bolivia, but that the deviations are smaller than in most other studies of developed and emerging economies. Moreover, several factors seem to contribute to the deviations from UIP. The so-called peso problem could possibly account for the observed data, but there is also evidence of a time-varying risk premium, as well as deviations from rational expectations.

Keywords: Uncovered interest parity, UIP, partial dollarization, time-varying risk premium, peso problem, rational expectations.
JEL codes: E43, F31, G15.

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1 Introduction

The Uncovered Interest Parity (UIP) condition states that interest rate differentials compensate for expected exchange rate changes, thereby equalizing the expected returns from holding any two currencies. UIP is a cornerstone assumption in open-economy macroeconomic models, but there is substantial evidence that the condition fails to hold empirically. Moreover, imposing UIP or not matters significantly for the quantitative results in dynamic stochastic general equilibrium (DSGE) models, as shown for example by Adolfson, Laséen, Lindé, and Villani (2008).

There is an extensive empirical literature which tests UIP.[1] Ideally, empirical tests of UIP should use interest rates on assets which are identical in every respect except currency denomination. Otherwise, deviations from UIP can be due to "political risk", i.e. deviations from Covered Interest Parity due to the presence or possible imposition of capital controls.[2] Data availability is not a problem for developed countries and emerging markets where eurocurrency interest rates and/or forward exchange rates exist. Therefore, almost all previous papers study industrialized countries (and to some extent emerging markets) rather than poorer, developing countries where such data do not exist.

The contribution of this paper is to fill this gap in the literature by studying a partially dollarized developing country, Bolivia, where deposits in different currencies only differ in terms of currency denomination and not in terms of political risk. The idea is to test UIP by using interest rates on assets in the same location (Bolivia) which only differ in terms of currency denomination (bolivianos and US dollars). This approach is analogous to the method used by Asplund and Friberg (2001) who test the Law of One Price by using prices

[1] For literature surveys, see Froot and Thaler (1990), Engel (1996), Isard (2006) and Chinn (2006).

[2] See Aliber (1973) and Dooley and Isard (1980).

on goods in the same location (Scandinavian duty-free stores) which only differ in terms of currency nomination (Swedish kronor and Finnish markka). In both cases, the idea is to use good data to construct a clean test of theoretical predictions.

A similar paper by Poghosyan, Kocenda, and Zemcik (2008) uses data from another partially dollarized developing economy (Armenia) to test UIP. My paper is different in a number of ways. First, I have a 50% larger data set with 12 years of weekly data. This diminishes the risk of small-sample bias. Second, Bolivia has had a fixed exchange rate regime (crawling peg against the U.S. dollar) rather than a freely floating exchange rate. Previous papers have found differences in the extent of UIP deviations between countries with fixed and floating exchange rates, which makes it interesting to study different regimes. Third, I study the ability of several possible factors to explain the deviations from UIP (time-varying risk premia, the so-called peso problem and deviations from rational expectations).

The main result of this paper is that UIP is rejected in the case of Bolivia. However, the rejection is less clear than in most previous studies of developed countries or emerging markets. In particular, there is no sign of any "forward premium puzzle", i.e. the common empirical result that high interest-rate currencies tend to *appreciate* (rather than depreciate as predicted by UIP). Another finding is that several different factors seem to contribute to the deviations from UIP.

The rest of this paper is organized as follows. Section 2 presents the theory behind UIP as well as the previous empirical evidence. In section 3, I describe the most important candidate explanations for empirical deviations from UIP, with a special focus on methods for empirical testing. Section 4 presents the data set and the main empirical analysis, while section 5 empirically investigates alternative explanations for deviations from UIP in Bolivia. Finally, section 6 concludes the paper.

2 The UIP hypothesis and previous empirical tests

In this section, I first describe the UIP hypothesis and derive a regression equation which is often used for empirical testing. Then I summarize the previous empirical literature.

2.1 The UIP hypothesis

Perhaps the most well-known theoretical relationship between interest-rate differentials and expected currency depreciation is known as Uncovered Interest Parity (UIP). If investors are risk-neutral and have rational expectations, interest rate differentials should compensate for expected depreciations so that the expected returns from holding any two currencies are equal. More formally, the UIP hypothesis can be expressed as:

$$1 + i_t = (1 + i_t^*)E_t(\frac{S_{t+k}}{S_t}) \tag{1}$$

where i_t and i_t^* are domestic and foreign interest rates with maturity k at time t, and S_t is the exchange rate at time t (expressed as domestic currency units per unit of foreign currency, so that an increase means a depreciation of the domestic currency). Taking logs of both sides of equation (1) gives :

$$\ln(1 + i_t) = \ln(1 + i_t^*) + \ln(E_t(\frac{S_{t+k}}{S_t})). \tag{2}$$

Expected exchange rates are not directly observable, so it is not possible to use equation (2) as a basis for empirical testing. Assuming rational expectations, using the approximation that $\ln(1+x)$ is close to x for small x and rearranging gives:

$$s_{t+k} - s_t = i_t - i_t^* + \varepsilon_{t+k} \tag{3}$$

where $s_t \equiv \ln(S_t)$ and ε_{t+k} is a rational expectations forecast error.[3]

Hence, in the regression:

$$s_{t+k} - s_t = \alpha + \beta(i_t - i_t^*) + \varepsilon_{t+k} \tag{4}$$

the coefficient values are $\alpha = 0$ and, in particular, $\beta = 1$, under the UIP hypothesis. A positive interest rate differential in favor of the domestic currency should, on average, be associated with a future depreciation of the domestic currency of equal magnitude. Ex-post returns from holding different currencies will differ, but only because of random rational expectations errors in the exchange rate forecasts.

An equivalent empirical specification could be obtained by replacing the interest differential on the right-hand side of equation (4) by the forward premium, i.e. the percentage difference between the forward and spot exchange rates. A forward premium means that the foreign currency is more expensive (sells at a premium) on the forward market than on today's spot market, i.e. the k-period log forward exchange rate, $f_{t,t+k}$, is higher than the current log spot exchange rate, s_t. The equivalence between the interest differential and the forward premium is known as Covered Interest Parity (CIP), and holds very well empirically (except perhaps during periods of financial market turmoil, as shown by, for example, Baba and Packer (2008)). CIP is an arbitrage condition

[3] The derivation ignores a Jensen's inequality term, which is very small empirically (see Engel (1996) for a discussion and references).

and thus holds even if investors are not risk neutral.[4]

2.2 Previous empirical tests of UIP

Equation (4) has been estimated in a large number of studies, for different countries and time periods.[5] In almost every study, the estimated β coefficient is significantly smaller than one, which is the value predicted by UIP. In fact, β is often estimated to be negative. Froot (1990) reports an average estimate across a large number of studies of -0.88, which constitutes strong evidence against UIP. A negative β coefficient has a surprising economic interpretation. When the domestic interest rate is higher than the foreign interest rate, the domestic currency on average *appreciates* (rather than depreciates by enough to exactly offset the interest rate differential, as predicted by UIP). The common finding of a negative β coefficient is known as the "forward premium puzzle" or "forward discount bias", since it implies that the forward market systematically mispredicts the direction of currency movements.[6]

Chinn (2006) runs UIP regressions using data from the G7 countries over the period 1980-2000 and does not find any evidence that the puzzle is becoming less pronounced over time. However, UIP seems to hold better at longer horizons. Most early studies which rejected the UIP hypothesis used data from industrial countries with floating exchange rates. More recent work, for example that by

[4] Assume that CIP did not hold, for example that a positive forward premium $(f_{t,t+k} - s_t)$ is smaller than a positive interest differential $(i_t - i_t^*)$. In other words, the positive interest differential more than compensates for the expected depreciation of the domestic currency in the forward market. Then it would be profitable to borrow abroad at the low foreign interest rate, exchange the foreign currency into domestic currency, invest the money at the high domestic interest rate and sell forward the returns in domestic currency. The interest rate gain would be larger than the currency loss, thus making a riskless profit possible. Such riskless profit opportunities will be arbitraged away, regardless of investor risk preferences.

[5] For surveys of the empirical literature, see Froot and Thaler (1990), Engel (1996), Isard (2006) and Chinn (2006).

[6] In equation (4), let us replace the interest differential by the forward premium. Suppose that the forward market predicts that the domestic currency will *appreciate*. The forward premium term $(f_{t,t+k} - s_t)$ is negative, so there is a forward discount. Then, a negative β coefficient implies that the (average) actual currency movement will be the opposite of the prediction of the forward market; the domestic currency will *depreciate*.

Flood and Rose (1996) and Bansal and Dahlquist (2000), also studies countries with fixed exchange rates and emerging economies. Flood and Rose (1996) find that UIP holds better for fixed exchange rates than for floating exchange rates. The authors point out that there is no *theoretical* reason to expect any difference across exchange rate regimes, but that the potential *empirical* peso problem is only present in fixed exchange rate countries. The problem arises when the sample includes periods when the interest rate is high to compensate for a small-probability, major depreciation, but is too short to include such depreciations. Thus, to the extent that the peso problem is a significant cause of UIP deviations in countries with fixed exchange rates, we should expect UIP to hold better empirically in countries with floating exchange rates. The evidence to the contrary presented in the paper is therefore puzzling. In contrast, Flood and Rose (2001) find that UIP, if anything, holds better for floating exchange rate countries, and they do not find any significant differences between countries with different income levels. Bansal and Dahlquist (2000) find that the forward premium puzzle is only present in industrial countries where the interest rates are lower than the U.S. interest rate, and not in emerging markets. Frankel and Poonawala (2006) also find smaller deviations from UIP for emerging markets.

A paper by Poghosyan, Kocenda, and Zemcik (2008) investigates whether UIP holds in Armenia. The authors use the fact that Armenian banks offer households a choice between domestic and foreign currency accounts. Such deposit accounts only differ in currency denomination and therefore provide useful interest rate data for tests of UIP. The authors find that UIP holds better than in many other studies, but there is evidence of positive and time-varying deviations from UIP, such that holders of domestic currency earn a higher average return. The paper investigates whether an affine term structure framework and GARCH-M methodology can produce such time-varying risk premia and obtain mixed results.

Some similar empirical work has been carried out at Banco Central de Bolivia. However, there are certain problems with the data and the empirical methodology. Morales (2003) estimates a version of the standard UIP regression with a yearly horizon using monthly data on domestic deposit rates for the period 1990-2003. He finds significant deviations from UIP. The main problem with the study is that Morales uses an average of interest rates across all available maturities, which is inconsistent with the yearly horizon used in the empirical specification. Another problem is that the combination of a yearly horizon and monthly observations induces moving-average serial correlation into the residuals, which is not taken into account in the estimation (Newey-West standard errors must be used). Finally, both the interest rate and the exchange rate data are monthly averages. Daily data or at least weekly averages would be preferable.

Morales also investigates the ability of the Ize and Levy Yeyati (2003) model to account for dollarization in Bolivia since the early 1990's. The model assumes that UIP holds and that depositors' choice of currency portfolio depends on the volatilities of real returns in dollars and bolivianos. The model does poorly and Morales views this as evidence against the time-varying risk premium explanation of UIP deviations. Therefore, he interprets all deviations from UIP as stemming from peso problems.

Escóbar (2003) uses interbank interest rates and finds evidence of non-cointegration between the interest differential and depreciation, which is naturally very problematic for the UIP hypothesis. However, the empirical methods suffer from the same problems as those in Morales' paper.

3 Different explanations for the empirical deviations from UIP and how to test them

As discussed in the previous section, there is abundant empirical evidence against UIP. But what are the underlying causes of the empirical deviations from UIP? There are three main explanations in the literature: the peso problem, time-varying risk premia and deviations from rational expectations.[7]

Before discussing these different explanations in more detail, it should be noted that the economic importance of deviations from UIP has been questioned by some authors. Burnside, Eichenbaum, Kleshchelski, and Rebelo (2006) argue that deviations from UIP do not necessarily imply unexploited profit opportunities, and that statistically significant deviations are of little economic significance. Similarly, Sarno, Valente, and Leon (2006) find evidence of nonlinear deviations from UIP, which is consistent with limits to speculation. Nevertheless, UIP is a key assumption in many macroeconomic models and a better understanding of empirical deviations from parity remains an important research challenge.

3.1 The peso problem

The peso problem (named after the Mexican currency) has been prominent in policy discussions in Bolivia and is viewed as a likely explanation for UIP deviations. If the sample is short and includes periods when investors put a small, but positive, probability on a large depreciation, but does not include periods when such large depreciations actually occur, then the estimated beta coefficient will have a downward bias. Domestic interest rates will tend to be high to compensate for an expected depreciation, but an actual depreciation

[7] Other explanations are monetary policy responses to exchange rate changes (McCallum (1994)), endogenous asset market segmentation (Alvarez, Atkeson, and Kehoe (2009)) and infrequent portfolio decisions (Bacchetta and van Wincoop (2009)).

does not occur in the sample.[8] Flood and Rose (1996) try to quantify the peso problem bias by testing UIP for two different samples of fixed exchange rate data: one full sample including realignment periods and one smaller sample excluding such periods. The estimated β coefficient for the full sample should not suffer from any bias, while the estimate using the smaller sample should be biased downwards due to the peso problem. By comparing the two estimated β coefficients, the authors estimate the peso problem bias to be -0.5.

Another possible explanation for UIP deviations, which is also related to expectations, is gradual investor learning of exchange rate regime shifts, for example from fixed to floating. Lewis (1989) finds some evidence of such expectational errors, but notes that they do not seem to decrease over time, which contradicts the learning hypothesis.

3.2 Time-varying risk premia

A second possible explanation for UIP deviations is a time-varying risk premium which is correlated with the expected depreciation and thus with the interest differential. Any time-varying risk premium is part of the residual in the UIP regression and its correlation with the regressor causes the estimated beta coefficient to be biased. The issue is best understood by decomposing the interest rate differential into an expected depreciation and a risk premium.[9] The decomposition can be expressed as $i - i^* = E(depr) + rp$, where $i - i^*$ is the interest rate differential, $E(depr)$ is the expected depreciation and rp denotes the risk premium. Using the expression to substitute for the interest differential in equation (4), the β coefficient can be expressed as follows:

$$\beta = \frac{Cov(depr, i - i^*)}{Var(i - i^*)} = \frac{Var(E(depr)) + Cov(rp, E(depr))}{Var(rp) + Var(E(depr)) + 2Cov(rp, E(depr))}. \quad (5)$$

[8] See Rogoff (1980) and Krasker (1980) for early discussions of the peso problem and Lewis (1995) for a survey.

[9] See Fama (1984) and Hodrick and Srivastava (1986) for more details.

First, suppose that the risk premium is constant ($Var(rp) = 0$), which implies that the covariance between the risk premium and expected depreciation is zero ($Cov(rp, E(depr)) = 0$). Then we have $\beta = 1$ and thus UIP holds. In contrast, suppose that $Cov(rp, E(depr)) < 0$ and that $Var(rp) > |Cov(rp, E(depr))| > Var(E(depr))$. Under these conditions β is negative and thus there is a forward premium puzzle. Intuitively, investors demand such a large risk premium for holding risky high-interest rate currencies that those currencies are expected to appreciate rather than depreciate. Holders of the risky currencies are compensated both by higher interest rates and by currency appreciation.

There are three different methods that have been used to test the risk premium explanation. One approach for testing the risk premium explanation is to examine whether the predictable excess returns caused by the forward discount bias can be explained by the expected variance of future returns. Domowitz and Hakkio (1985) were the first authors to use an autoregressive conditional heteroscedasticity (ARCH) model to obtain a measure of the expected variance. A second approach is to use a fundamentals-based model of time-varying risk premia, as in, for example, Giovannini and Jorion (1989). Finally, a third method for testing the risk premium explanation is to obtain a survey-based measure of expected depreciation rather than to rely on ex-post depreciation as a proxy. Froot and Frankel (1990) use a survey measure of expected depreciation to decompose the estimation bias into a risk premium bias and an expectational bias. They find that although the risk premium varies over time, it is not correlated with the expected depreciation and hence it cannot cause a downward bias in β. Instead, there is evidence of systematic prediction errors.

3.3 Deviations from rational expectations

The third and final possible explanation for the deviations from UIP is deviations from rational expectations. Froot and Thaler (1990) discuss the hypothesis that at least some investors respond to interest rate differentials with a lag. The hypothesis is testable, since it predicts that not only current but also lagged interest differentials affect the exchange rate in a UIP regression. Froot (1990) presents supportive empirical evidence. Similarly, Chinn (2006) finds that UIP holds better when using survey-based measures of expected depreciation.

4 An empirical test of UIP in Bolivia - data and results

4.1 The data set

The data set has been compiled from the Monthly Bulletins of Banco Central de Bolivia. It consists of weekly averages for nominal deposit interest rates in Bolivia for the period April 1994 – November 2006 and daily observations on the boliviano-dollar exchange rate for the same period. There are a number of different deposit rates which differ in terms of currency denomination (bolivianos or U.S. dollars) and maturity range (1-30, 31-60, 61-90, 91-180, 181-360 or 361-720 days). Data is also available on interbank rates and sight deposit rates. However, as pointed out by Escóbar (2003), interbank and sight deposit transactions are primarily made for transaction rather than investment purposes, which makes such rates less relevant for testing UIP. In Bolivia, there is no forward market, so I use the interest differential specification rather than the equivalent forward discount specification.

Figure 1 presents the boliviano-dollar interest differential and depreciation

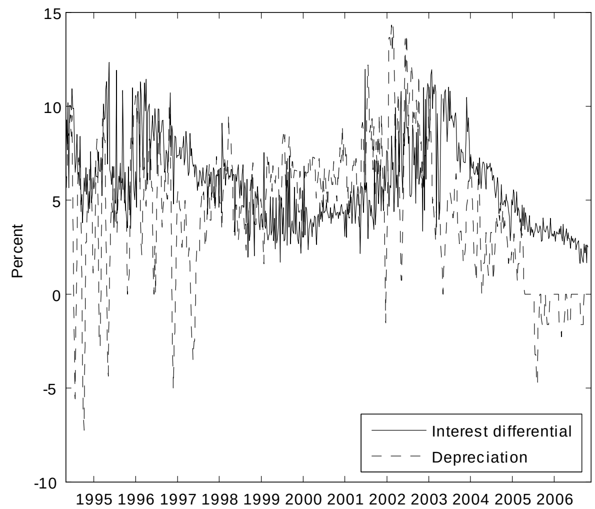

Figure 1: Deposit interest rate differential (boliviano-dollar) and depreciation of boliviano for the interest rate maturity range 1-30 days.

for the interest rate maturity range 1-30 days. The interest differential between bolivianos and dollars is always positive, i.e. deposits denominated in bolivianos yield a higher interest rate. Moreover, depreciation is generally positive, so the value of the boliviano against the dollar falls over time.

Some data transformations are necessary before proceeding to the empirical testing. The interest rate data are weekly; each observation is a weekly average of the interest rates registered for all deposit transactions during the week. In contrast, the exchange rate data are daily. To get the same frequency for all series, I convert the daily exchange rate data to a weekly frequency by calculating the average exchange rate for each week.

Another issue is that the exact interest rate maturity for each maturity range is not observable in the data. For example, should we match the interest rate with a 31-60 day maturity with the depreciation for, say, 33, 48 or 56 days? I

Table 1
Average interest rate maturity

		Maturity range (days)					
		1-30	31-60	61-90	91-180	181-360	361-720
BOB	Mean	30	52	85	160	294	414
	(Std dev)	(0)	(9)	(7)	(21)	(53)	(88)
USD	Mean	30	40	86	155	245	398
	(Std dev)	(0)	(10)	(8)	(27)	(73)	(1)
P-value for t-test		N/A	0.03**	0.85	0.87	0.97	0.04**
Average maturity (days)		30	46	85	158	265	406
Average maturity (weeks)		4	7	12	23	38	58

Note: the table presents average interest maturities for the different maturity ranges. The t-test p-value presented in the table is the p-value for a two-sided t-test for pairs of average maturities (weighted by transaction amount) for each currency, maturity range and date. The null hypothesis is that the pair of average maturities is generated from populations with the same mean. ** denotes significance at the 5% level.

deal with this problem by examining individual deposit transaction data for 12 specific dates during the period 2001-2006 (end-May and end-November). First, for each date, I calculated the volume-weighted average maturity within each range (separately for boliviano and dollar deposits). Second, I calculated the average maturity across the 12 dates within each range (separately for bolivianos and dollars). Finally, for each maturity range, I took the average of the boliviano and dollar maturities to get one single maturity for each range. The results are presented in Table 1. The data in the 1-30 day range are particularly reliable, since the transactions have exactly a 30-day maturity in all cases examined. In most other cases, the difference between the boliviano and dollar maturities is insignificant. The only exceptions are the maturity ranges 31-60 and 361-720 days, where the difference in maturity between boliviano and dollar interest rates is statistically significant at the 5% level. However, the estimated difference in maturity is only 10-15 days, so in quantitative terms the problem is not important.

Before proceeding to the estimation, I carry out a number of unit root tests

Table 2

Unit root tests for interest rate and depreciation variables

Variable	P-values for unit root test					
	ADF_CT	ADF_C	ADF_N	PP_CT	PP_C	PP_N
BOB 1-30	0.00***	0.59	0.08*	0.00***	0.00***	0.06*
BOB 31-60	0.21	0.88	0.04**	0.00***	0.00***	0.20
BOB 61-90	0.05*	0.66	0.00***	0.00***	0.00***	0.10*
BOB 91-180	0.05*	0.08*	0.00***	0.00***	0.00***	0.06*
BOB 181-360	0.00***	0.31	0.03**	0.00***	0.11	0.28
BOB 361-720	0.29	0.15	0.08*	0.00***	0.10	0.31
USD 1-30	0.55	0.87	0.04**	0.07*	0.81	0.07*
USD 31-60	0.81	0.83	0.04**	0.00***	0.73	0.10
USD 61-90	0.42	0.75	0.10	0.02**	0.72	0.09*
USD 91-180	0.87	0.78	0.07*	0.43	0.67	0.11
USD 181-360	0.66	0.71	0.14	0.00***	0.50	0.14
USD 361-720	0.77	0.77	0.12	0.07*	0.60	0.19
Depr 1-30	0.53	0.37	0.19	0.00***	0.00***	0.00***
Depr 31-60	0.73	0.57	0.23	0.01**	0.00***	0.03**
Depr 61-90	0.83	0.74	0.32	0.17	0.07*	0.05*
Depr 91-180	0.86	0.75	0.29	0.88	0.75	0.25
Depr 181-360	0.95	0.92	0.39	0.96	0.92	0.38
Depr 361-720	1.00	1.00	0.43	0.99	0.98	0.42

Note: the table presents p-values for various unit root tests for the interest rate and depreciation variables for different maturities. BOB denotes the boliviano interest rate in Bolivia, USD is the US dollar interest rate in Bolivia and Depr is depreciation. The unit root tests are ADF (Augmented Dickey-Fuller) and PP (Phillips-Perron) using different assumption regarding the deterministic regressor (CT = constant and trend, C = constant and N = no constant or trend). ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

for the following variables (for each maturity range): interest rate in bolivianos, interest rate in dollars and depreciation. The results are presented in Table 2. With the exception of the depreciation variables for the longer maturity ranges, the null hypothesis of a unit root is always rejected by at least some of the tests. Moreover, the non-rejection cases could be partially due to the low power of unit root tests. In the following, I treat all variables as stationary.

4.2 Empirical results: does UIP hold in Bolivia?

I do not use the standard UIP regression equation (4) since the approximation that x is close to $\ln(1+x)$ only holds for small x, and interest rates in Bolivia have at times been quite high. Without the approximation and lagging by k periods, the following regression equation is obtained:

$$s_t - s_{t-k} = \alpha + \beta[\ln(1 + i_{t-k}) - \ln(1 + i^*_{t-k})] + \varepsilon_t. \tag{6}$$

I present the OLS estimation results in Table 3. The estimated β is much lower than 1 for each maturity range and the UIP restriction $\beta = 1$ is always rejected. However, the estimated β coefficients are larger than those obtained in many other studies, where the coefficients are often negative (for developed countries) or close to zero (for emerging markets). The point estimates of β are positive in all cases. For the three shortest maturity ranges, the coefficients are significant at the 5% or 10% level, with point estimates of 0.31, 0.20 and 0.21, respectively. For the longer maturity ranges, the coefficients are closer to zero and insignificant. To some extent this could be due to measurement error in the longer-maturity interest rate data (which would cause a downward bias).[10]

These results are clearly more favorable to UIP than those previously obtained for developed countries, where the coefficients are often negative. They are also more favorable than previous results for emerging markets. Bansal and Dahlquist (2000) pool data from a number of emerging market countries and estimate a coefficient of 0.19, but with a standard error of 0.19. In sum, UIP does not hold in Bolivia, but the deviations are smaller than in previous studies.

The question is whether the relative success of UIP in Bolivia is due to the high-quality data set – with better dollar interest rate data than in existing

[10] In contrast, Chinn (2006) finds that UIP fails less clearly at longer horizons (using data from developed countries).

Table 3

OLS estimation of standard UIP regression

	Maturity range (days)					
	1-30	31-60	61-90	91-180	181-360	361-720
α	2.76***	3.32***	3.37***	3.77***	3.59***	3.37***
	(0.84)	(0.73)	(0.72)	(0.66)	(0.65)	(0.82)
β	0.31**	0.20*	0.21*	0.13	0.10	0.02
	(0.14)	(0.11)	(0.12)	(0.11)	(0.09)	(0.11)
P-value	0.00	0.00	0.00	0.00	0.00	0.00

Note: the estimated equation is $s(t)-s(t-k) = \alpha+\beta[\ln(1+i(t-k))-\ln(1+i^*(t-k))]+\varepsilon(t)$ where s is the log exchange rate (defined as bolivianos per dollar) and k is the interest rate maturity in weeks for each range (from Table 1). The depreciation variable was multiplied by 52/k to get an annualized measure corresponding to the annual interest rates. Newey-West standard errors (robust to heteroscedasticity and autocorrelation) are reported in parenthesis. The reported p-value is associated with the chi-square statistic for a Wald test of the restriction β=1 (which holds under UIP). ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

studies for emerging markets – or whether the results would be similar using more standard data for the dollar interest rate. In particular, would the results differ substantially if we used interest rates on certificates of deposit (CODs) in the United States instead of interest rates on dollar-denominated deposits in Bolivia? First of all, let us graphically compare the interest rate series in Figure 2. During most of the sample period, the Bolivian dollar-deposit interest rate is higher than the US COD interest rate, but since 2004 the opposite has been true. The correlations between the series are high, ranging from 0.73 for the shortest maturity to 0.80 for the longest maturity.

I re-estimate equation (6) using the US COD interest rate instead of the Bolivian dollar deposit rate. The results are presented in Table 4. The estimates are strikingly similar to those reported above, which indicates that political risk was not a significant cause of UIP deviations during the sample period. There is almost no difference in results for the shortest maturity range. For the longer maturity ranges, the coefficients on the interest rate variables are, if anything, somewhat more positive and significant when using US COD rates. In contrast,

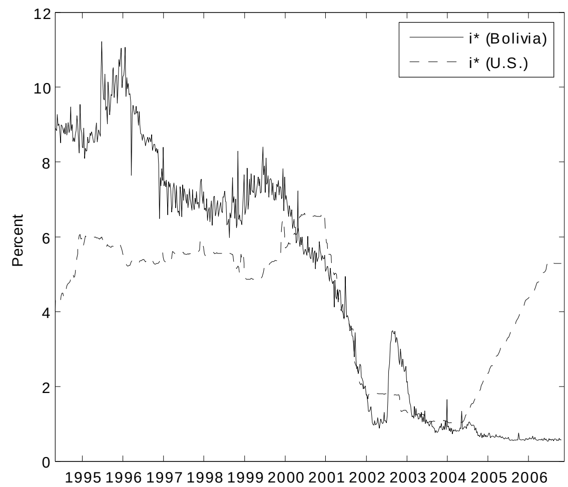

Figure 2: Interest rates on dollar-denominated deposits in Bolivia and Certificates of Deposit (CODs) in the United States (30-day maturities).

Poghosyan, Kocenda, and Zemcik (2008) find larger deviations from UIP in the cross-country case. The restriction $\beta = 1$ is rejected at the 1% level for all maturity ranges. The similarity of the results in Tables 3 and 4 suggests that it may be worthwhile to test UIP even in developing countries which are not partially dollarized and where it would be necessary to use US COD rates rather than local dollar-deposit rates.

5 Explaining the deviations from UIP in Bolivia

Previous tests of UIP in Bolivia do not investigate the underlying reasons for the empirical deviations from UIP. Morales (2003) attributes any deviations from UIP to the peso problem, but he does not test the explanatory value of different theories. This section studies the following three candidate explanations: the peso problem, time-varying risk premia and deviations from rational

Table 4

OLS estimation of standard UIP regression with US COD dollar interest rate

	Maturity range (days)		
	1-30	61-90	91-180
α	2.50***	2.47***	2.89***
	(0.57)	(0.67)	(0.76)
β	0.32***	0.30***	0.23**
	(0.08)	(0.09)	(0.09)

Note: the estimated equation is s(t)-s(t-k) = α+β[ln(1+i(t-k))-ln(1+i*(t-k))]+ε(t) where s is the log exchange rate (defined as bolivianos per dollar) and k is the interest rate maturity in weeks for each range. See Table 3 for additional notes. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

expectations.

5.1 How much can the peso problem explain?

Suppose that investors put a small, but positive, probability on a major depreciation of the domestic currency and, therefore, require high interest rates as compensation, but suppose that no such major depreciations actually occur in the sample. Then, the estimated beta coefficient will have a downward bias due to a "peso problem" (as discussed in subsection 3.1).

In the Bolivian case, the interest rate differentials presented in Figure 1 are almost always positive, and no major depreciation occurs in the sample. On average, the interest differential in favor of the boliviano was more than sufficiently large to compensate for depreciation. Thus, on average, the deviations from UIP follow the prediction of the peso problem explanation.

Froot and Thaler (1990) carry out some simple calculations to informally evaluate the peso problem as an explanation for the dollar appreciation in the early 1980's. It is instructive to perform a similar calculation for Bolivia during the sample period. In this period, the average depreciation of the boliviano was 4.5% per year. Suppose that the depositors expected this to be the "normal" depreciation rate, given no major depreciation, but that depositors put some probability on a very large depreciation of, say, 50%. The expected depreciation would be equal to the yearly probability π of a major depreciation times 50%, plus the yearly probability $(1-\pi)$ of a small depreciation times 4.5%. Moreover, suppose that, in fact, UIP held perfectly during the sample period (i.e. any empirical deviations are only due to empirical peso problems). Then, the expected depreciation must be equal to the interest rate differential of 6%.

Given these assumptions, it is possible to solve for the yearly probability of a major depreciation by solving the equation:

$$0.06 = \pi \cdot 0.5 + (1-\pi) \cdot 0.045 \tag{7}$$

which gives $\pi = 0.033$. The yearly probability of a major depreciation would be 3.3%, so the probability of not observing such an event in the sample would be $(1-\pi)\hat{}12 = 67\%$. This "p-value" is obviously not sufficiently low to reject the "null hypothesis" of the peso problem being responsible for all empirical deviations from UIP in Bolivia.[11] These calculations show that the peso problem alone might possibly account for the observed data. However, the calculation only shows that this possibility cannot be excluded, so it is important to also investigate the ability of other factors to explain deviations from UIP.

5.2 How much can time-varying risk premia explain?

I use generalized autoregressive conditional heteroscedasticity in mean (GARCH-M) modeling to examine the explanatory value of a time-varying risk premium, modeled as the expected variance of future returns. This approach follows Domowitz and Hakkio (1985), Tai (2001) and Poghosyan, Kocenda, and

[11] Varying the size of the hypothetical depreciation between 30% and 70%, the "p-value" only varies between around 50% and 75%. Thus, the result is robust to the assumed size of the major depreciation.

Table 5

ML estimation of GARCH(1,1)-M model for 1-30 days

	Coefficient (standard errors in parenthesis)					
	α	β	γ	c	a	b
	6.19***	-0.10***	-0.03***	0.85***	0.78***	0.22***
	(0.14)	(0.03)	(0.00)	(0.17)	(0.09)	(0.07)

Note: the estimated mean equation is s(t) - s(t-k) = α + β[ln(1+i(t-k)) - ln(1+i*(t-k))] + γσ^2(t-k)+ ε(t) where s is the log exchange rate (defined as bolivianos per dollar) and k is the interest rate maturity in weeks for each range (from Table 1). The variance equation is σ^2(t-k) = c + aε^2(t-k-1) + bσ^2(t-k-1). Bollerslev-Wooldridge standard errors (robust to non-normality in the residuals) are reported in parenthesis. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

Zemcik (2008). The methodology can also be motivated empirically; for all maturity ranges, OLS regressions show clear signs of ARCH (not reported).

Specifically, I estimate a GARCH (1, 1)-M model.[12] I present the results for the maturity range 1-30 days in Table 5. All coefficients are highly significant and there are clear deviations from UIP. The restriction $\beta = 1$ is rejected at the 1% level for all maturity ranges. Moreover, the coefficient for the conditional variance in the mean equation (γ) is significantly negative, indicating the presence of a time-varying risk premium. Intuitively, when uncertainty increases (σ goes up), the depreciation of the boliviano decreases, thus causing the expected returns from holding bolivianos to increase. The increase in expected returns is required by agents to compensate for the additional risk involved in holding bolivianos when uncertainty is high.

The estimated risk premium consists of a constant part, α, and a time-varying part, $\gamma \cdot \sigma^2$. Wald tests reject the null hypothesis of no risk premium at the 1% level. The estimated premium is presented in Figure 3 and it is large, positive and time-varying throughout the sample period. Thus, there is clear empirical evidence of a time-varying risk premium, which could account for at least part of the deviations from UIP.

[12] Before making the estimation, missing values in the interest rate series were replaced by the average value of adjacent observations.

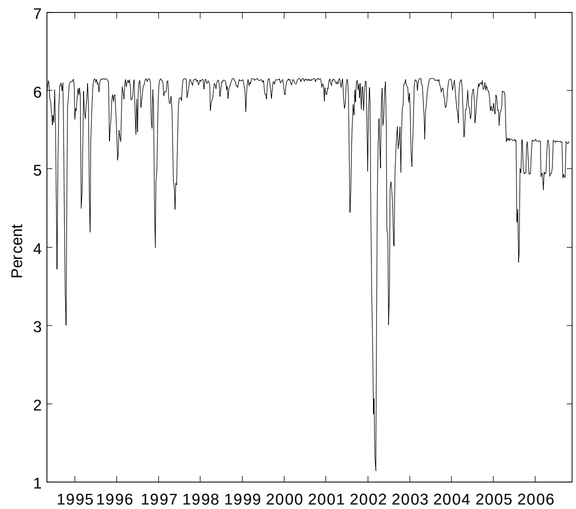

Figure 3: Estimated risk premium ($\alpha + \gamma \cdot \sigma^2$) for the interest rate maturity range 1-30 days.

However, a puzzling result is that the estimated coefficient on the interest rate differential goes from significantly positive (in the standard UIP regression) to significantly negative (in the GARCH-M regression). If the deviation from UIP were caused by a downward bias in β due to an omitted risk premium, the estimated β coefficient would be expected to increase rather than decrease when explicitly modeling the risk premium. Interestingly, Domowitz and Hakkio (1985) obtain the same result for the two countries (United Kingdom and Japan) for which they find a significant risk premium.

Another approach for dealing with possible endogeneity bias due to an omitted risk premium is to use instrumental variables (IV) methods rather than OLS. Instrumental-variables estimation of equation (6), using lagged interest differentials for the past 26 weeks as instruments for the current interest differential, gives similar results as OLS, but the β coefficients are generally somewhat higher (not reported). UIP is still rejected, but the deviations are smaller. Thus, while GARCH-M estimation gives mixed results, the IV estimates indicate that time-varying risk premia may be partially responsible for the empirical deviations from UIP in Bolivia.[13]

5.3 How much can deviations from rational expectations explain?

I test the non-rational expectations hypothesis presented in Froot and Thaler (1990). The hypothesis is that at least some investors respond with a lag to interest rate differentials. Table 6 presents estimation results for specifications including lagged interest-rate differentials for the past 26 weeks (only α and β coefficients are shown in the table). There are no substantial changes in the estimated β coefficient for any maturity range. However, the coefficients on the lagged interest rate differentials are jointly significant at the 1% level in two cases (for maturity ranges 61-90 and 181-360 days). Hence, there is some empirical evidence in favor of non-rational expectations.

6 Conclusions

The main finding of this paper is that while UIP does not hold in Bolivia, the deviations are smaller than in previous studies using data from developed or emerging economies. Moreover, several factors seem to have contributed to the observed deviations from UIP. The peso problem could possibly account for the observed data, but there is also evidence of a time-varying risk premium, as well as deviations from rational expectations. More generally, one would a priori expect the peso problem to be especially relevant in Bolivia with its history of

[13] Another interpretation would be that the OLS estimates have a downward bias due to measurement error in the interest rate data. Interest rates are measured as weekly averages and interest maturity is not measured perfectly.

Table 6

OLS estimation of standard UIP regression with lagged interest rate terms on the RHS (test for deviations from rational expectations)

	Maturity range (days)				
	1-30	31-60	61-90	91-180	181-360
α	2.89**	1.71	2.82***	-1.02	-0.21
	(1.23)	(1.22)	(1.05)	(1.09)	(0.15)
β	0.20	0.33**	0.30***	0.24	0.01
	(0.14)	(0.15)	(0.10)	(0.16)	(0.03)
P-value	0.74	0.92	0.01	0.11	0.00

Note: the estimated equation is s(t)-s(t-k) = α + β[ln(1+i(t-k))-ln(1+i*(t-k))] + c(1)[ln(1+i(t-k-1))-ln(1+i*(t-k-1))] +...+ c(26)[ln(1+i(t-k-26))-ln(1+i*(t-k-26))]+ε(t) where s is the log exchange rate (defined as bolivianos per dollar) and k is the interest rate maturity in weeks for each range (from Table 1). The depreciation variable was multiplied by 52/k to get an annualized measure corresponding to the annual interest rates. Newey-West standard errors (robust to heteroscedasticity and autocorrelation) are reported in parenthesis. The reported p-value is associated with the chi-square statistic for a Wald test of the significance of the coefficients for the lagged interest rate terms. ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively.

hyperinflation than in other countries. Therefore, the finding that deviations from UIP are smaller in the Bolivian case than in previous studies casts doubt on the peso problem as the main factor behind the general empirical failure of UIP.

Future research could test UIP with similar data from other partially dollarized developing economies. It would be particularly interesting to investigate whether a surprising result in this paper–that the UIP tests gave similar results irrespective of which dollar interest rate was used–holds more generally.

Another possibility would be to use pooled data from several partially dollarized countries rather than time-series data for separate countries. The drawback of the single-country approach used in this paper is that the estimates may be imprecise in small samples. Baillie and Bollerslev (2000) show that even when UIP holds, persistent exchange rate volatility might cause a wide dispersion of estimated β coefficients around the true value of one. However, the Bolivian data set consists of weekly data for a 12-year period, which gives a relatively large number of observations. Moreover, Flood and Rose (2001) test for UIP in individual countries using large samples and still obtain estimation results which vary considerably between countries. They argue that this makes pooling – i.e. estimating a single β for all countries – a somewhat dubious procedure. There are also data availability problems; it is likely to be difficult to find high-frequency interest rate data of sufficiently similar maturity for a large number of countries.

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