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Levent, Korap

Istanbul University Institute of Social Sciences, Besim Ömer Paşa Cd. Kaptan-ı Derya Sk. 34452 Beyazıt /ISTANBUL

2010

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Özgür Aslan[a,*] and Levent Korap[b]

[a] Department of Economics, Istanbul University, Istanbul 34590, Turkey
[b] Marmara University, Bahcelievler/Incirli, Turkey

In this article, one of the contemporaneous monetary theories of exchange rate determination, namely uncovered interest parity (UIP), is examined. The UIP hypothesis assumes that if capital is perfectly mobile, then investors around the world will be indifferent between holding their portfolios in domestic or foreign securities, because they obtain the same return from these assets. Based on a theoretical formulation, our *ex post* estimation results employing four developed countries exchange rates vis-á-vis US dollar indicate the failure of the UIP hypothesis using short-horizon interest differential and future spot exchange rate data, in line with most empirical papers in the economics literature.

I. Introduction

Understanding the behaviour of economic agents in financial markets requires the knowledge of what motives drive the contruction of expectations. In this line, one of the main recent issues of interest in policy design process is to reveal the fundamental building blocks of exchange rates and interest rates in international macroeconomics, and in turn such a policy debate based on theoretical underpinnings of exchange rate determination of economic agents would be of special concern for the effectiveness of interventions in exchange markets, revealing also some main motives that rule the exchange rate movements. As Isard (2006) emphasizes, the uncovered interest parity (UIP) condition would constitute a central focal point in contemporaneous exchange rate determination models and to the extent that the UIP is valid at short time horizons, official intervention cannot succeed in changing the spot

* Corresponding author. E-mail: ozgaslan@istanbul.edu.tr

exchange rate relative to the expected future spot rate unless the authorities choose to allow interest rates to change.

Following briefly Huisman et al. (1998), the UIP condition would hold if the return on a domestic currency deposit equals the expected return from converting the domestic currency into the foreign currency, investing it in a foreign deposit and then converting the proceeds back into the domestic currency at the future expected exchange rate. Thus the UIP assumes the existence of arbitrage in international markets linking the interest and exchange rates. If the *ex post* uncovered interest differential reflects the degree of capital mobility, then it implies that the sum of the risk premium and rational expectation error may diminish over time since the interdependence of world financial markets has increased (Sul, 1999). Or in other words, if capital is perfectly mobile, then investors around the world will be indifferent between holding their portfolios in domestic or foreign securities, which are also perfectly comparable denominated in different currencies because they obtain the same return from these assets (Bhatti and Moosa, 1995). Consequently, through the joint assumptions of rational expectations, risk neutrality, free capital mobility and the absence of taxes on capital transfers, expected excess returns in the foreign exchange markets then must equal zero on average (Baillie and Bollerslev, 2000).

There exists a large literature of theoretical and empirical papers examining the interest parity condition in the economics literature, of which most papers also fail to give evidence in favour of the UIP hypothesis. Likewise, Flood and Rose (2002) touch on this issue in the sense that although the UIP theorem predicts that countries with high interest rates should, on average, have depreciating currencies, much empirical papers indicate that such currencies in general have tended to appreciate.[1] And such findings in general are attributed to that the forward rate is a biased predictor of the future spot rate. For this failure of the predictive power of the UIP hypothesis in empirical papers, Chinn and Meredith (2004) consider that

[1] A large literature also have emerged on why the slope coefficient in the regression of the change in the logarithm of the spot exchange rate on the forward premium is less than unity or even negative. As expressed in Beyaert et al. (2007), this would imply that investors in the foreign exchange market do not behave rationally since they would not take profit of predictable excess returns. See also, among many others, Froot and Thaler (1990), Lewis (1995) and Engel (1996) on this issue. However, some papers are able to give evidence in favour of the UIP theorem, as well. See, for instance, Han (2004). Chinn and Meredith (2004) explain the contradiction between short- and long-term estimation results rejecting the validity of UIP theorem in the short-run but supporting it in long-horizon estimates in the sense that the long-horizon results differ sharply from the short horizon results because the model's 'fundamentals' play a more important role in trying down exchange rate movements over longer horizons.

much of the published studies examining the UIP phenomenon have been using financial instruments with relatively short maturities of 12 months or less, for which they assume some potential reasons such as constraints on sample size and difficulty of obtaining long-term fixed maturity interest rate data, while they report good performance of the UIP hypothesis using bonds with maturity ranging from 5 to 10 years. Also, Christensen (2000) attributes the rejection of the UIP theory to both the lack of assuming rational expectations and the existence of time-varying risk premia. As emphasized by Sachsida et al. (2001), the so-called peso problem can be considered one of the main reasons of empirical lack of the UIP theorem since most countries do not work with a pure floating exchange rate regime. In a fixed rate regime, due to a small probability of large alteration in the exchange rate within the period covered by the analysis, one can be misled to the conclusion that agents are showing systematic errors in their short-run predictions, i.e. they are not rational, and this can lead to biased estimates of slope parameters of the UIP equations in samples that are too short to accurately reflect the small probability of large events (Chinn and Meredith, 2004). Since the rational expectations assumption is one of the fundamental building blocks of the UIP theorem, the failure of the empirical tests applied can be a result of apparent lack of rationality in the exchange rate expectation. Finally, Beyaert et al. (2007) in a recent paper express that regime shifts stemming from institutional, political, and economic changes subject to modern world economies are responsible for the UIP puzzle estimated by researchers. Since regimes switch 'infrequently' at dates that are unknown, economic agents make rational forecast errors that are correlated with the forward premium or the interest rate spreads.

In our article, our aim is to give an empirical essay on the UIP theorem based on a theoretical formulation in line with economics theory. For this purpose, the next section provides a theoretical framework and Section III deals with an empirical model based on data from five developed country cases. And the final section concludes.

II. Theoretical Foundations

In this section, we try to construct analytically the relationships between the unbiasedness hypothesis, on which the UIP theorem is based, and covered (CIV) and uncovered interest parity (UIP) relationships. For this purpose, we will follow McCallum (1994) and Chinn and Meredith (2004).

Let s_t be the price of foreign currency in units of domestic currency at time t, and let f_t denote the one-period forward value of s, i.e., the home currency price in period t of a unit of foreign exchange to be paid for and delivered in period t+1. Then f_t might be said to be an unbiased predictor of s_{t+1} if $\alpha = 0.0$ and $\beta = 1.0$ in the relation:

$$\alpha + \beta f_t = E_t s_{t+1} \tag{1}$$

where $E_t s_{t+1} \equiv E(s_{t+1} \mid \Omega_t)$ is the conditional expectation of s_{t+1} formed on the basis of the information set Ω_t available at time t. With rational expectations, expectational error $\varepsilon_{t+1} = s_{t+1} - E_t s_{t+1}$ will be uncorrelated in the population with all elements of Ω_t so that we can rewrite Equation 1 as:

$$s_{t+1} = \alpha + \beta f_t + \varepsilon_{t+1} \tag{2}$$

Equation 2 can be estimated by means of ordinary least squares (OLS) if ε_t is white noise. Rearranging that:

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

Equation 3 is a more generalized form in conducting unbiasedness tests under the test hypothesis $\beta = 1.0$.

Let us now define covered and uncovered interest parity relationships based on the assumption of arbitrage between spot and forward foreign exchange markets. If the conditions for risk-free arbitrage exist, the ratio of the forward to the spot exchange rate will equal the interest differential between assets with otherwise similar characteristics measured in local currencies.[2] As for the CIP relationship and following the notation in Chinn and Meredith (2004), if we define s_t as considered above, $f_{t,t+k}$ forward value of s for a contract now expiring k periods in the future, $i_{t,k}$ one plus the k-period yield on the domestic instrument, and i^*_{t+k} the

[2] Such as identical default risk, tax treatment, the absence of restrictions on foreign ownership, and negligible transaction costs.

corresponding yield on the foreign instrument, all in natural logarithms, risk-free arbitrage condition regardless of investor preferences can be written in Equation 4 below:

$$f_{t,t+k} - s_t = (i_{t,k} - i^*_{t,k}) \qquad (4)$$

Following Taylor (1995), in other words, assuming the nonexistence of any barrier to arbitrage across international financial markets should lead us to hypothesize that the interest differential on similar assets, adjusted for covering in the forward foreign exchange market the movement of currencies at the maturity of the underlying assets, converge continuously to be equal to zero. To the extent that investors are risk averse, however, the forward rate can differ from the expected future spot rate by a premium that compensates for the perceived riskiness of holding domestic versus foreign assets as shown in Equation 5 below:

$$f_{t,t+k} = s^e_{t,t+k} - rp_{t,t+k} \qquad (5)$$

Expected change in exchange rate can be expressed by substituting Equation 5 into Equation 4, from period t to period $t+k$ to be expressed as a function of the interest differential and the risk premium:

$$\Delta s^e_{t,t+k} = (i_{t,k} - i^*_{t,k}) - rp_{t,t+k} \qquad (6)$$

UIP requires that the risk-premium in Equation 6 is zero through the assumption of risk-neutral investors. Making use of rational expectations in exchange rates for the purpose of direct testing, future realizations of s_{t+k} will equal the value expected at time t plus a white-noise error term that is uncorrelated with all information known at t, including the interest differential and the spot exchange rate:

$$s_{t+k} = s^{re}_{t,t+k} + \xi_{t,t+k} \qquad (7)$$

where $s^{re}_{t,t+k}$ is the rational expectation of the exchange rate at time $t+k$ formed in time t. Substituting Equation 7 into Equation 6 gives the following relationship:

$$\Delta s_{t,t+k} = (i_{t,t+k} - i^*_{t+k}) - rp_{t,t+k} + \xi_{t,t+k} \quad (8)$$

where the left-hand side of Equation 8 is the realized change in the exchange rate from *t* to *t+k*. As emphasized by Sachsida et al. (2001), a constant can be added to the above equation, which is aimed to capture any risk premium demanded by economic agents. Such a constant may also capture asymmetric information or other economic considerations that can justify the existence of a differential in yields of bonds measured in local currency.

III. Empirical Results

The theoretical UIP model constructed in the former section is tried to be estimated in a somewhat similar way to Sarantis (2006), considering four bilateral currency exchange rates vis-á-vis US dollar: Australia dollar / US dollar (AU), Canadian dollar / US dollar (CA), Japanese Yen / US dollar (JA) and UK pound / US dollar (UK). All the exchange rates present daily averages of spot rates quoted for the US dollar on national markets expressed as national currency per US dollar. Hence the numerator always refers to the home country and the denominator to the US. Data for interest rates are of the form short-term, i.e. 3-month interbank rate. We also use in the model estimation process below the long-term, i.e. 10-year, government bond yield and share prices which are averages of daily quotations.[3] Following Sarantis (2006), we include the last two variables as instruments in order to capture the potential interdependence of financial markets.[4] We use monthly frequency data over the period January 1987 to December 2006 for AU, CA and UK data, while the period January 1989 to December 2006 is considered for the JA data due to the data availability problems for the latter case. All the data are taken from the electronic data delivery system of the OECD Main Economic Indicators. Since exchange rates and interest rates are jointly determined, we consider both exchange rates and interest rate differentials as endogeneous variables. We estimate the model with the Generalized Method of Moments (GMM) estimator of Hansen (1982).[5] The GMM estimator selects parameter estimates so that the correlations between the

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[3] All quoted interest rates are in percentages. Hence, following Sarantis (2006), the rates used in the estimation are measured by r=ln(1+i/100). Besides, stock returns are measured by $\ln(P_t/P_{t-1})$, where P is the stock price index.

[4] Our *ex post* estimation results not reported here reveal that the main findings obtained in this article do not sensitive to whether or not these latter instruments have been included into the model.

[5] Following QMS (2004), the starting point of GMM estimation is a theoretical relation that the parameters should satisfy. The idea is to choose the parameter estimates so that the theoretical relation is satisfied as closely

instruments and disturbances are as close to zero as possible, as defined by a criterion function. For estimation purposes, we need some instruments when applying to the GMM procedure, and we choose the 12-month lagged values of the exchange rates, short- and long-term interest differentials and stock return differential.[6]

Table 1. GMM estimates of the UIP relationship ($\Delta s_{t+1} = \alpha + \beta(i_t - i_t^*) + u_t$)

	$\frac{Australiadollar}{USdollar}$	$\frac{Canadiandollar}{USdollar}$	$\frac{Japaneseyen}{USdollar}$	$\frac{UKpound}{USdollar}$
α	0.00068 (0.20273)	0.00027 (0.18393)	-0.02292 (-5.00046)	0.00046 (0.13412)
β	-0.02201 (-0.26520)	-0.06950 (-1.28262)	-1.09821 (-8.07244)	-0.36597 (-2.08033)
Adj.R^2	-0.00197	-0.00420	-0.02403	-0.02307
J-stat.	0.14210	0.12403	0.15146	0.10192
$\alpha = 0$	0.04110 (0.840)	0.03383 (0.8541)	29.8622 (0.0000)	0.01799 (0.8933)
$\beta = 1$	151.7156 (0.000)	389.616 (0.0000)	237.868 (0.0000)	60.2905 (0.0000)

Notes: Numbers within parentheses next to regression coefficients are the heteroskedasticity and autocorrelation consistent *t*-values. Adj.R^2 is the adjusted coefficient of determination statistic and *J*-statistic the Hansen's (1982) *J*-statistic for testing the overidentification restrictions. The statistics for restrictions $\alpha = 0$ and $\beta = 1$ are the Wald statistics which are distributed as a $\chi^2(1)$ under the null.

In Table 1, we report the GMM estimation results of the standard UIP relationship with serial correlation robust *t*-statistics in parentheses employing the future spot exchange rate (s_{t+3}) and 3-month interest differential. Since we use more instruments than parameters to estimate, the validity of overidentifying restrictions is tested by the Hansen's (1982) *J*-statistic. Under the null hypothesis that the overidentifying restrictions are satisfied, the *J*-statistic times the number of regression observations is asymptotically χ^2 with degrees of freedom equal to the

as possible. GMM estimation is based upon the assumption that the disturbances in the equations are uncorrelated with a set of instrumental variables. The theoretical relation is replaced by its sample counterpart and the estimates are chosen to minimize the weighted distance between the theoretical and actual values. GMM is a robust estimator in that, unlike maximum likelihood estimation, it does not require information of the exact distribution of the disturbances. For the GMM estimates reported in this article, we use the Newey and West (1987) weighting matrix, which ensures that the GMM estimates and their standard errors are robust to heteroskedasticity and autocorrelation of unknown form.

[6] The smaller lagged values was also tried to be employed to the data. Although estimating similar results, the *J*-statistic expressed below to test the validity of overidentifying restrictions under the null hypothesis was rejected for small lagged values of the variables. But using 12-lags fitted to the statistical prerequisites.

number of overidentifying restrictions. In our case, we have four instruments to estimate two parameters and so there are two overidentifying restrictions.

In Table 1, we find anomalous estimation results as for our theoretical model construction in Section II above, with estimates of α being close and generally not significantly different from zero except the case of Japanese Yen / US dollar future spot exchange rate return equation, and with estimated slope coefficients β, which are negative in all cases. Thus, our findings confirm the failure of the UIP hypotheses in the sense that over short horizons we give support to the common perception in the economics literature that the exchange rates move inversely with interest differentials (Chinn and Meredith, 2004). All adjusted determination coefficients are very low and insignificant carrying negative signs, and following Sarantis (2006), these reveal that interest rate differentials alone cannot possibly explain short-horizon exchange rate movements. Wald tests restrictions that $\alpha = 0$ or $\beta = 1$ under $\chi^2(1)$ give supportive estimation results to those estimated in the unrestricted GMM system equations, as well.

Following Chinn and Meredith (2004), we can attribute these perverse relationships between interest rates and exchange rates to using short-horizon data. However, when considered longer horizon data for the G-7 countries they somewhat support the UIP hypothesis, with slope parameters that are positive and closer to the hypothesized value of unity than to zero. Thus some robustness checks of our findings with longer horizon data such us five or ten year homogenous interest rate data and exchange rate return should be applied to verify our main findings in this article. But we leave such an attempt to future papers.

IV. Concluding Remarks

One of the contemporaneous monetary theories of exchange rate determination can be explained in line with the uncovered interest parity (UIP) relationship between bilateral exchange rates. The UIP hypothesis assumes that under the existence of arbitrage in international markets linking the interest and exchange rates which reflects the degree of capital mobility, the return on a domestic currency deposit would equal the expected return from converting the domestic currency into the foreign currency, investing it in a foreign deposit and then converting the proceeds back into the domestic currency at the future expected exchange rate. If such a theoretical relationship holds, investors around the world would be indifferent between holding their portfolios in domestic or foreign securities. Our empirical findings employing GMM estimation method on four developed countries bilateral exchange rates vis-á-vis US dollar reveal that we verify the failure of the UIP theorem using short-horizon interest differential and future spot exchange rate data as was found in much empirical papers in the economics literature.

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