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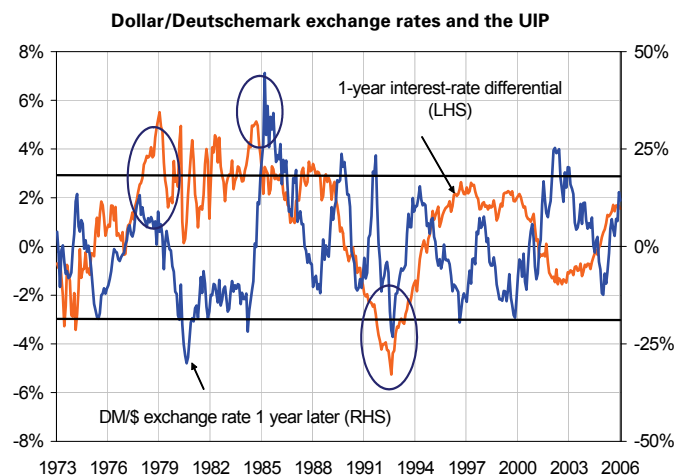
# TRÉSOR-ECONOMICS

## Do interest rates help to predict exchange rates?

- The link between exchange rates and interest rates is a recurring topic of discussion among economists and financial analysts, with particular emphasis on how a monetary policy shift affects the exchange rate.
- This article focus on the relationship referred to as uncovered interest-rate parity (UIP). UIP formalises the following principle: when two currencies' relative interest rates diverge substantially and durably, exchange rates will move so that a risk-free investment in one of the currencies will be equivalent to a risk-free investment of the same maturity in the other currency, otherwise it would become possible to achieve limitless returns at no risk.
- Empirical studies show that this relationship between interest rates and exchange rates is better verified in the long run (beyond one year), and when interest-rate differentials are sufficiently large. In the short run, on the other hand, the relationship between interest rates and exchange rates in the developed countries is unstable and tends, on average, to display the opposite sign to the one predicted by the uncovered interest-rate parity relationship.
- This short-term deviation may be due to the existence of shocks of a monetary origin, whose unexpected character may explain why the uncovered interest-rate parity is not verified *ex post* even though it remains an equilibrium relationship at each moment in time.
- The introduction of agents' uncertainty as to future movements in financial variables, exchange rates in particular, in the presence of transaction costs, may also explain the phenomenon of deviation from the uncovered parity: agents' uncertainty would in that case prevent them from carrying out arbitrages arising from the deviation from the equilibrium relationship, thereby dampening speculation.

Source: Datastream, BIS and Bundesbank.

This study was prepared under the authority of the Treasury and Economic Policy General Directorate and does not necessarily reflect the position of the Ministry of the Economy, Finance and Employment.



## 1. How uncovered interest-rate parity works

### 1.1 The link between interest rates and exchange rates

The link between interest rates and exchange rates is a recurring topic of discussion among economists and financial analysts. One of the main questions concerns the extent to which a change in monetary policy affects the exchange rate. The principle at work here is simple: when a substantial and durable gap arises between the relative interest rates of two currencies, the exchange rates will move so that a risk-free investment in one of the currencies will be equivalent to a risk-free investment of the same maturity in the other currency. If this did not happen it would become possible to achieve limitless returns at no risk.

Economic theory has formalised this linkage as "interest-rate parity". When the exchange rate guaranteed by the money markets today for a given time horizon-i.e. the observed exchange rate, adjusted for the interest-rate differential-corresponds to the expected exchange rate at that time horizon, this interest-rate parity is said to be "uncovered" (UIP). The "covered" parity links the forward exchange rate to the observed exchange rate.

In efficient markets<sup>1</sup>, when agents' expectations are rational, the uncovered interest-rate parity implies that the best possible expectation of a change in the exchange rate derives from the yield differential between the two currencies: the one offering the highest return can be expected to depreciate, ultimately, such as to cancel out the returns generated by the higher interest rate.

This theoretical analytical framework serves as a useful benchmark, particularly for macroeconomic modelling purposes. But it is often disproved in practice: as for example, between 2002 and 2004, when 1-year interest rates in the euro zone were 120 basis points higher than US rates, on average, which ought to have brought about a depreciation of the euro according to the UIP, whereas in fact it appreciated 46% against the dollar over the period in question.

To gain insight into the exchange rate / interest rate relationship, the economic literature has therefore sought to understand the conditions of validity of this equilibrium relationship and the reasons for deviations from it.

### 1.2 How does this relationship change over time?

The absence of the expectation of returns is a fundamental condition of financial markets efficiency. UIP reflects this condition between money markets by assuming that agents' expectations of fluctuations in an exchange rate between two currencies offset the observed interest-rate differences between these countries.

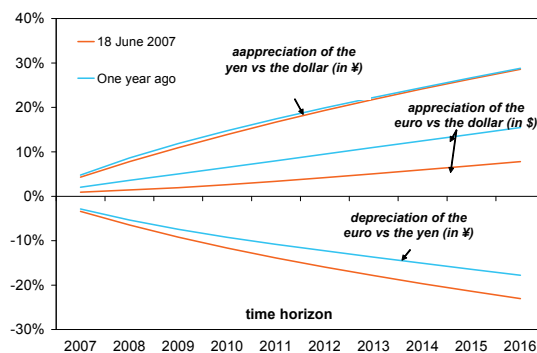
For example, when the 1-year interest rates are higher in the United States than in the euro zone, as is currently the case, agents ought to expect the dollar to depreciate sometime between today and one year hence. The expectation of a change in the exchange rate over the coming year is thus expressed as a function of the 1-year interest rate differential observed today<sup>2</sup>.

#### Box 1: What does UIP tell us about agents' expectations with regard to exchange rate movements in the long run?

The expected evolution of exchange rates according to the UIP corresponds to the difference between the two countries' yield curves. The trajectories are presented in the following chart for euro-dollar, yen-dollar and yen-euro exchange rates.

According to the UIP observed on 18 June 2007, the euro was expected to appreciate by 4.5% against the dollar within five years, and by 10% over the next 10 years. The yen was expected to appreciate by 17.5% against the dollar within five years, and by 30% over the next 10 years. It was expected to appreciate by 14% against the euro within five years, and by 23% over the next 10 years (see chart 1). If they occurred, these exchange rate movements would reflect the rebalancing of world growth, accompanied in turn by corresponding interest-rate movements.

Chart 1: expected evolution of exchange rates provided that UIP assumption is fulfilled



Source: Datastream, DGTPE calculations based on zero-coupon rates.

- (1) A market is said to be "efficient" when the prices of financial assets reflect all of the available relevant information.
- (2) The relationship is written:  $E_t(e_{t+n}) - e_t = n(r_{\$t \rightarrow n} - r_{€t \rightarrow n})$ , where  $e_t$  is the exchange rate observed today ( $(1€ = e_t \$)$ ), and  $r_{\$t \rightarrow n} - r_{€t \rightarrow n}$  the nominal interest rate differential between the dollar and the euro at maturity  $n$ , the variables being expressed logarithmically.  $E_t(e_{t+n})$  designates the expectation at date  $t$  of an exchange rate change at date  $t+n$ .

**The UIP is an equilibrium relationship that needs to be verified at each moment in time, markets being obliged to adjust in order to eliminate arbitrage opportunities.** An upward revision of the expected dollar exchange rate for a given time horizon, due to faster productivity growth for example, will be reflected in a narrowing of the interest-rate gap between Europe and the United States. For a constant expectation of the exchange rate level at a given time horizon, a widening of the interest rate differential following a monetary

policy shock, for example, will imply an immediate fall in the observed exchange rate such as to restore the UIP equilibrium.

**If this theoretical relationship between exchange rates and interest rates proves to be validated, and if agents are rational, it then becomes possible to use interest-rate differentials in order to understand and predict exchange rate movements.**

## 2.2. Traditional tests of uncovered interest-rate parity

### 2.1 A simple econometric test

The empirical literature has sought to verify whether this UIP relationship actually works. For that, the traditional tests consist in regressing a measure of exchange-rate movement expectations, over one year here for example, on the 1-year interest rate differential observed today:

$$E_t(e_{t+1}) - e_t = \alpha + \beta (r_{t,t+1}^s - r_{t,t+1}^f) + \varepsilon_{t+1}$$

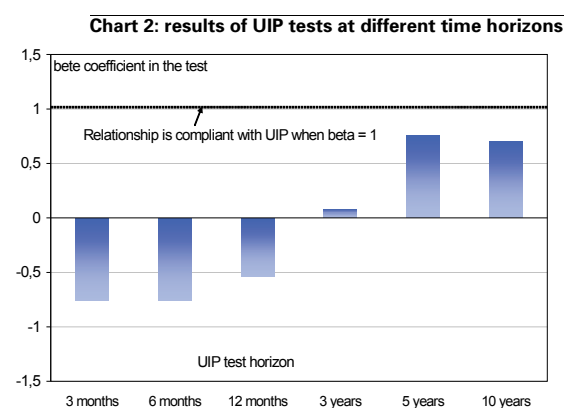
For UIP to be verified, the measured exchange-rate expectations must change in the same way and by the same orders of magnitude as the interest-rate differential. This implies that the coefficient  $\beta$  thus estimated<sup>3</sup> is equal to one; the constant  $\alpha$  may differ from zero without disproving the relationship: for example, a constant risk premium included in the interest rate differential will result in a non-nil constant without necessarily rejecting the hypothesis that the interest-rate differential reflects expected exchange rate movements. This test implies a range of assumptions, which are discussed in box 2.

### 2.2 These tests entail the rejection of UIP under certain conditions

*2.2.1. UIP is clearly rejected for exchange rates between developed countries when the time horizon of expectations is not too distant*

Froot (1990)<sup>4</sup>, for example, indicates that out of 75 studies testing UAP up to a time horizon of one year with agents presumed to be rational, on average the country with a short-term interest rate 100 basis points higher saw its currency appreciate by 0.88% in the following year, whereas it ought to have depreciated by 1% according to UIP.

The same test carried out on a panel of developed countries' exchange rates and using more recent observations confirms this result: between 1980 and 2004, Meredith and Chinn (2005)<sup>5</sup> have shown that UIP was rejected for a horizon of up to 12 months: the country with an interest rate that is 100 basis points higher sees its currency appreciate by 0.5% on average over a 1-year time horizon (chart 2).



Source: Meredith and Chinn (2005). Interpretation: when the bars in the bar chart are in negative territory, the relationship between exchange rates and interest rates displays the opposite sign to the one expected by the UIP.

*2.2.2 As the horizon of expectations lengthens, the exchange-rate-interest-rate linkage between developed countries appears to be better verified*

Meredith and Chinn (2005), for example, have shown that for a 3-year horizon onwards, the econometric estimation points in the direction indicated by UIP, and that it moves closer to the theoretical linkage at the 5-year and 10-year horizons.

- (3) The values of these coefficients are often estimated using the ordinary least squares method, corrected if necessary for the self-correlation of residues when the expectation horizon is greater than the panel frequency (this is a problem of overlapping).
- (4) Froot (1990): "Short rates and expected asset returns", NBER Working Paper no. 3247.
- (5) Chinn and Meredith (2005): "Testing uncovered interest parity at short and long horizons during the post-Bretton Woods era", NBER, Working Paper no. 11077

## Box 2: conditions of validity of traditional UIP tests

**The UIP test traditionally used in empirical studies (see paragraph 2) relies on several assumptions that, if not verified, can result in the rejection of UIP even though it actually works.**

Among these assumptions, those that concern problems of definition of the variables used in the tests, and the estimation techniques to be employed, have been widely discussed in the literature and have been the subject of detailed overviews<sup>a</sup>. Overall it looks as if none of them alone can explain the deviations from UIP:

**1 - When exchange-rate expectations are measured by the exchange rate actually achieved ex-post, the traditional regression tests the dual assumption that UIP works and that expectations are rational.**

While the estimations yielded by a test thus specified result in a relationship contrary to that suggested by UIP, we cannot conclude with certainty that either the UIP or the agents' rationality should be rejected. Survey data may be used as a measure of exchange-rate expectations, but what emerges is that deviations from the UIP persist in the short run. Nevertheless, measuring this is not without its difficulties, since the survey data reflect only the expectations of certain agents regarding the exchange rate, and that they may be endogenous to the interest-rate differentials.

**2 - The non-inclusion of the existence of a variable risk premium in the interest-rate differential, when estimating the tests, may lead to the mistaken rejection of UIP.**

It has nevertheless been shown that the extent of the deviations from the UIP cannot be explained using existing risk premium models.

**3 - The test is statistically valid only if the interest-rate differential and the measurement of exchange-rate expectations are either stationary or co-integrated.**

This is not the case in the short run, insofar as the exchange-rate movements are stationary, while the stationary character of the interest-rate differential is more uncertain. It has nevertheless been shown that the short-term interest-rate differential displayed a high degree of persistence that could be modelled using a stationary process, and that in this case the usual UIP tests displayed a bias that could be corrected. The estimations made using this method suggest that this bias is again insufficient, alone, to account for the extent of the deviations observed in the short run.

a. See in particular Baillie and Bollerslev (2000): "The forward premium anomaly is not as bad as you think", *Journal of International Money and Finance*, vol. 19; Engel (1995): "The forward discount anomaly and the risk premium: a survey of recent evidence", *NBER Working Paper no. 5312*; Lewis (1995): "Puzzles in international financial markets", *Handbook of International Economics*, vol.3.

The robustness of this test at distant horizons remains uncertain, however, owing to the small number of independent observations used to make these estimates<sup>6</sup>. Even so, other methods reach the same conclusion. For example Lothian and Simaan (1998)<sup>7</sup> have identified a relationship consistent with UIP for 22 developed countries' currencies versus the dollar, between the annual average change in exchange rates over 20 years and the respective interest-rate differential.

### 2.2.3 The UIP could be a non-linear relationship in the short run

Empirical studies suggest potential sources of non-linearity in the short-term relationship:

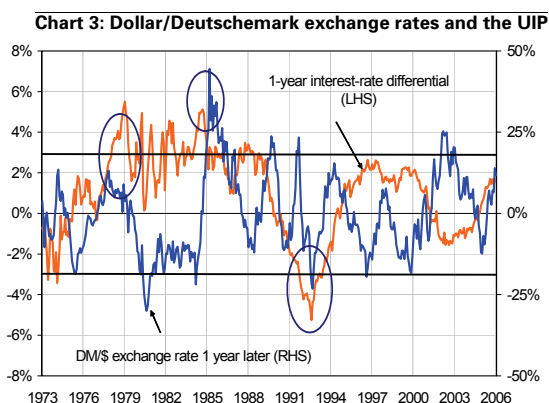
- Monetary policy: Christiano et al. (1999)<sup>8</sup> establish that a rise in key rates in the United States was followed by a gradual dollar appreciation, whereas according to UIP one would have expected the appreciation to take place rapidly;

(6) As the expectation horizon lengthens, the ex-post exchange-rate movements used to measure the expectations grow more persistent from one period to the next, and the number of independent observations declines in consequence. For example the Meredith and Chinn estimation (2005) uses a quarterly panel containing 352 observations: in this case the change in the exchange rate over 10 years corresponds to the aggregate sum of quarter-to-quarter exchange-rate movements over 40 quarters. Consequently there are only 9 independent observations (=352/40).

(7) Lothian and Simaan (1998): "International financial relations under the current float, evidence from panel data", *Open Economies Review*, vol.9-4-)

(8) Christiano, Eichenbaum and Evans (1999): "Monetary policy shocks: what have we learned and to what end?", *Handbook of Macroeconomics*, vol.1 part A, p.65-148.

- The size of the interest-rate differential: UIP tends to function better in the short run when interest-rate differentials are high, as is often the case between developed and emerging countries<sup>9</sup>;



Interpretation: for each observation, the expected changes in the exchange rate are compared with their outcome. The circled periods are those that correspond to a high interest-rate differential and for which UIP is verified.

Source: Datastream, BIS and Bundesbank.

However, UIP is not systematically observed to function better when the interest-rate differential is high: the 1-year interest-rate differential between the deutschemark and the dollar was greater than 300 bp in absolute terms on several occasions after 1973, even though the exchange-rate movements did not continuously comply with UIP, as they did between 1981 and 1985 (chart 3).

Overall these results are encouraging, albeit fragile, notably because they delineate the conditions in which UIP is most likely to be verified. For example, the possibility of UIP functioning in the long run suggests that, today, the expectations of agents extrapolated from interest-rate differentials are consistent with the assumption of a dollar depreciation, especially vis-à-vis the Asian currencies (see Box 1).

At the same time, the fact that the empirical literature rejects the validity of UIP in the short run could have a foundation in theory.

### 3.3. The existence of shocks that do not cancel each other out, on average, can deviate the UIP exchange rate

UIP tests assume that, for each horizon tested, shocks that modify the equilibrium cancel each other out on average. Relaxing this assumption may, in certain circumstances, lead to a reversal of the expected outcome. For instance, if the 1-year interest-rate differential initially points to a fall in the exchange rate at that horizon, and if in the course of the year several shocks occur resulting in an upward revision of the equilibrium exchange rate, the exchange rate will

### 2.3 Why does the UIP work poorly in the short run?

The traditional tests of UIP relies on a number of assumptions which, when not verified, are liable to lead to mistaken rejection of UIP when subjected to econometric testing.

For example, these tests assume that, if the interest-rate differential incorporates a risk premium, it must be constant, if not the estimations would be biased. Similarly, if the exchange-rate expectations selected in order to carry out the test are *ex-post* fluctuations, it is implicitly assumed that agents are rational. If the traditional test rejects UIP, then this would imply either that UIP does not work or that agents are not rational.

Overall, the literature on these subjects suggests that, once cleared up, none of these assumptions alone could explain the scale of the deviations from UIP in the short run (see Box 2). On the other hand, two approaches allow us to explain these deviations in the short run.

- The first discusses the assumption that the markets are capable of anticipating monetary shocks. Here, when the markets fail to anticipate these shocks, they are liable to deviate the exchange rate from the level initially suggested by the interest-rate differential. They may even lead to the observation, *ex post*, of a relationship contrary to UIP. Within this framework, UIP is an equilibrium relationship at each moment in time but is not verified *ex post*.
- The second views UIP as an imperfect equilibrium, due to agents' uncertainty as to future exchange-rate fluctuations and to the existence of transaction costs. In this case, agents are prepared to accept that the interest-rate differential does not precisely reflect their exchange-rate expectations, their uncertainty making them reluctant to make the necessary investment in order to profit from this difference.

have risen even though UIP suggested a decline. In this example, whereas the observation of *ex-post* data appears to require a rejection of UIP, since the exchange rate appreciates even though agents were expecting a depreciation, the possibility remains that the equilibrium relationship could still be verified at each date.

Several studies appear to confirm that deviations due to monetary shocks could be sufficiently large to explain the

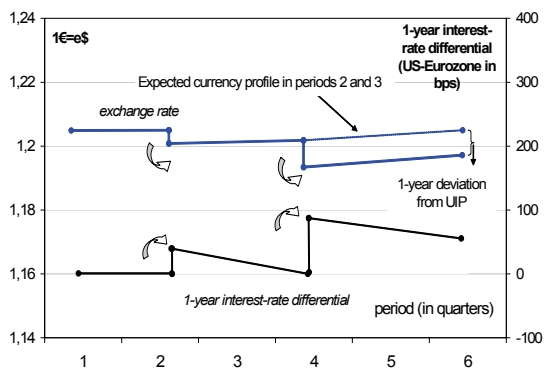
(9) See in particular Bansal and Dahlquist (1999): "The forward premium puzzle: different tales from developed and emerging economies", CEPR, *Discussion paper no. 2169*.

deviations from UIP observed in the short run. The importance of the role of monetary policy in explaining these deviations, moreover, appears to be consistent with the results of empirical tests: on the one hand the empirical observations of Christiano et al. (see §2) suggest that monetary policy could partly be responsible for the instability of the relationship in the short run<sup>10</sup>; on the other, insofar as monetary policy acts more at the short end than at the long end of the yield curve, it is not surprising that it does not powerfully affect UIP in the longer run.

### 3.1 Agents may wrongly anticipate monetary policy shifts

When agents underestimate the extent of a monetary tightening by a central bank, each monetary policy decision acts as a shock to the yield curve. Each time the central bank informs the market that its tightening will exceed market expectations, the entire yield curve will be pushed upwards. Each revision of expectations should be reflected in a currency appreciation and a widening of the interest-rate differential, provided the expected exchange rate remains unchanged. If the revisions of expectations are sufficiently large, the currency will appreciate even though the interest-rate differential initially suggested a depreciation (see chart 4 for an illustration of this case based on an example of the Federal Reserve's monetary policy).

Chart 4: deviation from UIP when agents revise upwards the extent of a monetary tightening



Source: DGTPE calculations.

Period 1: the money markets are in a situation where the exchange rate is at its equilibrium level and the interest-rate differential is nil.

Period 2: the Fed announces it is entering a monetary policy tightening cycle and the dollar immediately appreciates (UIP).

Period 3: agents do not expect the tightening to last long, hence the interest-rate differential narrows.

Period 4: the Fed adopts a tougher stance, hence agents revise their interest-rate expectations upwards and the dollar appreciates again.

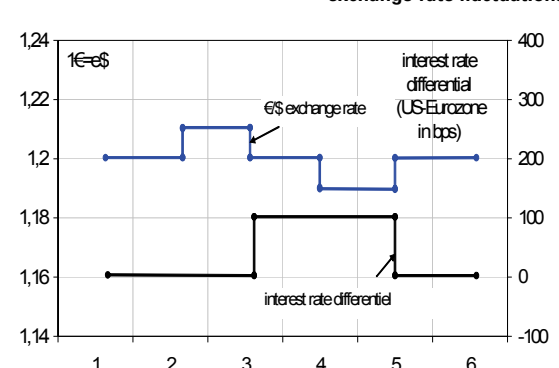
Periods 5-6: the 1-year interest-rate differential in the second quarter suggested a dollar depreciation within 12 months (quarter 6), whereas in fact the dollar appreciated. Consequently there was a deviation from UIP between periods 2 and 6.

### 3.2 Case where the central banks' monetary policy goal is currency stability

If monetary policy pursues an exchange-rate target in addition to purely domestic objectives (e.g. inflation and/or economic activity), monetary policy then becomes endogenous to exchange-rate fluctuations. In that case, without undermining the arbitrage condition between foreign-exchange and interest-rate markets, the relationship observed after a shock to the foreign-exchange market may be contrary to the one suggested by UIP<sup>11</sup>.

This apparent paradox can be illustrated very simply by means of the example given in chart 5 concerning the dollar/euro parity (in a hypothetical scenario in which the Fed is seeking to maintain a specific dollar/euro parity).

Chart 5: deviation from UIP-monetary policy is endogenous to exchange-rate fluctuations



Source: DGTPE calculations.

In period 1, the money markets are in a situation where the exchange rate is at its equilibrium level and the interest-rate differential is nil;

In period 2, an unexpected temporary shock leads to a depreciation of the dollar against the euro;

In period 3, the Fed responds by raising its key rates: the dollar immediately rises, and the widening of the interest-

(10) It is also possible that it is the expected equilibrium exchange rate that moves in a self-correlated manner over the horizon of the UIP tests. This possibility is not discussed here insofar as it is covered in a different body of literature on the determinants of the equilibrium exchange rate.

(11) See McCallum (1994): "A reconsideration of the uncovered interest rate parity relationship", *NBER Working Paper no. 4113*.

rate differential implies the expectation of a currency depreciation, in line with UIP;

In period 4, the temporary exchange-rate shock wears off, leading to an appreciation, even though the interest-rate differential suggested a depreciation. The relationship thus runs counter to UIP in this period;

In period 5, the central bank reacts to the fading impact of the shock by bringing its key rate back to its initial level, finally restoring the initial equilibrium.

In all, there is an inverse relationship to UIP between periods 3 and 4: the positive interest-rate differential in favour of the United States in period 3 suggested expectations of a dollar depreciation against the euro in the following period, whereas in fact the currency appreciated as the initial shock wore off.

### 3.3 Central bank interventions in the foreign exchange markets are unexpected by agents

When a central bank's intervention takes place contrary to agents' expectations, like monetary policy decisions, they can trigger temporary deviations from UIP. This happens, for example if their purpose is to support a currency when the interest-rate differential pointed to a depreciation of that currency.

Mark and Moh (2003)<sup>12</sup> studied the conditions in which foreign exchange interventions could lead to deviations that are sufficiently wide to account for those actually observed. Starting from a model in which interventions are triggered whenever the interest-rate differential exceeds a specified threshold<sup>13</sup>, they conclude that unexpected interventions would occur in 8 weeks out of 100. This theoretical finding is very close to the average number of interventions in the currency markets by the Fed between 1987 and 1995<sup>14</sup>.

## 4. Agents' uncertainty can also cause deviations from uncovered interest-rate parity

UIP presupposes that, at each moment in time, agents express their expectations of exchange-rate fluctuations in the interest-rate differential, for otherwise there would be an expectation of a return. But these expected returns are uncertain, notably due to the currency volatility expected by agents. This could result in a situation where agents, who are risk-averse, decide to refrain from making the necessary arbitrages even though there may be a deviation from UIP, especially if the associated returns are low in relation to the uncertainty over foreign-exchange fluctuations. In that case there would be a limit to speculation that would prevent UIP from functioning at all times.

### 4.1 Agents face a limit to speculation

Sarno et al. (2005)<sup>15</sup> set out to test the assumption that there is a limit to speculation. They use a model in which agents do not take advantage of an expectation of a surplus return yield differentials for as long as these expectations of surplus returns, corrected for the uncertainty due to

currency volatility<sup>16</sup> are unprofitable by comparison with the expected return on other assets.

This model's findings tend rather to validate UIP, given that the presence of a spring-back force guarantees that there can be no substantial deviation from it: the more agents' expectations deviate from those suggested by the interest-rate differential, the greater the expected return, and the greater the incentive for agents to carry out the underlying arbitrages permitting a return to equilibrium.

However, this model does not allow us to reproduce all of the empirical observations presented above. On the one hand it is possible to explain why UIP functions better in the long run than in the short run, insofar as a small shock to the long-term interest-rate differential implies expectations of high returns. But, on the other hand, the model specifies an absence of any linkage between exchange rates and short-term interest rates when agents have no incentive to make the necessary investments to restore the UIP; therefore it does not explain why the traditional tests indicate a contrary relationship in the short run.

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(12) Mark and Moh (2003): "Official interventions and occasional violations of uncovered interest parity in the dollar-DM market" *NBER Working Paper no. 9948*.

(13) This is based on the idea that interest rates are relatively distant from their implicit target when the interest-rate differential is wide, as a result of which the central bank will be readier to intervene during these periods.

(14) Conversely, in this model the source of non-linearity is bound up with the size of the interest-rate differential, the UIP then ceasing to function when the interest-rate differential is high, whereas the empirical evidence points in the other direction.

(15) Sarno, Valente and Leon (2005): "The forward bias puzzle and nonlinearity in deviations from uncovered interest parity: a new perspective", *EFA Moscow meeting paper*.

(16) This is a Sharpe ratio, in which the expected surplus return on the investment corresponds to the difference between agents' foreign-exchange rate expectations and those suggested by the interest-rate differential. This return is then normalised by the standard deviation from the observed return on this strategy in the past.

## 4.2 The heterogeneousness of expectations

In addition to assuming a limit to speculation we may also assume that agents' expectations are heterogeneous. Alongside agents who are rational but risk-averse, who do not always seize an arbitrage opportunity, there could also exist a group of slightly less risk-averse and less rational agents: the latter may be mistaken in their expectations of exchange-rate fluctuations yet at the same time readier to take advantage of the expectations of returns implicit in their expectations. For example, non-rational agents could interpret a currency shock as a signal, whereas in fact it could just be noise. In this case, rational agents will expect the exchange rate to move back towards its equilibrium value, unlike non-rational agents. This configuration leads to the emergence of an interest-rate differential, with non-rational agents taking advantage of it. In the short run, the exchange rate will revert distinctly less rapidly than

expected to its long-term equilibrium. This mechanism thus results in a short-term deviation from UIP. These deviations will be all the more long-lived in that the investment opportunities permitting a return to UIP, for rational agents, remain weak. These models of the heterogeneousness of expectations thus reconcile the theoretical approach with empirical observations, but their validity remains hard to test.

In the final analysis, these findings appear to rehabilitate UIP as a theoretical relationship between exchange-rate and interest-rate fluctuations, regardless of the horizon considered. These findings are encouraging, suggesting that UIP is either an equilibrium relationship that functions at each moment in time, or an equilibrium around which deviations are temporary and relatively insignificant.

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